

SCHOOL LAUNCH · EXPLORE TRACKS

EXPLORE DINOSAURS · RANGER

The Dinosaurs track at the  Ranger level for curious young naturalists: five trails and fifty short stops on the great beasts, the people who dug them up, how they lived, what Scripture says about the creatures God made, and the sea reptiles, flying reptiles and Ice Age giants. True stories, careful facts, diagrams, hands-on projects and games.

First edition

O LORD, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches.

Psalms 104:24 (KJV)

COURSE GUIDE

Explore Tracks are for children who want more of what they love. Each track is a trail of short stops. At every stop the child reads a true story, studies a great picture, does something with his or her hands, plays a game and adds a page to a Field Notebook. At the ● Ranger level each stop adds more facts, a map or diagram and a short written notebook entry, and links (“Goes deeper in.”) to the matching full lesson in a School Launch course such as Earth Science, Life Science, History, Geography, Arithmetic, Art or Literature.

Trail A meets ten dinosaurs, from Tyrannosaurus rex to Argentinosaurus, and measures them against things the child knows. Trail B follows the dinosaur hunters, from Mary Anning’s first ichthyosaur (1811) and William Buckland’s Megalosaurus (1824) to Sue the T. rex (1990) and Mary Schweitzer’s soft tissue (2005). Trail C reads the clues of teeth, eggs, footprints and bones to learn how dinosaurs ate, grew, moved and lived together. Trail D opens the Bible: the land animals of day six, Behemoth and Leviathan in Job, the Ark, the Flood and the dragon legends of the nations. Trail E dives with ichthyosaurs, plesiosaurs and mosasaurs, flies with the pterosaurs, then walks among woolly mammoths, saber-toothed cats and giant ground sloths, and ends with the child building a museum display.

Throughout, the track practices one skill above all: telling what we observe from how it is interpreted. Stops marked ⌚ include a box with three parts, “What the sign says,” “What we observe” and “How Christians read it,” so the child can read a museum sign carefully and charitably. The trails may be done in any order.

WHO IT IS FOR

Written for children about ages 10–13 who read on their own and can write a short paragraph. Younger siblings can join at the ● Scout level of the same stop; older ones can take the ● Expert level. Nothing earlier is required.

HOW TO USE THIS COURSE

1. **One stop at a time.** A stop takes 20–30 minutes: read the story, study the picture and the diagram, do the hands-on part, play the game and write the notebook entry. Two or three stops a week works well.
2. **Any order.** The five trails are independent. Trail D reads best after a few stops of Trails A–C, but it is not required.
3. **Look for ⌚.** At a stop marked ⌚, read the three-part dating box together and talk it over before the notebook entry.
4. **Field Notebook.** Every stop ends with a written entry of three to five sentences, plus a drawing, diagram or measurement. At the end of each trail the pages become a booklet, and the parent signs the trail certificate.
5. **Goes deeper in.** Each stop names the School Launch course lesson that teaches the same subject in full, for a child who wants more.

6. **Badge quizzes.** Every five stops earns a printable badge, with a short, optional quiz the child can answer aloud or in writing. They are for fun, not grades.

SCOPE AND SEQUENCE

Trail 1: Dinosaurs 🦖 **Trail A: Meet the Dinosaurs** (Self-paced)

Trail 2: Dinosaurs 🦖 **Trail B: Dinosaur Hunters** (Self-paced)

Trail 3: Dinosaurs 🦖 **Trail C: How Dinosaurs Lived** (Self-paced)

Trail 4: Dinosaurs 🦖 **Trail D: Dinosaurs and the Bible** (Self-paced)

Trail 5: Dinosaurs 🦖 **Trail E: Sea and Sky Reptiles, and the Ice Age** (Self-paced)

MATERIALS

- **Field Notebook (a sketchbook or composition book)** One for the whole track, or one per trail.
- **Colored pencils, a metric ruler, graph paper, scissors and glue** For drawings, scale diagrams and maps.
- **A tape measure (at least 10 m, or a 1 m string used several times) and sidewalk chalk** For life-size outlines, such as a T. rex about 12 m long.
- **Plaster of Paris, modeling clay and a shallow box of sand** For fossil casts, clay models and a dig box. Each project gives a safety line; an adult mixes the plaster.
- **Household things** Each hands-on project lists what it needs: cups, string, a kitchen scale, toy figures, a magnifying glass.
- **A Bible (KJV)** For the verse at each stop and the readings in Trail D.

GRADING

Explore Tracks are not graded. A stop is done when the child has read the story, done the hands-on part and written the notebook entry.

A badge is earned for every five stops finished, and a trail certificate for each finished trail.

- A good Ranger notebook entry states one fact from the stop, explains one thing in the child's own words and, at a ⌚ stop, keeps observation and interpretation apart.

A NOTE TO PARENTS

You do not need to be an expert. Read the story together, look at the picture and ask, "What do you notice?" and "How do we know?" Each stop has a short *For families* note with background, sources and any facts that scholars still discuss or that this book has left out because they could not be checked.

Dinosaur dates: museums and most videos give ages in millions of years. This track teaches the period names (Triassic, Jurassic, Cretaceous, Ice Age) as museum words and explains

that the dates are interpretations built on assumptions. Stops marked ⌚ carry a three-part box, “What the sign says / What we observe / How Christians read it,” which presents the museum’s view honestly and the creation view with care. Many Christian families understand the fossils within a young earth and the Flood of Genesis 6–9; other Christians hold an older earth. Stops B10 and D9 (soft tissue) present the young-earth reading and the discoverer’s own old-earth reading fairly.

Trail D treats Scripture as true history. Where the text leaves a question open, such as exactly what Behemoth and Leviathan were, the stop gives the main Christian readings and lets the family discuss them.

Some stops show predators and fossil graveyards. They are told plainly and without gore. The plaster, chalk and dig projects each include a safety line; plaster of Paris should be mixed by an adult, never poured on skin and never rinsed down a drain.

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Trails may be done in any order.

DINOSAURS TRAIL A: MEET THE DINOSAURS

The first trail of the Dinosaurs track meets ten famous dinosaurs one at a time: Tyrannosaurus rex, Triceratops, Stegosaurus, Brachiosaurus, Velociraptor at its real size, Ankylosaurus, Spinosaurus, Parasaurolophus and its crest, Pachycephalosaurus and Argentinosaurus, one of the biggest land animals ever found. Each stop tells who found the animal and when, what the bones show, which questions are still open, and how scientists corrected earlier mistakes.

This is the  **Ranger** level, for ages 10 to 13. The student reads each stop alone, works the five practice problems, draws a labeled diagram or map and writes a short paragraph in the Field Notebook. Each stop takes 25 to 35 minutes. The track is creation-friendly: God made the land animals, dinosaurs among them, on the sixth day (Genesis 1:24-25). Period names such as **Jurassic** and **Cretaceous** are taught as museum vocabulary, and Stops A1, A4 and A10, where a museum date in millions of years comes up, have the  box: *What the sign says / What we observe / How Christians read it.*

Five stops earn the **Dinosaur Ranger badge, part 1**, and ten stops earn part 2 and the **Trail A certificate**. The two badge quizzes at the end of the trail are optional; badges are earned by doing the stops, not by scores.

BEFORE YOU BEGIN

- Read a page of nonfiction on your own and tell back the main points in your own words.
- Measure in meters and centimeters, and multiply and divide whole numbers and simple decimals.

MASTERY CHECKLIST

- ☐ I can name the ten dinosaurs of this trail and give one true, measured fact about each.
- ☐ I can tell who found or named at least five of them, and when.
- ☐ I can tell the difference between a measurement, an estimate and an interpretation, and explain why size estimates are given as ranges.
- ☐ I can draw a labeled scale diagram comparing the sizes of several dinosaurs with a person.
- ☐ I can read a museum sign, find the period name and the date, and say what is observed and what is interpreted.

OPTIONAL BOOKS AND RESOURCES

- **Smithsonian National Museum of Natural History: David H. Koch Hall of Fossils** (<https://naturalhistory.si.edu>): Free online pages and photos of T. rex, Triceratops, Stegosaurus and many other skeletons.

- **Field Museum (Chicago)** (<https://www.fieldmuseum.org>): Pages on the Brachiosaurus discovered by Elmer Riggs (Stop A4) and Charles R. Knight's murals (Stop A1).
- **Biodiversity Heritage Library** (<https://www.biodiversitylibrary.org>): Free scans of the original descriptions and plates used in the picture studies: Marsh (1891), Brown (1908), Stromer (1915), Parks (1922), Osborn (1924) and Gilmore (1931).
- **Your public library** (<https://www.worldcat.org>): Search for a recent illustrated dinosaur encyclopedia for ages 10 and up to compare pictures with the facts in each stop.

1.1 TYRANNOSAURUS REX: THE TYRANT LIZARD KING

OBJECTIVES

- Give the length, height, weight and bite of T. rex in numbers and compare them with things you know.
- Explain what the skull, teeth and arms of T. rex show about how it lived and sensed the world.
- Tell the difference between a measurement, an estimate and the date printed on a museum sign.

Warm-up. Take a tape measure outside and mark 12 meters (about 40 feet) on the ground. That is the length of a big T. rex from snout to tail tip. Stand at one end and look at the other. How many of you, lying head to toe, would fit along that line?

Video slot. Video coming. Tyrannosaurus rex skeleton and anatomy: skull, teeth, arms and posture. Search approved channels (Field Museum, American Museum of Natural History, Smithsonian National Museum of Natural History, Museum of the Rockies); preview first.

KEY TERMS

theropod

A dinosaur that walked on two legs and had hollow bones and three main toes, such as T. rex and Velociraptor. Most were meat-eaters.

serrations

Tiny saw-like bumps along the edge of a tooth that help it cut through meat.

binocular vision

Seeing the same thing with both eyes at once, which helps an animal judge distance.

olfactory bulbs

The parts of the brain that handle the sense of smell.

estimate

A careful best guess worked out from evidence and a model, such as a weight figured from the size of the bones.

CORE IDEAS

The king's name. In 1902 the fossil hunter Barnum Brown dug the skeleton of a huge meat-eater out of the Hell Creek badlands of eastern Montana. In 1905 Henry Fairfield Osborn of the American Museum of Natural History gave it a royal name: *Tyrannosaurus rex*, “tyrant lizard king.” More than a century later it is still the most famous dinosaur in the world, and dozens of partial skeletons have now been found in Montana, the Dakotas, Wyoming and western Canada.

By the numbers. A full-grown T. rex was about 12 meters (40 feet) long and stood about 4 meters (13 feet) tall at the hips. Scientists estimate its weight at about 8 to 9 metric tons, more than an African elephant. Its skull alone was about 1.5 meters (5 feet) long. It had roughly 50 to 60 teeth, and the biggest, counting the root hidden in the jaw, were about 30 centimeters (12 inches) long. Each tooth had fine **serrations** along its edges, and new teeth grew in to replace worn or broken ones all its life.

A bone-crushing bite. Many meat-eating dinosaurs had thin, blade-like teeth for slicing. T. rex had thick teeth shaped more like bananas, rooted in deep jaws with room for enormous muscles. In 2017 two scientists used models of the skull and jaw muscles to estimate its bite at about 35,000 newtons near the back teeth, roughly the weight of two or three small cars pressing down. A large fossil dropping (a *coprolite*) found in Saskatchewan and thought to come from a tyrannosaur is packed with crushed bits of bone, and a Triceratops hip bone shows dozens of T. rex tooth marks. T. rex did not only tear meat; it cracked bones too.

Senses and small arms. The eyes of T. rex faced forward more than those of most dinosaurs, giving it good **binocular vision**, as a hawk has. Scans of its braincase show very large **olfactory bulbs**, so it probably had a keen sense of smell. Its arms were short, only about 1 meter (3 feet) long on a 12-meter animal, with two working fingers each. Yet they were not weak: the arm bones are thick and show strong muscle scars. No one is sure how the arms were used. Ideas include gripping prey close or helping the animal push up from the ground after resting.

How do we know? Almost everything in this stop comes from careful observation: measuring bones, counting teeth, scanning skulls and comparing them with living animals such as birds and crocodiles. Weights and bite forces are **estimates** built on models, so different scientists give somewhat different numbers. Museums place T. rex in the **Late Cretaceous**, a period name you will see on many signs; treat it as museum vocabulary for a set of rock layers. Scripture tells us that God made the beasts of the earth on the sixth day (Genesis 1:24-25). The power and balance of T. rex, a 9-ton animal walking on two legs, show the skill of its Maker.

PICTURE STUDY



Tyrannosaurus and Triceratops (Field Museum mural), Charles R. Knight, 1927 · Oil painting (museum mural) · Field Museum of Natural History, Chicago
Wikimedia Commons · Public domain

Between 1926 and 1930 Charles R. Knight painted 28 large murals of ancient animals for the Field Museum in Chicago. This one, painted in 1927, became the most copied dinosaur picture of the twentieth century. Knight worked from real skeletons and the advice of scientists, so his paintings also show us what experts believed in his day.

Look closely

- Look at how the T. rex stands. Is its body upright like a kangaroo or level like a seesaw? Where is its tail?
- Compare the two animals. Which looks heavier? Which looks taller?
- Look at the arms of the T. rex. How big are they next to its head?

Talk about it

1. Today most scientists draw T. rex with its back level and its tail held off the ground, balancing the heavy head. What new evidence might have changed their minds since 1927?
2. Which parts of a painting like this come from the bones, and which must come from the artist's imagination?

HANDS-ON: CHALK A LIFE-SIZE T. REX

Draw a T. rex outline at full size, 12 meters long, and then compare your own body with its skull, arm and leg. This turns the numbers in the story into something you can walk around.

You will need

- Sidewalk chalk in two colors
- A tape measure at least 10 meters long, or a string marked every meter
- A meter stick

- One or two helpers
- A flat paved space at least 13 meters long, away from traffic (a driveway, playground or park path, with permission)

Steps

1. Draw a straight ground line 12 meters long. Mark 0 m at the snout end and 12 m at the tail tip.
2. Mark the back of the skull at 1.5 m, the hips at about 5 m and the start of the thin part of the tail at about 6 m.
3. Measure 4 meters out from the ground line above the hip mark. This is the height of the hips. Draw the back level from the neck to the hips, then let the tail taper down to the 12 m mark.
4. Draw a skull 1.5 m long at the front with a row of teeth, the two legs under the hips, and two arms, each only 1 m long, with two fingers.
5. In your second color, label the skull, teeth, eye, arm, hip, leg and tail. Write “T. rex · 12 m” beside it.
6. Lie down next to the skull, then next to the arm. Have a helper photograph you. Is the skull longer than you are tall?

Check your work

- My outline is 12 m long and about 4 m tall at the hips.
- I labeled at least six parts.
- I compared my own height with the skull and the arm and wrote down the results.

FIELD NOTEBOOK

1. **Diagram.** Draw a side view of a T. rex skeleton to scale, using 1 centimeter for every meter, so your drawing is 12 cm long and 4 cm tall at the hips. Label: skull, serrated teeth, forward-facing eye socket, arm (two fingers), hip, thighbone and tail. Draw a 1.7 m adult beside it at the same scale and add a scale bar.
2. **Notebook entry.** Write a paragraph of five to seven sentences: “What evidence tells us T. rex was a powerful animal?” Use at least two numbers from the story, and underline one sentence that is an estimate rather than a measurement.

Did you know? T. rex grew fastest as a teenager. By counting growth lines in thin slices of leg bone, much like tree rings, scientists estimated that it gained up to about 2 kilograms (nearly 5 pounds) a day in its fastest-growing years. The oldest individuals studied so far were in their late twenties or early thirties when they died.

Map or diagram. On an outline map of North America, shade where most T. rex fossils have been found: eastern Montana, the western Dakotas, eastern Wyoming, and southern Alberta and Saskatchewan in Canada. Mark three museums where you can see a T. rex:

the Field Museum (Chicago), the Museum of the Rockies (Bozeman, Montana) and the Royal Tyrrell Museum (Drumheller, Alberta). Add a compass rose and a title.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** “Tyrannosaurus rex lived about 68 to 66 million years ago, at the end of the Cretaceous Period.” **What we observe:** T. rex bones are found in certain rock layers, such as the Hell Creek Formation, near the top of the dinosaur-bearing layers of western North America, together with Triceratops, Ankylosaurus, Pachycephalosaurus and many other creatures. No layer comes labeled with its age. **How Christians read it:** the date comes from measuring radioactive elements in volcanic ash layers and rests on assumptions about starting amounts, constant decay rates and nothing being added or lost. Young-earth Christians, the position of this course, read these layers as laid down rapidly, many during the Flood year, only thousands of years ago. Other Christians accept the long ages. Everyone agrees on the observation: these bones lie in these layers with these neighbors.

Goes deeper in. Life Science, the units on reptiles, birds and animal design (coming soon); Earth Science, fossils and rock layers. On this track, Trail B, Stop B7 (Barnum Brown finds T. rex) and Trail C, Stop C1 (Teeth tell diet).

For families. Brown found the type specimen in 1902 (it is now at the Carnegie Museum, Pittsburgh); Osborn named it in 1905. Mass estimates range from about 6 to over 9 tonnes depending on the method. The bite estimate is Gignac and Erickson, *Scientific Reports* (2017); the bone-filled coprolite is Chin et al., *Nature* (1998); the bitten Triceratops pelvis is Erickson and Olson (1996); the growth-rate figure is Erickson et al., *Nature* (2004). Whether T. rex mainly hunted or scavenged is still argued; most paleontologists think it did both. Knight’s upright posture reflected the science of his day.

PRACTICE

1. **EASY** What does *Tyrannosaurus rex* mean, and who named it in what year?
2. **EASY** Name two features of T. rex teeth.
3. **MEDIUM** A 12-meter T. rex had arms about 1 meter long. What fraction of its length is that? If a person 1.5 m tall had arms in the same proportion, how long would they be?
4. **MEDIUM** Sort these into measurement or estimate: (a) the skull is 1.5 m long; (b) T. rex weighed 8 to 9 tons; (c) its bite was about 35,000 newtons.
5. **CHALLENGE** Give two separate kinds of evidence that T. rex could crush bone.

Make it a game · T. rex Arms Relay. Tuck your elbows tight against your sides so only your forearms and hands can move. Race to carry a soft ball, a book and a cup from one end of the room to the other, one at a time. Then talk about it: what could T. rex do with its short arms, and what could it not do?

Scripture. “And God made the beast of the earth after his kind, and cattle after their kind, and every thing that creepeth upon the earth after his kind: and God saw that it was

good.” (Genesis 1:25, KJV)

T. rex was one of the beasts of the earth God made on the sixth day. Even the fiercest creature was part of a world God called good.

Practice: answers

1. “Tyrant lizard king.” Henry Fairfield Osborn named it in 1905.
2. Any two: serrated edges; thick, banana-shaped; up to about 30 cm long counting the root; replaced through life; about 50 to 60 of them.
3. $1/12$. $1.5 \text{ m} \div 12 = 0.125 \text{ m}$, about 12.5 cm, shorter than a pencil.
4. (a) measurement, taken from the bone; (b) estimate, from models of body size; (c) estimate, from models of jaw muscles.
5. Any two: thick, banana-shaped teeth and deep jaws with room for huge muscles (and bite-force models); a tyrannosaur coprolite full of crushed bone; a Triceratops hip bone with many T. rex bite marks.

1.2 TRICERATOPS: THREE HORNS AND A FRILL

OBJECTIVES

- Describe the skull of Triceratops with its parts and measurements.
- Tell how O. C. Marsh first mistook Triceratops horns for a bison's and how better fossils corrected him.
- Weigh the evidence for what the horns and frill were used for.

Warm-up. Put one finger on your nose and two fingers above your eyebrows. Now hold a paper plate flat behind your head. You have made a Triceratops face! Its real skull could be longer than a grown man is tall.

Video slot. Video coming. Triceratops skull and skeleton, horns, frill and teeth. Search approved channels (Smithsonian National Museum of Natural History, American Museum of Natural History, Museum of the Rockies, Natural History Museum London); preview first.

KEY TERMS

ceratopsian

A horned, frilled plant-eating dinosaur with a parrot-like beak, such as Triceratops (from Greek for “horned face”).

frill

The wide shield of bone that spread back from the skull over the neck.

rostral bone

A special bone at the tip of the upper jaw that formed a ceratopsian's hooked beak. No other animals have one.

dental battery

Rows of tightly packed teeth stacked in columns, with new teeth ready to replace worn ones.

herbivore

An animal that eats plants.

CORE IDEAS

A mistaken bison. In 1887 a pair of large horn cores attached to part of a skull was found near Denver, Colorado, and sent to Othniel Charles Marsh of Yale College, one of the leading fossil experts in America. Marsh thought they belonged to a giant extinct bison and named it *Bison alticornis*. Then the collector John Bell Hatcher began sending him far better skulls from eastern Wyoming, with a beak, a nose horn, two long brow horns and a broad bony shield. In 1889 Marsh named the animal *Triceratops*, “three-horned face,” and soon saw that

his “bison” horns belonged to the same kind of creature. Good scientists correct their mistakes when better evidence comes.

By the numbers. A grown Triceratops was about 8 to 9 meters (26 to 30 feet) long and is estimated to have weighed 6 to 12 metric tons. Its skull could reach about 2.5 meters (8 feet) long, one of the largest skulls of any land animal ever found. The brow horn cores were about 1 meter (3 feet) long, and in life they were covered by a sheath of keratin, the same tough material as your fingernails, so the horns were even longer.

A plant-cutting machine. Triceratops was a **herbivore**. At the front of its mouth was a toothless beak built on the **rostral bone**, good for snipping tough stems. Farther back were **dental batteries**: on each side of each jaw, 36 to 40 columns of teeth, with three to five teeth stacked in each column. That is several hundred teeth in all, though only the top layer was in use at once. The teeth worked like scissors, slicing tough plants such as ferns, palms and cycads.

What were the horns for? Scientists weigh several lines of evidence. A Triceratops hip bone carries dozens of T. rex tooth marks, and one Triceratops brow horn had been bitten off and then healed, so the animal survived an attack. In 2009 a study of skulls found more healed injuries on the cheek and frill bones of Triceratops than on a frilled relative, in just the places you would expect if two Triceratops locked horns and shoved. The **frill**, solid bone in Triceratops, may also have helped them recognize one another and show off, as deer antlers do today. Horns may have served for defense, for contests and for display all at once.

Common, yet still debated. Triceratops is the most common large dinosaur in the Hell Creek rocks of Montana; hundreds of skulls and partial skulls have been collected. In 2010 two scientists argued that *Torosaurus*, a frilled dinosaur with holes in its frill, was really a fully grown Triceratops. Others disagreed, and the question is still open. Museums label Triceratops as a **Late Cretaceous** animal, a period name for a set of rock layers. Like every creature, it was made by God “after his kind,” and its jaws, beak and horns show remarkable design.

PICTURE STUDY



Triceratops, Charles R. Knight, 1901 · Painting · American Museum of Natural History, New York
Wikimedia Commons · Public domain

Charles R. Knight painted this Triceratops for the American Museum of Natural History in New York, only twelve years after Marsh named the animal. Knight studied the skulls, talked with scientists and spent hours watching rhinoceroses and elephants at the zoo, so that his dinosaurs would look like living, breathing animals.

Look closely

- Find the beak, the nose horn and the two brow horns. Which way do the brow horns point?
- Look at the edge of the frill. Is it smooth or bumpy?
- Look at the skin. Which living animals do you think Knight used as models?

Talk about it

1. Knight had only bones to work from. What could he know for certain, and what did he have to guess?
2. If you were a T. rex, from which direction would you least want to meet this animal? Why?

HANDS-ON: A ONE-TENTH-SCALE TRICERATOPS SKULL

Build a model skull at one tenth of real size, so that every 10 centimeters of real skull becomes 1 centimeter of model. A 2.5-meter skull becomes 25 centimeters long.

You will need

- A cereal box or thin cardboard
- Air-dry clay or salt dough (about two fist-sized lumps)
- A ruler
- Scissors (with a grown-up), pencil and markers
- Toothpicks for the bumps on the frill

Steps

1. Work out the model sizes: skull 25 cm long; brow horns 10 cm (the real horn cores were about 1 m); nose horn about 3 cm.
2. Cut a frill shape from cardboard about 18 cm wide. Press clay over it and add small bumps along the edge.
3. Shape the face in clay: a hooked beak at the front, a short nose horn, two eye sockets and two long brow horns above the eyes.
4. Join the face to the frill. Let it dry.
5. Make a small label card: "Triceratops skull, 1:10 scale. Real length about 2.5 m." Name each part on the card.

Check your work

- My model is about 25 cm long and has a beak, three horns and a frill.
- I did the scale math for the horns.
- My label card names at least five parts.

FIELD NOTEBOOK

1. **Diagram.** Draw the Triceratops skull from the side and label: rostral bone (beak), nose horn, brow horns, eye socket, frill, bumps on the frill edge and dental battery. Beside it, draw a close-up of one column of three stacked teeth with an arrow showing which way new teeth move up.
2. **Notebook entry.** Write a paragraph on Marsh's "bison" mistake. What did he think at first, what new evidence came, and what did he do? End with one sentence on why being willing to change your mind is part of good science.

Did you know? Triceratops is the state fossil of South Dakota and the state dinosaur of Wyoming. A few fossils even preserve patches of skin impressions, showing large scales, some with a raised bump in the middle.

Map or diagram. On a map of the western United States, mark Denver (where the first horns were found in 1887), eastern Wyoming (Hatcher's skulls) and the Hell Creek area of eastern Montana. Draw a dashed line from each to New Haven, Connecticut, where Marsh worked at Yale, to show how far the fossils traveled.

Goes deeper in. Life Science, the units on animal design and how teeth fit diet (coming soon). On this track, Trail B, Stop B6 (The Bone Wars) and Trail C, Stop C1 (Teeth tell

diet).

For families. Marsh named *Bison alticornis* in 1887 and *Triceratops* in 1889. Weight estimates vary widely with method. The healed brow horn is Happ (2008); the skull-injury study is Farke, Wolff and Tanke, *PLoS ONE* (2009); the Torosaurus proposal is Scannella and Horner (2010), still debated. Tooth counts are given as ranges because they vary with the size of the animal. The Knight painting is widely dated 1901; the exact medium is not given here.

PRACTICE

1. **EASY** What does the name Triceratops mean, and who named it?
2. **EASY** What material covered the horn cores in life?
3. **MEDIUM** One side of one jaw has 38 tooth columns with 4 teeth in each. How many teeth is that? How many in all four jaw sides?
4. **MEDIUM** Why did Marsh first think Triceratops horns came from a bison?
5. **CHALLENGE** Give two pieces of evidence about how Triceratops used its horns, and say what each suggests.

Make it a game · Three-Horn Ring Toss. Tape three paper cones to a cardboard box, two long ones on top and a short one in front, and draw a frill behind them. Make rings from paper plates with the middles cut out. Score 1 point for the nose horn and 2 for each brow horn. Stand farther back each round.

Scripture. “O LORD, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches.” (Psalm 104:24, KJV)

“Manifold” means many and varied. A beak, horns, a frill and hundreds of teeth on one animal show how varied and wise God’s works are.

Practice: answers

1. “Three-horned face.” O. C. Marsh, in 1889.
2. Keratin, the tough material in fingernails and cow horns.
3. $38 \times 4 = 152$ teeth on one side; $152 \times 4 = 608$ teeth in all.
4. He had only the horn cores and part of a skull, which looked like a giant bison’s. Better skulls with a beak, nose horn and frill showed his mistake.
5. Any two: a healed, bitten-off brow horn and a hip bone with T. rex tooth marks (attacks by T. rex, and survival); healed injuries on the cheek and frill in the places horns would strike (horn-locking contests with other Triceratops); the large showy frill (display and recognition).

1.3 STEGOSAURUS: PLATES, SPIKES AND A SMALL BRAIN

OBJECTIVES

- Describe the body plan of Stegosaurus: plates, tail spikes, legs and head.
- Explain how the picture of Stegosaurus was corrected as better skeletons were found.
- Weigh the ideas about what the plates and spikes were for.

Warm-up. Hold a lime or a small plum in your hand. Scientists estimate that the brain of a Stegosaurus, an animal as long as a school bus, was not much bigger than that. Why might a big animal not need a big brain?

Video slot. Video coming. Stegosaurus skeleton, plates and tail spikes; the “Sophie” Stegosaurus at the Natural History Museum, London. Search approved channels (Natural History Museum London, Smithsonian National Museum of Natural History, Denver Museum of Nature & Science); preview first.

KEY TERMS

osteoderm

A bone that grows inside the skin, such as the plates and spikes of Stegosaurus or the armor of a crocodile.

thagomizer

The nickname for the group of four spikes at the end of a Stegosaurus tail.

reconstruction

A drawing, model or mounted skeleton showing what scientists think an extinct animal looked like.

glycogen body

A pocket of energy-storing tissue in the hips of birds; a similar space in Stegosaurus hips was once mistaken for a “second brain.”

Morrison Formation

A great spread of rock layers in the western United States, rich in dinosaur bones, where Stegosaurus, Allosaurus and Brachiosaurus are found.

CORE IDEAS

A roof of plates. In 1877 Arthur Lakes, an English-born teacher and geologist, found huge bones near the town of Morrison, Colorado, and sent them to O. C. Marsh at Yale. Among them were flat, triangle-shaped plates of bone. Marsh thought the plates lay flat along the animal’s back like roof tiles, so he named it *Stegosaurus*, “roof lizard.” The name stuck even after scientists learned that the plates stood upright.

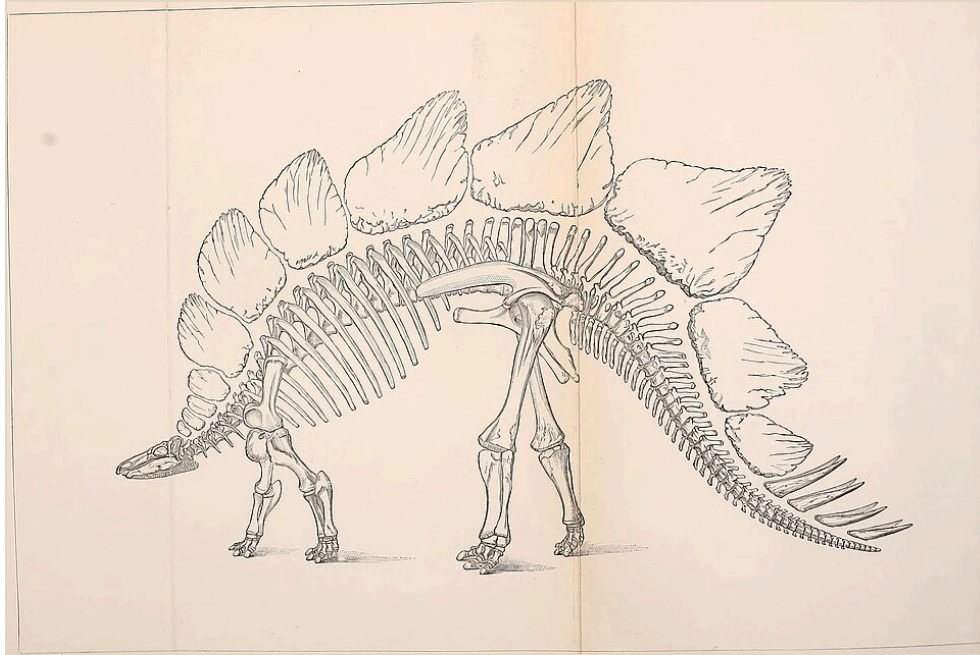
Fixing the picture. In 1891 Marsh published a **reconstruction** showing a single row of plates down the middle of the back and eight spikes on the tail. Better skeletons told a different story. Today scientists agree that Stegosaurus had 17 plates set in two staggered rows, the largest over the hips about 60 centimeters (2 feet) tall, and only four tail spikes. In 2014 the Natural History Museum in London put on show “Sophie,” the most complete Stegosaurus skeleton yet found, from Wyoming, which helped settle many details.

By the numbers. A large Stegosaurus was about 9 meters (30 feet) long and is estimated to have weighed around 5 metric tons. Its back legs were much longer than its front legs, so the hips were the highest point and the small head hung low, near the ground plants it ate. The skull was long and narrow, and the brain was very small for the body, estimated at only about 80 grams, under 3 ounces. Marsh noticed a large hollow in the hip bones and wondered if it held a “second brain.” Today most scientists think it held a **glycogen body**, an energy store like the one found in the hips of birds.

What were plates and spikes for? The plates are **osteoderms**, bones that grew in the skin. They are thin, and their surfaces are covered with grooves for blood vessels. They were too thin to be good armor, so many scientists think they were mainly for display, helping Stegosaurus recognize its own kind; some think they also helped shed or gather heat. The tail spikes, up to about 60 to 90 centimeters (2 to 3 feet) long, were real weapons. An Allosaurus tail bone found in the Morrison rocks has a hole that matches the size and shape of a Stegosaurus spike, and many spikes have broken and healed tips.

Reading the label. Museums call Stegosaurus a **Late Jurassic** dinosaur, a period name for the Morrison rock layers in which it is found, along with Allosaurus and long-necked giants. Stegosaurus fossils have also turned up in Portugal. The story of Stegosaurus is a good lesson: first ideas are often wrong, and patient digging corrects them. The tail spikes earned their funny nickname, the **thagomizer**, from a 1982 newspaper cartoon, and scientists liked it so much that they now use it too.

PICTURE STUDY



Restoration of Stegosaurus ungulatus, Othniel Charles Marsh (drawn under his direction), 1891 · Line drawing, printed in a scientific journal · Published in the American Journal of Science, 1891
Wikimedia Commons · No restrictions

This is the first full skeleton reconstruction of Stegosaurus ever published. Marsh drew together the bones he had and arranged them as best he could. Compare it with a modern picture, and you will see how much has been learned since.

Look closely

- Count the plates. Are they in one row or two?
- Count the tail spikes. How many does a modern Stegosaurus have?
- Compare the front and back legs. Which are longer? Where is the highest point of the back?

Talk about it

1. What did Marsh get right in this drawing, and what has been corrected?
2. Why is it good for scientists to publish their best idea even if it may later be corrected?

HANDS-ON: PLATE PUZZLE: ONE ROW OR TWO?

Build a simple cardboard Stegosaurus and test where the plates should go. Then compare your model with Marsh's 1891 drawing.

You will need

- A cardboard paper-towel tube (the body)
- Thin cardboard or card stock for 17 plates and 4 spikes

- Modeling clay for the head, legs and tail
- Scissors (with a grown-up), tape, ruler and markers

Steps

1. Cut 17 plates of different sizes: small ones for the neck and tail, the biggest (about 6 cm tall) for the hips. This is a 1:10 scale of the real 60 cm plates.
2. Make a tail from clay that tapers to a point, with four spikes near the end pointing out and back.
3. Give the body long back legs and short front legs, and a small, low head.
4. First, stand the plates in a single row along the top, as Marsh did. Then pull them out and set them in two staggered rows, like teeth on a zipper.
5. Decide which looks more balanced, and write down which arrangement the best skeletons show.

Check your work

- My model has 17 plates, 4 tail spikes and longer back legs than front legs.
- I tested one row and two staggered rows.
- I can explain what the skeleton called “Sophie” helped scientists confirm.

FIELD NOTEBOOK

1. **Diagram: then and now.** Divide a page in half. On the left, draw Marsh’s 1891 Stegosaurus with one row of plates and eight spikes, labeled “1891.” On the right, draw the modern version with 17 plates in two staggered rows and four spikes, labeled “Today.” Label on both: head, plates, front leg, back leg, hips, tail spikes. Circle each difference.
2. **Notebook entry.** Write a paragraph: “What were the plates of Stegosaurus for?” Give the evidence (thin bone, blood-vessel grooves, staggered rows), name at least two ideas scientists hold, and tell which you find most convincing and why.

Did you know? Stegosaurus is the state fossil of Colorado. The Colorado law was pushed by schoolchildren, who wrote letters and campaigned for it in the 1980s. It became official in 1982, the same year as the cartoon that gave us the word “thagomizer.”

Map or diagram. On a map of the western United States, shade the Morrison Formation area across Colorado, Utah, Wyoming and parts of Montana, New Mexico and the Dakotas. Mark Morrison, Colorado (Lakes’s find, 1877), Garden Park near Cañon City, Colorado (another early quarry) and Dinosaur National Monument on the Utah–Colorado border.

Goes deeper in. Life Science, animal design and the bones of vertebrates (coming soon); Earth Science, rock layers and formations. On this track, Trail B, Stop B6 (The Bone Wars) and Trail C, Stop C1 (Teeth tell diet).

For families. Marsh named *Stegosaurus armatus* in 1877. Weight and brain-size estimates vary by method. The Allosaurus vertebra with a spike-shaped wound is Carpenter, Sanders, McWhinney and Wood (2005). “Sophie” (NHM London) went on display in December 2014. The word “thagomizer” comes from a 1982 *The Far Side* cartoon by Gary Larson; the cartoon itself is copyrighted and is not reproduced here. Colorado adopted *Stegosaurus* as its state fossil in 1982 after a letter-writing campaign by schoolchildren; the details of that campaign are told differently in different sources, so the stop keeps them brief.

PRACTICE

1. **EASY** What does the name *Stegosaurus* mean, and why did Marsh choose it?
2. **EASY** How many plates and how many tail spikes did *Stegosaurus* have, according to today’s best skeletons?
3. **MEDIUM** A *Stegosaurus* weighed about 5,000 kg and its brain about 80 g. How many times heavier was the body than the brain?
4. **MEDIUM** What evidence shows that *Stegosaurus* used its tail spikes as weapons?
5. **CHALLENGE** Marsh thought the hollow in *Stegosaurus* hips held a “second brain.” What do most scientists think it held, and what living animals helped them decide?

Make it a game · Spike or Plate?. One player calls out a fact; the others hold up a flat hand (plate) if it is about the plates and make a fist with a pointing finger (spike) if it is about the tail spikes. Examples: “Grooves for blood vessels” (plate). “Matches a hole in an *Allosaurus* bone” (spike). “Seventeen of them” (plate). “Four of them” (spike). Take turns making up new facts.

Scripture. “But ask now the beasts, and they shall teach thee; and the fowls of the air, and they shall tell thee: Or speak to the earth, and it shall teach thee: and the fishes of the sea shall declare unto thee.” (Job 12:7–8, KJV)

Job says the creatures and the earth itself can teach us. Patient study of *Stegosaurus* bones taught scientists things their first guesses got wrong.

Practice: answers

1. “Roof lizard.” He thought the plates lay flat along the back like roof tiles.
2. 17 plates in two staggered rows, and 4 tail spikes.
3. $5,000,000 \text{ g} \div 80 \text{ g} = 62,500$ times.
4. An *Allosaurus* tail bone has a hole matching a *Stegosaurus* spike, and many spikes have broken and healed tips.
5. A glycogen body, an energy-storing tissue. Birds have a similar space in their hips.

1.4 BRACHIOSAURUS: THE ARM LIZARD

OBJECTIVES

- Tell how Elmer Riggs’s team found Brachiosaurus in Colorado in 1900.
- Explain what the long front legs and air-filled bones show about how Brachiosaurus was built.
- Compare the height of Brachiosaurus with a giraffe and a house in a scale diagram.

Warm-up. Measure the bone in your upper arm, from shoulder to elbow. Now measure your thighbone, from hip to knee. Which is longer? In almost every four-legged animal the thigh is longer. Brachiosaurus was different.

Video slot. Video coming. Brachiosaurus and Giraffatitan skeletons; the Brachiosaurus cast at the Field Museum; the mounted Giraffatitan in Berlin. Search approved channels (Field Museum, Museum für Naturkunde Berlin, Smithsonian National Museum of Natural History); preview first.

KEY TERMS

sauropod

A huge plant-eating dinosaur with a long neck, long tail, small head and four pillar-like legs, such as Brachiosaurus and Argentinosaurus.

humerus

The bone of the upper arm or upper front leg, between the shoulder and the elbow.

femur

The thighbone, between the hip and the knee.

pneumatic bone

A bone with hollow spaces filled by air sacs from the lungs, as in birds; it is strong but light.

holotype

The single specimen a scientist uses when first naming a new kind of animal; it is the official example of the name.

CORE IDEAS

A Fourth of July find. In the summer of 1900 Elmer Riggs led a fossil-hunting party from the Field Columbian Museum of Chicago to the dry hills near Grand Junction, Colorado. On July 4, while scouting on horseback, his assistant Harold Menke found an enormous bone weathering out of a hillside. The team spent weeks digging out the bones: part of a backbone, ribs, a hip, a thighbone and that first great bone, the upper arm. In 1903 Riggs named the animal *Brachiosaurus altithorax*, “arm lizard with a deep chest.” The skeleton is

the **holotype** of *Brachiosaurus* and is kept at the Field Museum today. The hill where it was found is now called Riggs Hill.

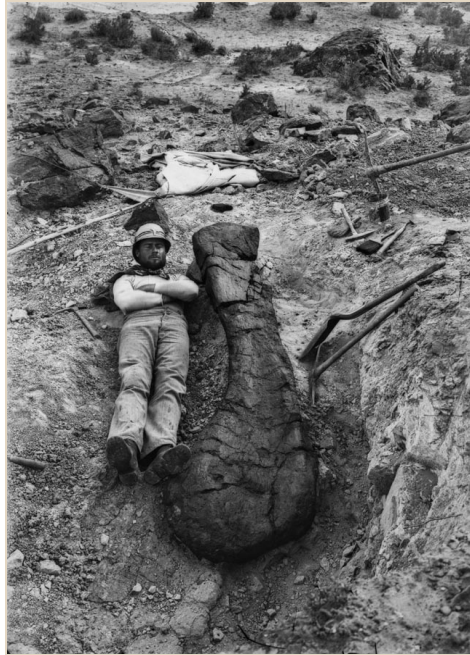
Arms longer than legs. The bone Menke found was a **humerus** about 2 meters (6.7 feet) long, longer than the animal's own **femur**. Almost every other **sauropod** had longer back legs, but *Brachiosaurus* had longer front legs, so its back sloped up from hips to shoulders like a giraffe's. With its long neck rising from tall shoulders, its head may have reached about 9 meters (30 feet) or more above the ground, high enough to look into a third-story window.

By the numbers. *Brachiosaurus* is estimated to have been about 18 to 22 meters (60 to 70 feet) long. Weight estimates range widely, from about 30 to over 50 metric tons, because only one partial skeleton of *Brachiosaurus altithorax* is known and the rest must be worked out from relatives. How could such a heavy animal hold up such a long neck? Its neck bones were **pneumatic**: they had hollow chambers filled by air sacs, as in birds today, which made them strong but much lighter than solid bone.

A cousin in Africa. Between 1909 and 1913 German expeditions dug at Tendaguru in what is now Tanzania and found many skeletons of a similar animal. For decades it was called *Brachiosaurus brancai*, and its tall skeleton in the Museum für Naturkunde in Berlin became one of the most famous dinosaur mounts in the world, about 13 meters (43 feet) tall. In 2009 a study of the bones showed enough differences that it now has its own name, *Giraffatitan*, "giant giraffe." Many pictures labeled "*Brachiosaurus*" in older books really show *Giraffatitan*.

Big questions. To feed a body this size, *Brachiosaurus* must have eaten a great deal of plant food every day, likely from tall trees such as conifers and ginkgoes. Pumping blood up to a head 9 meters high would have needed a powerful heart, and scientists still debate how high it held its neck. Museums call it a **Late Jurassic** animal from the Morrison Formation, the same rock layers that hold *Stegosaurus*. Whatever the answers, the "arm lizard" is a wonder of strength and engineering from the hand of God.

PICTURE STUDY



Harold Menke beside the Brachiosaurus upper-arm bone, Elmer S. Riggs (photographer), Field Columbian Museum, 1900 · Black-and-white photograph · Field Museum archives, Chicago
Wikimedia Commons · Public domain

Elmer Riggs took this photograph at the dig in western Colorado in 1900. His assistant, Harold Menke, lies down next to the great upper-arm bone of *Brachiosaurus* so that everyone could see how big it was. Old photographs like this are records: they show exactly what the fossil looked like when it was found.

Look closely

- Compare the bone with the man. Is the bone longer or shorter than he is?
- Why do you think Menke is lying down instead of standing up next to the bone?
- Look at the ground and the clothes. What clues tell you this is more than a hundred years old?

Talk about it

1. Why is a photograph sometimes better evidence than a painting?
2. If you had found this bone and knew only that it was an upper arm, what could you guess about the rest of the animal?

HANDS-ON: HOW TALL WAS BRACHIOSAURUS?

Make a scale height chart that compares *Brachiosaurus* with a giraffe, a two-story house and you.

You will need

- A long strip of paper at least 1 meter long (taped sheets or a roll of paper)
- A meter stick or tape measure
- Markers or colored pencils
- A 2-meter string (the length of the humerus)

Steps

1. Use a scale of 10 centimeters for every meter. Draw a ground line at the bottom of the strip.
2. Draw yourself at your real height at this scale (for example, 1.5 m tall becomes 15 cm).
3. Draw a giraffe 5.5 m tall (55 cm), a two-story house 7 m tall (70 cm) and Brachiosaurus with its head at about 9 m (90 cm).
4. Label each figure with its real height. Add a title and the scale, "10 cm on paper = 1 m in life," and check your math for each figure.
5. Outside, stretch the 2-meter string on the ground. Lie down beside it. Is the humerus longer than you are tall?

Check your work

- My chart has a ground line, a scale, a title and four labeled figures.
- My Brachiosaurus head is drawn at about 90 cm above the ground line.
- I compared my height with the 2-meter humerus.

FIELD NOTEBOOK

1. **Diagram.** Draw a Brachiosaurus skeleton from the side. Label: skull, neck (pneumatic bones), shoulders, humerus, femur, hips and tail. Draw an arrow showing which way the back slopes. Beside it, draw a small cross-section of a neck bone with its hollow air spaces shaded in.
2. **Notebook entry.** Write a paragraph about the 1900 discovery: who, where, when and what was found. Then explain in two sentences why the length of the humerus surprised Riggs.

Did you know? Since 2018 a full-size cast of the Brachiosaurus skeleton has stood in the great main hall of the Field Museum in Chicago, and another cast was put up in O'Hare International Airport. At Riggs Hill near Grand Junction, a short marked trail now leads past the spot where the bones were dug.

Map or diagram. On a world map, mark Grand Junction, Colorado (Brachiosaurus, 1900) and Tendaguru, Tanzania (Giraffatitan, 1909-1913). Draw an arrow from each to the museum that holds the bones: Chicago and Berlin. Measure on your map roughly how far apart the two finds are.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** "Brachiosaurus lived about 154 to 153 million years ago, in the Late Jurassic."
What we observe: Brachiosaurus bones lie in the Morrison Formation, a widespread set

of mudstone and sandstone layers across the western United States, with Stegosaurus, Allosaurus and other sauropods, often in river-channel sandstones and big bone beds.

How Christians read it: the number comes from radiometric dating of volcanic ash in the layers, which rests on assumptions about starting amounts, constant decay rates and closed systems. Young-earth Christians, the position of this course, read the Morrison bone beds as laid down quickly by moving water, many during the Flood year, thousands of years ago; other Christians accept the long ages. Both agree on what is observed: the bones, the layers and the animals found together.

Goes deeper in. Life Science, bones, lungs and the circulatory system (coming soon); Arithmetic, scale drawings and ratios. On this track, Trail C, Stop C9 (Sauropod necks) and Stop A10 (Argentinosaurus).

For families. Riggs's party found the specimen (now FMNH P 25107) in 1900; Menke spotted the humerus on July 4; Riggs named it in 1903. Brachiosaurus is known from one partial skeleton plus a few referred bones, so size and weight figures are rough estimates. *Giraffatitan* was separated by Michael Taylor in 2009. The Berlin mount's height is often given as about 13 m. The picture-study photograph is from the Field Museum archives; its exact date and photographer are not certain.

PRACTICE

1. **EASY** What does Brachiosaurus mean, and why was it a good name?
2. **EASY** Who led the 1900 expedition that found Brachiosaurus, and where?
3. **MEDIUM** If Brachiosaurus held its head 9 m high and a giraffe holds its head 5.5 m high, how much higher could Brachiosaurus reach? About how many times as high is that?
4. **MEDIUM** What are pneumatic bones, and why would they help Brachiosaurus?
5. **CHALLENGE** Why do weight estimates for Brachiosaurus vary from about 30 to over 50 tons?

Make it a game • Reach for the Treetops. Hang paper “leaves” at different heights on a wall or tree, from knee height to as high as an adult can reach. Each player picks the leaves they can reach while standing flat-footed, then on tiptoe. Then a grown-up (the Brachiosaurus) picks the rest. Talk about how being tall gave Brachiosaurus food that other animals could not reach.

Scripture. “O LORD, how great are thy works! and thy thoughts are very deep.” (Psalm 92:5, KJV)

Engineers marvel at how a neck so long could be held up by light, air-filled bones. God's works are great, and His thoughts are deeper than ours.

Practice: answers

1. “Arm lizard.” Its upper arm bone (humerus) was unusually long, longer than its thighbone.

2. Elmer Riggs of the Field Columbian Museum, near Grand Junction, Colorado.
3. $9 - 5.5 = 3.5$ m higher; $9 \div 5.5 \approx 1.6$ times as high.
4. Bones with hollow spaces filled by air sacs from the lungs. They are strong but light, so the long neck was easier to hold up.
5. Only one partial skeleton is known, so much of the body must be filled in from relatives, and different scientists use different methods (bone measurements, scale models, computer models) and assumptions about how much air and flesh the body held.

1.5 VELOCIRAPTOR, THE REAL SIZE

OBJECTIVES

- Give the real size of Velociraptor and compare it with familiar animals.
- Tell how Velociraptor was found in Mongolia and what the “Fighting Dinosaurs” fossil shows.
- Explain how quill knobs on a forearm bone show that Velociraptor had feathers.

Warm-up. Guess how big a Velociraptor was. Taller than a man? As big as a horse? Write down your guess. By the end of this stop you will know the answer, and you may be surprised.

Video slot. Video coming. Velociraptor real size, feathers and quill knobs; the Fighting Dinosaurs fossil from Mongolia. Search approved channels (American Museum of Natural History, Natural History Museum London, PBS Eons once vetted); preview first.

KEY TERMS

dromaeosaur

A family of small to medium feathered meat-eating dinosaurs with a large curved claw on each foot, such as Velociraptor and Deinonychus; often called “raptors.”

sickle claw

The large, curved claw on the second toe of a dromaeosaur’s foot, held up off the ground when walking.

quill knobs

Small bumps on a bone where the strong feathers of a wing were anchored, as on the forearm of many birds.

Gobi Desert

A huge, dry desert in Mongolia and northern China, famous for its red sandstone cliffs and fossils.

Protoceratops

A sheep-sized, beaked, frilled plant-eating dinosaur common in the Gobi, a smaller relative of Triceratops.

CORE IDEAS

From the Flaming Cliffs. In 1923 the American Museum of Natural History’s Central Asiatic Expedition, led by Roy Chapman Andrews, was exploring the red sandstone bluffs of the Mongolian **Gobi Desert**, a place they called the Flaming Cliffs. There a team member named Peter Kaisen found a small, crushed skull and a clawed finger. In 1924 Henry Fairfield Osborn named the animal *Velociraptor mongoliensis*, “swift seizer from Mongolia.”

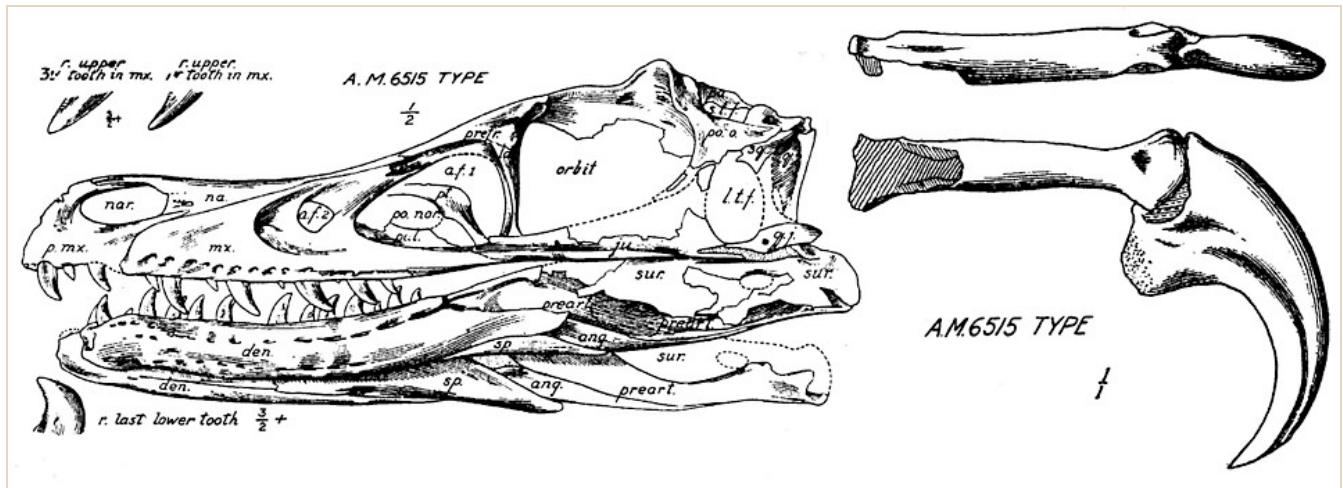
The real size. Many people picture Velociraptor as tall as a man, because that is how it appears in popular movies. The fossils tell a different story. A grown Velociraptor was about 2 meters (6.5 feet) long, but much of that was its long, stiff tail. It stood only about half a meter (1.6 feet) tall at the hips and weighed about 15 to 20 kilograms (33 to 44 pounds), the weight of a large turkey or a medium-sized dog. Its skull was long and low, about 25 centimeters (10 inches), with dozens of small, sharp, widely spaced teeth that curved backward. The large “raptors” in movies were based more on *Deinonychus*, a bigger relative from North America about 3.4 meters (11 feet) long, and then made larger still.

The sickle claw. Like the other **dromaeosaurs**, Velociraptor had a large, curved **sickle claw** on the second toe of each foot. The bony core of the claw was about 6.5 centimeters (2.5 inches) long, and in life it was covered by a longer horny sheath. Velociraptor held this toe up off the ground as it walked, keeping the claw sharp. Many scientists now think it used the claw mainly to pin down and grip small prey, much as hawks and eagles do with their talons today.

The Fighting Dinosaurs. In 1971 a Polish and Mongolian expedition found one of the most famous fossils ever discovered: a Velociraptor and a **Protoceratops** locked together. The raptor’s foot claw is up against the plant-eater’s neck, and the Protoceratops has the raptor’s right arm clamped in its beak. Both animals were buried suddenly, most likely by a collapsing sand dune or a flood of wet sand, while still in the struggle. This single fossil shows that Velociraptor did hunt animals close to its own size.

A feathered hunter. In 2007 three scientists studied a Velociraptor forearm bone and found a row of small bumps called **quill knobs**. In birds, these bumps anchor the strong wing feathers. Velociraptor could not fly, but this evidence shows it had large feathers on its arms, and many scientists think its body was covered in feathers too. So the real Velociraptor was turkey-sized, feathered and quick: different from the movie version, and just as remarkable. Museums label it as a **Late Cretaceous** animal of the Gobi rock layers.

PICTURE STUDY



Skull of Velociraptor mongoliensis, from Osborn's first description, Henry Fairfield Osborn (figure in his 1924 paper), 1924 · Scientific illustration, printed · Published in American Museum Novitates, no. 144 (1924); fossil at the American Museum of Natural History, New York
Wikimedia Commons · Public domain

When Osborn named Velociraptor in 1924, he printed a figure of the skull Peter Kaisen had found the year before. Scientific drawings like this show every bone carefully and include a scale, so that other scientists around the world can study the fossil without traveling to New York.

Look closely

- Find the eye socket, the nostril opening and the other large holes in the skull. Why might a skull have so many openings?
- Look at the teeth. Are they curved, straight, large or small?
- Look for a scale or measurement. How long is the real skull?

Talk about it

1. Compare this drawing with a painting such as Knight's. What does a scientific drawing do better, and what does a painting do better?
2. From the skull alone, what can you tell about what Velociraptor ate?

HANDS-ON: A LIFE-SIZE VELOCIRAPTOR ON PAPER

Draw a Velociraptor at its real size and compare it with yourself, a dog or a cat. Then measure: was your warm-up guess right?

You will need

- A roll of brown paper or newspaper sheets taped together, at least 2.2 meters long and 70 centimeters tall
- A tape measure and a meter stick

- Markers or crayons
- A kitchen scale and a bag you can fill with 15 kg of books (with a grown-up's help)

Steps

1. Lay the paper on the floor. Draw a ground line along the bottom. Mark 0 at the snout and 2 meters at the tail tip.
2. Mark the hips at about 50 centimeters above the ground line, about 80 centimeters back from the snout.
3. Draw the head 25 cm long, the S-shaped neck, a body, a long stiff tail held straight out, two legs and folded feathered arms.
4. Draw the sickle claw on the second toe, held up off the ground. Add feathers on the arms, body and tail.
5. Label: skull, teeth, feathered arm, quill-knob row, sickle claw, stiff tail. Write "Velociraptor, real size: 2 m long, 0.5 m at the hip."
6. Fill a bag with books until it weighs about 15 kg. Lift it with a grown-up nearby. That is a whole Velociraptor.

Check your work

- My drawing is 2 meters long and about 50 cm tall at the hips.
- I drew and labeled the sickle claw and the feathers.
- I wrote my warm-up guess and the real size side by side.

FIELD NOTEBOOK

1. **Diagram.** Draw a Velociraptor foot from the side. Label the four toes, the raised second toe, the sickle claw and the horny sheath. Next to it, draw a forearm bone (ulna) with a row of quill knobs, and draw three feathers rooted in them.
2. **Notebook entry.** Write a paragraph comparing the movie raptor with the real Velociraptor. Use at least three numbers (length, height, weight). End by naming the evidence that shows it had feathers.

Did you know? The Fighting Dinosaurs fossil is a national treasure of Mongolia and is kept in Ulaanbaatar. It has only rarely left the country for exhibits abroad. Velociraptor is not the largest raptor: *Utahraptor*, named in 1993 from Utah, may have reached about 5 to 6 meters (16 to 20 feet) long.

Map or diagram. On a map of Asia, find Mongolia and shade the Gobi Desert across southern Mongolia and northern China. Mark the Flaming Cliffs (Bayanzag), Ulaanbaatar, and Beijing, where the Central Asiatic Expedition set out. Add a scale bar and estimate the distance from Beijing to the Flaming Cliffs.

Goes deeper in. Geography, Asia and the deserts of the world (coming soon); Life Science, birds and feathers. On this track, Trail B, Stop B8 (Roy Chapman Andrews and

the Gobi eggs) and Trail C, Stop C7 (Feathers: what the fossils show).

For families. Kaisen found the type skull (AMNH 6515) in August 1923; Osborn named it in 1924. Size figures follow standard estimates; individual specimens vary. The Fighting Dinosaurs (found 1971) are in the Mongolian Institute of Paleontology; how the pair was buried is still discussed. The quill-knob study is Turner, Makovicky and Norell, *Science* (2007). Whether birds descended from dinosaurs like Velociraptor is a separate question taught in Life Science; this stop reports only what the bones show. Popular films are mentioned but not named or quoted.

PRACTICE

1. **EASY** About how long, how tall and how heavy was a grown Velociraptor?
2. **EASY** Where and when was Velociraptor first found, and what does its name mean?
3. **MEDIUM** Deinonychus was about 3.4 m long; Velociraptor about 2 m. How much longer was Deinonychus? What percent of Deinonychus's length was Velociraptor?
4. **MEDIUM** What are quill knobs, and what do they tell us about Velociraptor?
5. **CHALLENGE** The Fighting Dinosaurs were buried while still locked together. What does that tell us about how quickly they were buried, and why does that matter for fossils in general?

Make it a game • Real or Reel?. One player reads a statement about Velociraptor; the others say "Real!" if the fossils show it, or "Reel!" (as in a movie reel) if it comes only from films. Try: "As tall as a man" (reel). "Had feathers on its arms" (real). "Size of a large turkey" (real). "Could open doors" (reel). "Had a sickle claw on each foot" (real). Then make up your own.

Scripture. "The simple believeth every word: but the prudent man looketh well to his going." (Proverbs 14:15, KJV)

A wise person checks what he hears against the evidence. A movie may show one thing, but the bones tell us what Velociraptor was really like.

Practice: answers

1. About 2 m long, about 0.5 m tall at the hips, and about 15 to 20 kg.
2. At the Flaming Cliffs in the Gobi Desert of Mongolia in 1923; "swift seizer."
3. 1.4 m longer. $2 \div 3.4 \approx 0.59$, so about 59 percent.
4. Bumps on a forearm bone where large feathers were anchored. They show Velociraptor had large feathers on its arms.
5. They must have been buried very suddenly, before either could escape or scavengers could pull them apart. Most good fossils need quick burial, or bodies are eaten, scattered or rot away.

1.6 ANKYLOSAURUS: THE ARMORED TANK

OBJECTIVES

- Describe the armor, skull and tail club of Ankylosaurus.
- Explain how a tail club works using the idea of a swinging weight.
- Tell why Ankylosaurus is famous but known from only a few fossils.

Warm-up. Tie a sock around a tennis ball and swing it slowly in a circle. Then swing it faster (carefully, away from people and windows). Feel the pull get stronger? Ankylosaurus carried a bony weight at the end of its tail.

Video slot. Video coming. Ankylosaurus armor and tail club; the armored dinosaur Borealopelta at the Royal Tyrrell Museum. Search approved channels (Royal Tyrrell Museum, Royal Ontario Museum, American Museum of Natural History, Canadian Museum of Nature); preview first.

KEY TERMS

ankylosaur

A low, wide, four-legged plant-eating dinosaur covered in bony armor. Some, like Ankylosaurus, had tail clubs.

osteoderm

A plate or knob of bone that grows in the skin, forming armor.

tail club

A heavy knob made of large osteoderms fused together at the tip of an ankylosaur's tail.

fused

Grown together into one solid piece. “Ankylosaurus” comes from the Greek word for fused or stiffened.

momentum

The “oomph” of a moving object; a heavier or faster object has more momentum and hits harder.

CORE IDEAS

A fused lizard. In 1906 Barnum Brown, the same collector who had found the first T. rex, dug up part of a skull, some backbones, ribs and dozens of bony armor plates in the Hell Creek rocks of Montana. In 1908 he named the animal *Ankylosaurus magniventris*, “fused lizard with a great belly,” because so many of its bones and armor plates were joined together, and its ribs showed that its body was extremely wide. Brown later found more pieces, including a tail club in Alberta.

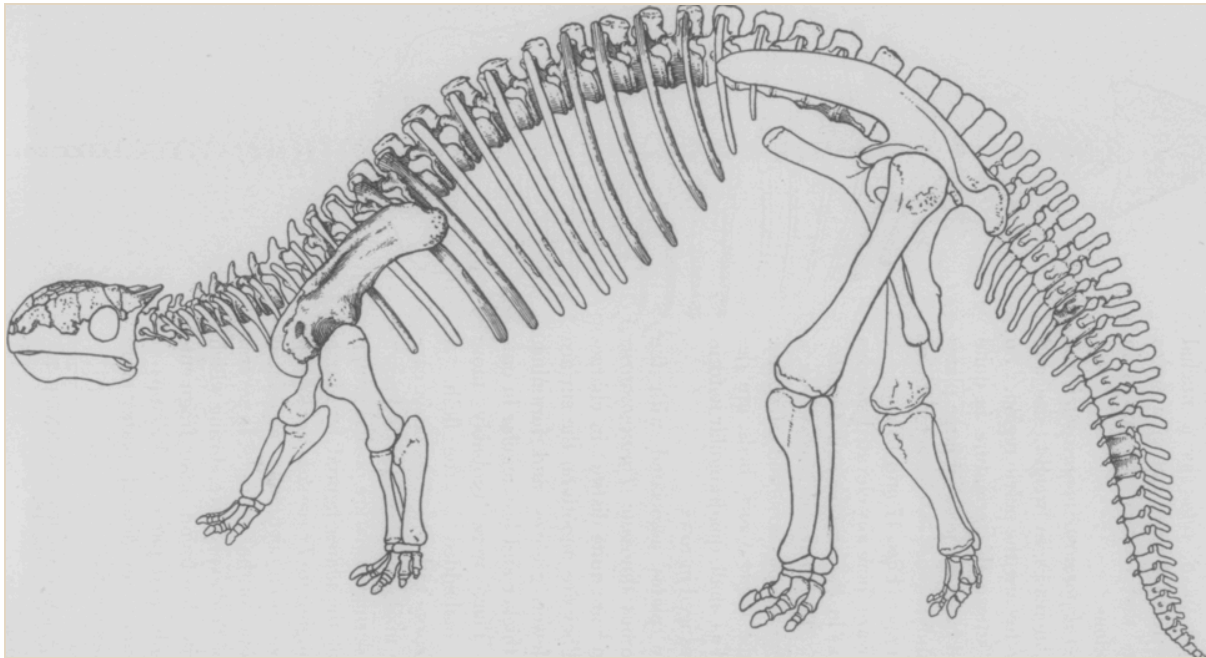
By the numbers. Ankylosaurus was the largest known **ankylosaur**, about 6 to 8 meters (20 to 26 feet) long and estimated at 5 to 8 metric tons. It was wider than it was tall, with short, sturdy legs and a broad body slung low to the ground. Its skull, about 65 centimeters (2 feet) long and even wider in some specimens, was a solid box of bone with short pyramid-shaped horns at its back corners. Its teeth were tiny and leaf-shaped, smaller than your fingernail, for snipping low plants. Its enormous gut probably worked like a fermenting vat to break down tough plant food.

Armor and club. The back, neck and sides were covered with **osteoderms**: flat plates, oval keels and rings of bone set in the skin, with smaller pebbly ones between them. At the end of the tail was a **tail club** made of large osteoderms **fused** together. The tail bones just in front of the club were locked together by bony tendons into a stiff “handle,” while the base of the tail could swing freely. The biggest club found, from Alberta, is about 60 centimeters (2 feet) wide. A 2009 study estimated that a large club swung hard could break bone.

Who got hit? Swinging a heavy weight on a long handle builds **momentum**, the way a baseball bat does. The club may have been aimed at the legs of a tyrannosaur. But a 2022 study of *Zuul*, a club-tailed relative from Montana with its skin and armor still in place, found broken and healed spikes along its sides, just where another ankylosaur’s club would strike. So these animals may also have used their clubs in contests with one another, as rams use their horns.

Famous but rare. Though Ankylosaurus is in almost every dinosaur book, only a few partial skeletons and skulls are known, and no complete skeleton has ever been found. Much of what we draw comes from better-known relatives such as *Euoplocephalus*. Museums place Ankylosaurus in the **Late Cretaceous** layers alongside T. rex and Triceratops. Its armor reminds us of the many ways God equipped His creatures to live in a fallen world where they must protect themselves.

PICTURE STUDY



Skeleton of Ankylosaurus, from “*The Ankylosauridae, a New Family of Armored Dinosaurs*”, Barnum Brown, 1908 · Scientific illustration, printed · Published in the Bulletin of the American Museum of Natural History, vol. 24 (1908)

Wikimedia Commons · Public domain

When Barnum Brown named *Ankylosaurus*, he drew this picture of what he thought the whole skeleton looked like. But he had found only parts of one animal. The shaded bones are the ones he did not have; he borrowed their shapes from *Stegosaurus*, a different armored dinosaur. Every painting of *Ankylosaurus* starts with drawings like this.

Look closely

- Find the shaded bones. Which parts of the body did Brown not have?
- Look at the back. Is it flat or high and rounded like a hill?
- Look at the end of the tail. Do you see the big bony club that *Ankylosaurus* is famous for?

Talk about it

1. Brown borrowed missing bones from *Stegosaurus*. Why might that make his drawing wrong in places?
2. Today *Ankylosaurus* is drawn low and wide with a tail club. What would scientists need to find to change a drawing like this?

HANDS-ON: TAIL-CLUB PENDULUM

Build a small tail club and test how weight and swing speed change the force of a hit, using paper cups as targets.

You will need

- A ruler or paint stirrer (the stiff “handle”)
- String about 30 cm long
- A ball of modeling clay about the size of a golf ball, and a second ball twice as big
- Eight paper or plastic cups
- Masking tape and a pencil

Steps

1. Stack the cups in a pyramid on the floor near a table edge.
2. Tape the string to the end of the ruler and press the small clay ball onto the other end of the string. Hold the ruler at the table edge; this is the tail.
3. Pull the clay back a short way and let it swing into the cups. Count how many fall.
4. Repeat, pulling it back farther. Then repeat with the larger clay ball.
5. Make a table: ball size, pull-back distance, cups knocked down. Do three tries of each and find the average.
6. Swing only toward the cups, never toward people or anything breakable.

Check your work

- I tested two ball sizes and two pull-back distances.
- I recorded three tries for each and found the averages.
- I can explain why a heavier, faster club hits harder (more momentum).

FIELD NOTEBOOK

1. **Diagram.** Draw Ankylosaurus seen from above, so its width shows. Label: skull with corner horns, neck rings, back osteoderms, wide belly, legs, stiff tail “handle” and tail club. Then draw a cross-section across its back, like a slice of bread, showing how flat and wide the body was and where the armor sat.
2. **Notebook entry.** Copy your pendulum results table and write a paragraph explaining what you found. Then answer: what two uses of the tail club do scientists suggest, and what evidence supports each?

Did you know? In 2011 a miner in Alberta uncovered an armored dinosaur so well preserved that its skin, armor and even traces of its color remain. Named *Borealopelta* in 2017, it is a nodosaur, a club-less cousin of Ankylosaurus, and it is displayed at the Royal Tyrrell Museum looking almost like a statue.

Map or diagram. On a map of North America, mark Hell Creek, Montana (Brown’s first Ankylosaurus, 1906), the Red Deer River area of Alberta (more Ankylosaurus pieces and many relatives), north-central Montana (Zuul) and Fort McMurray, Alberta (*Borealopelta*). Use one symbol for club-tailed ankylosaurs and another for club-less nodosaurs.

Goes deeper in. Life Science, animal defenses and armor in living creatures such as armadillos and crocodiles (coming soon); Arithmetic, averages and tables of data. On this track, Trail C, Stop C1 (Teeth tell diet).

For families. Brown found the type specimen (AMNH 5895) in 1906 and named it in 1908. Size estimates follow Arbour and Mallon (2017) and vary by method. The club-impact study is Arbour, *PLoS ONE* (2009); the Zuul flank-injury study is Arbour, Zanno and Evans, *Biology Letters* (2022). The picture study is a page of Brown's 1908 figures; the exact plate shown on Commons may differ from the description, so preview it before teaching. The sentence about a fallen world reflects the Christian reading of Genesis 3.

PRACTICE

1. **EASY** What does Ankylosaurus mean, and who named it?
2. **EASY** What are osteoderms?
3. **MEDIUM** In the pendulum test, the small club knocked down 2, 3 and 4 cups; the large club knocked down 5, 6 and 7. Find each average. How many more cups did the large club knock down on average?
4. **MEDIUM** Why was the stiff "handle" in front of the club important?
5. **CHALLENGE** Ankylosaurus is known from only a few partial skeletons. How can artists draw a whole animal? What is the risk?

Make it a game • Armor Up. Players take turns naming an animal, living or extinct, with armor, and the way it protects itself: "armadillo, bony bands"; "turtle, shell"; "Ankylosaurus, osteoderms and a club"; "porcupine, quills." A player who cannot think of a new one in five seconds sits out. The last player in wins.

Scripture. "The LORD is my rock, and my fortress, and my deliverer; my God, my strength, in whom I will trust; my buckler, and the horn of my salvation, and my high tower." (Psalm 18:2, KJV)

A buckler is a shield. Ankylosaurus carried its armor on its back, but David says our true shield and fortress is the Lord Himself.

Practice: answers

1. "Fused lizard." Barnum Brown, in 1908.
2. Plates or knobs of bone that grow in the skin, forming armor.
3. Small: $(2 + 3 + 4) \div 3 = 3$. Large: $(5 + 6 + 7) \div 3 = 6$. The large club knocked down 3 more on average (twice as many).
4. The locked tail bones turned the end of the tail into a rigid lever, so the swing from the flexible base of the tail could be delivered with force, like a bat.

5. They fill in missing parts from better-known relatives such as *Euoplocephalus* and from the pieces that are known. The risk is that *Ankylosaurus* differed in ways no one has seen yet, so the drawing may need correcting when new fossils are found.

1.7 SPINOSAURUS: THE SAIL-BACKED FISHER

OBJECTIVES

- Tell the story of Ernst Stromer’s Spinosaurus and how the original bones were lost in 1944.
- Describe the features that suggest Spinosaurus caught fish.
- Explain why scientists still debate whether Spinosaurus swam, waded or both.

Warm-up. Look at a heron or a crocodile picture, then at a T. rex skull. Which jaws look better for catching slippery fish, and why? Keep your answer in mind; Spinosaurus had something of both.

Video slot. Video coming. Spinosaurus: Stromer’s lost fossils, the Moroccan discoveries and the tail paddle. Search approved channels (National Geographic, University of Detroit Mercy / Nizar Ibrahim lab, Natural History Museum London); preview first.

KEY TERMS

neural spine

The bony blade that sticks up from the top of a backbone. In Spinosaurus these were very tall and held up a sail.

piscivore

An animal that eats mostly fish, such as a heron, an otter or a crocodile.

semiaquatic

Living partly in the water and partly on land.

neotype

A new specimen chosen as the official example of a species when the original was lost or destroyed.

conical teeth

Straight, cone-shaped teeth without sharp cutting edges, good for gripping slippery prey.

CORE IDEAS

A find in the Egyptian desert. Ernst Stromer was a German paleontologist who explored the deserts of Egypt. In 1912 his collector, Richard Markgraf, dug fossils from the rocks of the Bahariya Oasis, about 300 kilometers (190 miles) southwest of Cairo. Among them were jaw pieces, teeth and backbones with astonishing blades of bone rising from the top, some about 1.65 meters (5.4 feet) tall. In 1915 Stromer named the animal *Spinosaurus aegyptiacus*, “Egyptian spine lizard,” and published careful drawings and descriptions.

Lost in the war. The bones were kept in the state museum in Munich. During the Second World War, Stromer, who openly opposed the Nazi government, urged the museum’s director

to move the collection to safety. The director refused. In April 1944 an Allied bombing raid destroyed the building, and the original Spinosaurus bones were lost. For about seventy years, Stromer's drawings and a few photographs were almost all anyone had. This is one reason careful scientific drawings matter so much.

New bones from Morocco. Starting in the 2000s, more Spinosaurus fossils came out of the Kem Kem beds of southeastern Morocco. In 2014 a team led by Nizar Ibrahim described a partial skeleton and proposed it as a **neotype** to stand in for the lost original. In 2020 the same team reported a tail whose bones carry tall, thin spines above and below, making a flexible, fin-like paddle. Spinosaurus may have been about 14 meters (46 feet) long, possibly longer than T. rex, though lighter in build.

Built for fishing. Many clues suggest Spinosaurus was a **piscivore**. Its snout was long and narrow like a crocodile's, with **conical teeth** that interlocked at the front for gripping slippery prey. Its nostrils sat far back on the snout, so it could dip its jaws in water and still breathe. Its bones were very dense, which helps animals sink and stay steady in water, as in penguins and hippos. The same rocks hold fossils of huge fish, such as the sawfish-like *Onchopristis* and big coelacanths, plenty of food for a fisher.

Swimmer or wader? Here scientists disagree. Ibrahim's team and a 2022 study of bone density argue that Spinosaurus swam and dove after fish. Other researchers, such as David Hone and Thomas Holtz, argue that its tall sail and body shape made it a poor swimmer and that it hunted more like a giant heron, wading in shallows. Both sides study the same bones. Museums label Spinosaurus a **mid-Cretaceous** animal of North Africa. Its story shows that knowledge grows by patient searching, and that some answers are still waiting to be found.

PICTURE STUDY

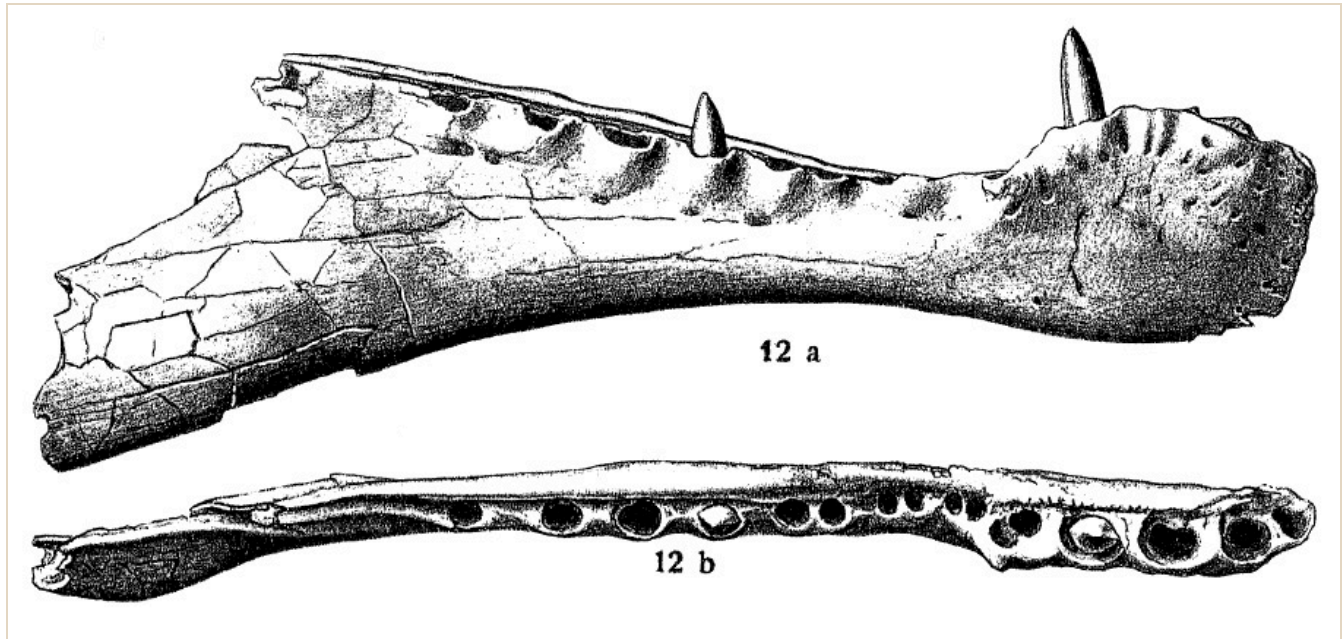


Plate of the original Spinosaurus aegyptiacus bones, Ernst Stromer (plate in his 1915 description), 1915 · Scientific illustration (lithographic plate) · Published in the Abhandlungen of the Bavarian Academy of Sciences, Munich (1915); the bones themselves were destroyed in 1944
Wikimedia Commons · Public domain

This plate is one of the few records left of the first Spinosaurus. Stromer's artist drew each bone with great care. When the fossils were destroyed in 1944, these drawings became the main evidence scientists had for seventy years.

Look closely

- Find the tallest spine. Compare its height with the size of the backbone it sits on.
- Find the lower jaw. Is it short and deep or long and narrow?
- Look for numbers, scale bars or labels. How would a scientist use them?

Talk about it

1. If the only record of a discovery were a drawing, what would you want the drawing to include?
2. What does this plate teach about keeping careful records of your own work?

HANDS-ON: FISHING JAWS TEST

Make two model jaws, one with flat blade teeth like T. rex and one with cone teeth like Spinosaurus, and test which grips a slippery "fish" better.

You will need

- Two pairs of tongs or two clothespins
- Air-dry clay or poster putty

- Toothpicks (for cone teeth) and small cardboard triangles (for blade teeth)
- A bowl of water with five or six cooked noodles or wet slices of cucumber (the “fish”)
- A timer

Steps

1. Press clay along the gripping edges of each pair of tongs.
2. Fit one pair with cardboard triangles pointing inward: these are flat blade teeth.
3. Fit the other pair with toothpick points sticking inward, set so the top and bottom points slide between each other when closed: these are interlocking conical teeth.
4. Set a timer for 30 seconds. Using one pair, catch as many “fish” as you can out of the water. Repeat with the other pair.
5. Do three rounds with each and record the results in a table. Which jaw caught more?

Check your work

- I built both jaws and tested each three times.
- I recorded my results in a table.
- I can explain why conical, interlocking teeth help catch fish.

FIELD NOTEBOOK

1. **Diagram.** Draw the head of Spinosaurus from the side and label: long narrow snout, conical teeth, interlocking tooth rosette at the front, nostril set far back, eye. Beside it, draw one backbone with its tall neural spine and label its height (about 1.65 m) next to a 1.5 m child for scale.
2. **Notebook entry.** Write a paragraph on the swimmer-or-wader debate. Give one piece of evidence each side uses, then say which side you find stronger right now and what new fossil would help settle it.

Did you know? Before the Moroccan finds, researcher Nizar Ibrahim tracked down a fossil collector in a Moroccan town with only a mustache and a few memories to go on. After weeks of searching, he found the man in a café, and the man led him to the site where the new skeleton came from. Stromer also named another big meat-eater from Bahariya, *Carcharodontosaurus*, whose bones were lost in the same raid.

Map or diagram. On a map of northern Africa, mark Cairo, the Bahariya Oasis in Egypt’s Western Desert (Stromer’s finds, 1912) and the Kem Kem beds near Erfoud in southeastern Morocco (the new finds). Draw the Nile River and label the Sahara. Then on a map of Europe, mark Munich, where the bones were kept and lost.

Goes deeper in. Geography, North Africa and the Sahara (coming soon); History, the Second World War; Life Science, how animals are built for water. On this track, Trail C, Stop C1 (Teeth tell diet) and Trail E (sea reptiles).

For families. Stromer described the holotype in 1915; it was destroyed in the bombing of Munich on the night of April 24–25, 1944, and the director’s refusal to move it is recorded in histories of the collection (see Nothdurft’s book *The Lost Dinosaurs of Egypt*, 2002). The neotype proposal is Ibrahim et al., *Science* (2014); the tail is Ibrahim et al., *Nature* (2020); the bone-density study is Fabbri et al., *Nature* (2022); the wading view is Hone and Holtz (2021) and later papers by Sereno and others. Length estimates vary (about 12 to 15 m). The café story is told by Ibrahim in interviews; details vary by retelling.

PRACTICE

1. **EASY** Who named Spinosaurus, when, and from what country did the first bones come?
2. **EASY** What happened to the original Spinosaurus bones?
3. **MEDIUM** Name three features that suggest Spinosaurus ate fish.
4. **MEDIUM** The bones were found in 1912 and the new Moroccan skeleton was described in 2014. How many years apart is that? How many years passed between the loss (1944) and 2014?
5. **CHALLENGE** Two teams study the same Spinosaurus bones and reach different conclusions. Is that a failure of science? Explain.

Make it a game • Heron or Diver?. Players stand in a line. The leader calls “Wade!” and everyone walks slowly with high, careful steps, pretending to peer into water. On “Dive!” everyone crouches and makes swimming arms. On “Snap!” everyone claps hands together like jaws. Anyone who does the wrong motion sits out. Speed up as you go.

Scripture. “It is the glory of God to conceal a thing: but the honour of kings is to search out a matter.” (Proverbs 25:2, KJV)

God has hidden many wonders in His creation for us to find. Searching them out patiently, as the Spinosaurus hunters did, is an honorable work.

Practice: answers

1. Ernst Stromer, in 1915, from Egypt (the Bahariya Oasis).
2. They were destroyed when a bombing raid hit the Munich museum in April 1944.
3. Any three: long narrow crocodile-like snout; conical, interlocking teeth; nostrils far back on the snout; dense bones; found with many large fish fossils.
4. $2014 - 1912 = 102$ years; $2014 - 1944 = 70$ years.
5. No. The observations (bone shapes, density, tail spines) are shared; the interpretations differ. Debate pushes both sides to test their ideas, look for new fossils and check their reasoning, which is how knowledge grows.

1.8 PARASAUROLOPHUS AND ITS CREST

OBJECTIVES

- Describe Parasaurolophus and the hollow tubes inside its crest.
- Explain why a longer tube makes a lower sound, and connect it to the crest.
- Tell how a young Parasaurolophus fossil showed that the crest grew with age.

Warm-up. Hum into a short cardboard tube, such as a toilet-paper roll, then into a long one, such as a wrapping-paper tube. Which sounds lower? Scientists think Parasaurolophus could do something like this with its head.

Video slot. Video coming. Parasaurolophus crest, CT scans and the sound it may have made; the baby Parasaurolophus “Joe.” Search approved channels (Royal Ontario Museum, Raymond M. Alf Museum of Paleontology, New Mexico Museum of Natural History and Science); preview first.

KEY TERMS

hadrosaur

A “duck-billed” dinosaur: a large plant-eater with a broad, flat beak and hundreds of grinding teeth. Some, like Parasaurolophus, had crests.

crest

A ridge or growth of bone on top of the head. The Parasaurolophus crest was a long, hollow, backward-curving tube.

nasal passage

The airway that runs from the nostrils to the throat.

resonate

To make a sound fuller and louder by setting air vibrating inside a hollow space, as in a trumpet or organ pipe.

CT scan

A set of X-ray pictures taken in slices, which a computer puts together to show the inside of an object without cutting it open.

CORE IDEAS

A crest from Alberta. In 1920 a field party from the University of Toronto, digging along the Red Deer River in Alberta, Canada, uncovered a skull and partial skeleton with something no one had seen before: a long bony tube sweeping back from the top of the head. In 1922 William Parks named it *Parasaurolophus walkeri*. The name means “near crested lizard,” because it seemed close to another crested dinosaur, *Saurolophus*; the second name honors Sir Edmund Walker, chairman of the Royal Ontario Museum’s trustees. The skull,

crest included, is about 1.6 meters (5.2 feet) long, and it is still at the Royal Ontario Museum in Toronto.

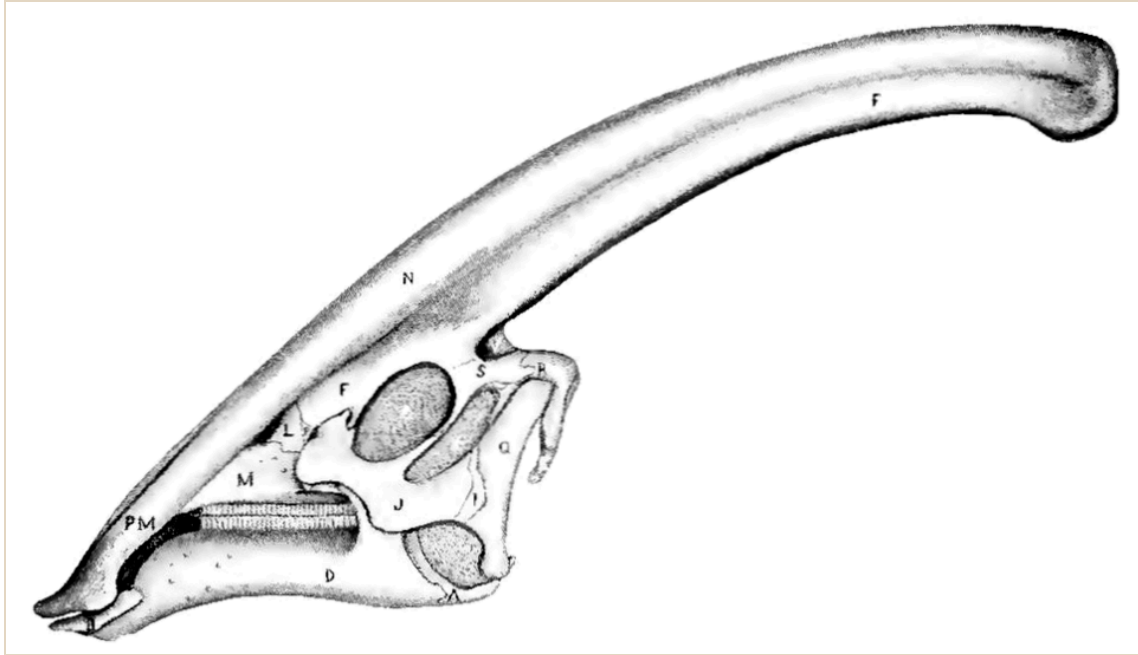
A duck-billed plant-eater. Parasaurolophus was a **hadrosaur** about 9.5 meters (31 feet) long, estimated at about 2.5 metric tons. It could walk on all fours while feeding and probably rose onto its hind legs to run. Its wide beak cropped plants, and behind it lay rows of hundreds of tightly packed teeth that ground food like a millstone, with new teeth always growing in below.

Tubes inside the crest. The **crest** was not solid. Inside it, the **nasal passages** ran from the nostrils all the way up to the tip of the crest and back down again before reaching the throat, a loop of tubes several meters long in all. What was it for? Scientists once guessed it was a snorkel, but there is no hole at the tip. Others suggested an air tank or a better sense of smell. In 1981 David Weishampel compared the crest to a long wind instrument and argued that it helped Parasaurolophus **resonate**, making deep, carrying calls. The crest's shape may also have helped these animals recognize one another at a distance.

Hearing a dinosaur? In 1995 a fine skull of a related species, *Parasaurolophus tubicen*, was found in New Mexico. Scientists used a **CT scan** to map the tubes inside it, and in 1997 a computer team at Sandia National Laboratories used that map to model the sound the crest might make. The result was a deep, rumbling, trumpet-like tone. No one can be sure it sounded exactly like that, because we do not know the shape of the soft parts, such as the voice box. But a longer tube gives a lower note, and the crest gave Parasaurolophus a very long tube.

A crest that grew. In 2009 a high-school student named Kevin Terris found a tiny Parasaurolophus skeleton in southern Utah. Described in 2013 and nicknamed "Joe," it was less than a year old and about 2 meters (6 feet) long. Instead of a long tube, it had only a small rounded bump on its head. So the crest grew as the animal grew, and young ones may have had higher voices than adults. Museums place Parasaurolophus in the **Late Cretaceous** rocks of Alberta, New Mexico and Utah.

PICTURE STUDY



Skull of Parasaurolophus walkeri, from the first description, William A. Parks (figure in his 1922 description), 1922 · Scientific illustration, printed · Published in University of Toronto Studies, Geological Series (1922); fossil at the Royal Ontario Museum, Toronto
Wikimedia Commons · Public domain

When William Parks named *Parasaurolophus*, he showed its skull in his report. Look at how long the crest is compared with the rest of the head. Parks could see the outside of the crest, but it took X-rays and CT scans many years later to see the tubes inside.

Look closely

- Measure with your fingers: is the crest longer or shorter than the rest of the skull?
- Find the beak, the eye socket and the place where the crest leaves the head.
- Look for any break, crack or missing piece. How might that affect what Parks could tell?

Talk about it

1. If you could see only the outside of the crest, what would you guess it was for?
2. Why might a scientist in 1922 not be able to answer that question, while a scientist today can try?

HANDS-ON: CREST HORN: TUBE LENGTH AND PITCH

Test the rule that a longer air tube makes a lower note, the idea behind the *Parasaurolophus* sound.

You will need

- Five glass bottles of the same size (or tall glasses)
- Water and a measuring cup
- Cardboard tubes of three lengths (toilet-paper roll, paper-towel roll, wrapping-paper roll)
- A ruler and a pencil

Steps

1. Fill the bottles with different amounts of water: nearly full, three-quarters, half, one-quarter and empty.
2. Measure the height of the air space above the water in each bottle and write it down.
3. Blow gently across the top of each bottle. Put them in order from highest note to lowest.
4. Compare: does the longest air space make the lowest note?
5. Hum the same note into each cardboard tube and listen to how the sound changes. Which tube rumbles the most?
6. Write a rule in one sentence: "The longer the air column, the ____ the note."

Check your work

- I measured five air spaces and ordered the notes.
- I tested three tubes.
- I wrote the rule and connected it to the crest.

FIELD NOTEBOOK

1. **Diagram.** Draw the Parasaurolophus skull from the side, and inside the crest draw the air path in blue: from the nostril up into the crest, to the tip, back down and into the throat. Add arrows for the direction of the air. Label: beak, nostril, crest, air tubes, eye, throat. Beside it, draw Joe's small skull with its little bump.
2. **Notebook entry.** Copy your bottle results table, then write a paragraph explaining how your experiment supports the idea that the crest made low sounds, and one reason we cannot be completely sure what Parasaurolophus sounded like.

Did you know? There are three named species of Parasaurolophus: *P. walkeri* from Alberta, *P. tubicen* from New Mexico, which had the longest crest, and *P. cyrtocristatus* from New Mexico and Utah, which had a short, strongly curved crest. Some scientists wonder whether the short-crested ones were simply younger animals.

Map or diagram. On a map of North America, mark the Red Deer River in Alberta (*P. walkeri*, 1920), the San Juan Basin of northwestern New Mexico (*P. tubicen*, the 1995 skull) and Grand Staircase-Escalante National Monument in southern Utah (Joe, 2009). Connect them with a line and measure about how far it is from the Alberta find to the New Mexico find.

Goes deeper in. Life Science, sound and hearing in animals (coming soon); Arithmetic, tables and patterns; Art, the music of wind instruments. On this track, Trail C, Stop C10 (Dinosaur sounds).

For families. The type specimen (ROM 768) was found in 1920 and named by Parks in 1922. Weishampel's acoustic study was published in 1981. The New Mexico skull was described by Sullivan and Williamson (1999), and the Sandia sound model was made public in 1997. Joe (RAM 14000) was described by Farke and others in *PeerJ* (2013) and is at the Raymond M. Alf Museum of Paleontology. The computer sound is a model, not a recording; the stop says so. Weight figures are estimates.

PRACTICE

1. **EASY** Who named Parasaurolophus, in what year, and what does the name mean?
2. **EASY** What runs inside the Parasaurolophus crest?
3. **MEDIUM** Why do scientists not think the crest was a snorkel?
4. **MEDIUM** Joe was about 2 m long; an adult was about 9.5 m. About how many times longer was the adult? What does Joe's small bump tell us about the crest?
5. **CHALLENGE** The 1997 computer model produced a deep rumbling sound. Name one thing the model knew for sure and one thing it had to guess.

Make it a game • Crest Call. Each player makes a "crest horn" from a cardboard tube and invents a short call. One player hides in another room or behind a tree and makes a call; the others try to tell whose call it is and point toward where it came from. Talk about how a herd might have used calls to stay together.

Scripture. "Let every thing that hath breath praise the LORD. Praise ye the LORD."
(Psalm 150:6, KJV)

The last verse of the Psalms calls every breathing creature to praise God. Parasaurolophus breathed through a crest like a trumpet, and we praise Him with our own breath and voices.

Practice: answers

1. William Parks, in 1922; "near crested lizard" (near Saurolophus).
2. The nasal passages, a loop of air tubes from the nostrils up to the tip of the crest and back down to the throat.
3. There is no opening at the tip of the crest for air to come in.
4. $9.5 \div 2 \approx 4.75$, almost 5 times longer. The crest grew as the animal grew.
5. Known: the shape and length of the bony tubes, from the CT scan. Guessed: the soft parts, such as the voice box, throat and lining of the tubes, which do not fossilize.

1.9 PACHYCEPHALOSAURUS: THE DOME-HEADED DINOSAUR

OBJECTIVES

- Describe the thick dome and knobby skull of Pachycephalosaurus with measurements.
- Explain how its name changed from *Troodon wyomingensis* to *Pachycephalosaurus*.
- Weigh the evidence for and against head-butting.

Warm-up. Hold a ruler up to your forehead and measure 25 centimeters (10 inches) out from it. The bony dome of a big Pachycephalosaurus may have been that thick: as thick as a large dictionary is tall.

Video slot. Video coming. Pachycephalosaurus skull and dome; head-butting debate and growth stages. Search approved channels (Museum of the Rockies, Smithsonian National Museum of Natural History, Burpee Museum of Natural History); preview first.

KEY TERMS

pachycephalosaur

A two-legged plant-eating dinosaur with a thick, dome-shaped skull roof. The name means “thick-headed lizard.”

dome

The rounded, thickened bone on top of a pachycephalosaur’s skull.

lesion

A wound or damaged spot. In a fossil bone, a healed lesion shows the animal was injured and lived.

growth stage

A step in an animal’s life, such as baby, young or adult. Animals can look very different at different growth stages.

synonym

In science, a second name given to an animal that already has a name. The older valid name is kept.

CORE IDEAS

A name that changed. In 1931 Charles Gilmore of the Smithsonian Institution described a thick, broken skull dome from the Lance rocks of eastern Wyoming. He thought it belonged to a small dinosaur already known only from teeth, called *Troodon*, so he named it *Troodon wyomingensis*. Then, in 1943, Barnum Brown and Erich Schlaikjer described a much more complete skull from Montana and named a new genus, *Pachycephalosaurus*, “thick-headed lizard.” Scientists later agreed that Gilmore’s dome belonged to the same animal, so today its full name is *Pachycephalosaurus wyomingensis*.

By the numbers. Pachycephalosaurus was the largest of the **pachycephalosaurs**. Its skull was about 60 centimeters (2 feet) long, and the bony **dome** on top could be up to about 25 centimeters (10 inches) thick. Bony knobs and short spikes ringed the back of the skull, and more bumps covered the snout. Because almost all the fossils are skulls, its body size is an estimate, worked out from smaller relatives with more complete skeletons: perhaps 4.5 meters (15 feet) long and a few hundred kilograms. It walked on two legs and had small, leaf-shaped teeth with ridged edges, probably for plants, seeds and fruit, and perhaps small animals too.

Head-butting rams? For many years books showed pachycephalosaurs crashing heads like bighorn sheep. In 2004 two scientists studied slices of dome bone and argued that the domes were too spongy and too rounded for head-on ramming; they thought the domes were mainly for display. But in 2013 another team examined over a hundred pachycephalosaur domes and found healed **lesions**, signs of injury and infection that had healed, on about one in five. Those injuries sat on the top of the dome, where blows would land. Many scientists now think pachycephalosaurs did hit each other, perhaps with glancing blows or by butting each other's sides.

Babies with spikes? Two other dome-headed dinosaurs were found in the same rocks: *Stygimoloch*, with long spikes and a small dome, and *Dracorex*, with spikes and a flat head. In 2009 Jack Horner and Mark Goodwin argued that these were not separate kinds at all, but younger **growth stages** of Pachycephalosaurus: as the animal grew, the dome swelled and the spikes shrank. Not every scientist agrees, but many do. If they are right, those names are **synonyms** of Pachycephalosaurus, just as *Troodon wyomingensis* turned out to be.

Why it matters. Pachycephalosaurus teaches that names can change as more fossils are found, and that two careful teams can read the same evidence in different ways until more evidence comes. Museums place it in the **Late Cretaceous** rocks of Montana, Wyoming and South Dakota, with T. rex and Triceratops. Its thick skull is a striking example of protection built into a creature's design.

PICTURE STUDY



Skull dome of Pachycephalosaurus wyomingensis, USNM 12031, Michael Brett-Surman (photographer), 2009 (the fossil was described in 1931) · Color photograph · Smithsonian National Museum of Natural History, Washington, D.C.
Wikimedia Commons · CC0

This is the very bone that gave Pachycephalosaurus the second half of its name. Charles Gilmore described it in 1931, and at first he thought it belonged to a different dinosaur entirely. A Smithsonian scientist photographed it in the museum's collection so others could study its shape.

Look closely

- Find the highest point of the dome. Is the dome smooth or rough?
- Find the knobs and bumps around its edge.
- Which parts of the skull are missing? Is this a whole head or only the top?

Talk about it

1. Gilmore had only part of a skull. What else would he have needed to find to know it was a new kind of dinosaur?
2. Is it a failure that Gilmore's name was later changed? Why or why not?

HANDS-ON: DOME TEST: HEAD-ON OR GLANCING?

Test what happens when two domes meet, and compare head-on hits with side hits.

You will need

- Two oranges or two grapefruits (the domes)

- Two small, flat-sided boxes (flat heads), such as tissue or cereal boxes
- A ruler and a smooth table
- Tape

Steps

1. Roll the two oranges toward each other along the table so they meet exactly head-on. What happens?
2. Now roll them so they meet a little off-center. Do they slide off each other? Record which way they go.
3. Slide the two flat boxes toward each other the same way, head-on and off-center. Do they slide off or push square against each other?
4. Try ten off-center rolls with the oranges. Count how many times they glance off to the side.
5. Write a conclusion: would a round dome make head-on ramming easy or hard? What kind of contest might fit a dome better?

Check your work

- I tested head-on and off-center meetings for domes and flat heads.
- I recorded ten off-center rolls.
- I wrote a conclusion and connected it to the debate.

FIELD NOTEBOOK

1. **Diagram.** Draw three heads side by side, labeled “Young (Dracorex?),” “Older (Stygimoloch?)” and “Adult Pachycephalosaurus.” Show the dome getting taller and the spikes getting shorter. Under the adult, draw a cut-away slice of the dome and label its thickness (up to about 25 cm), the knobs and the spot where healed lesions are often found.
2. **Notebook entry.** Write a paragraph: “Did Pachycephalosaurus butt heads?” Give one piece of evidence for and one against, then tell what your dome test suggests.

Did you know? Dracorex hogwartsia was named in 2006 after a school in a children’s fantasy series, because its spiky, dragon-like skull was donated to the Children’s Museum of Indianapolis. If Horner and Goodwin are right, that dragon was really a young Pachycephalosaurus.

Map or diagram. On a map of the northern Great Plains, mark Niobrara County in eastern Wyoming (Gilmore’s dome), southeastern Montana (Brown and Schlaikjer’s skull) and western South Dakota (Dracorex). Shade the region where the Hell Creek and Lance rock layers are found and add a key.

Goes deeper in. Life Science, bones and how they heal (coming soon); Literature, how names and words are chosen. On this track, Trail C, Stop C8 (Babies and growth).

For families. Gilmore named *Troodon wyomingensis* from USNM 12031 in 1931; Brown and Schlaikjer named *Pachycephalosaurus* in 1943 and made *T. wyomingensis* its type species. Body size is uncertain because no complete skeleton is known. The spongy-dome study is Goodwin and Horner (2004); the lesion study is Peterson, Dischler and Longrich, *PLoS ONE* (2013); the growth-stage proposal is Horner and Goodwin, *PLoS ONE* (2009). The picture-study plate is in the public domain because Gilmore died in 1945; check that the Commons image matches before teaching. The fantasy series behind Dracorex's name is not named here.

PRACTICE

1. **EASY** What does Pachycephalosaurus mean?
2. **EASY** Why is the second part of its name “wyomingensis”?
3. **MEDIUM** In a 2013 study, about one in five domes had healed lesions. If a museum had 110 domes, about how many would you expect to show lesions?
4. **MEDIUM** Why is the body size of Pachycephalosaurus only an estimate?
5. **CHALLENGE** Horner and Goodwin argued that Dracorex and Stygimoloch were young Pachycephalosaurus. What would you expect to find if they are right?

Make it a game · Name Change. One player is the “scientist” and gives each other player a made-up dinosaur name. Then the scientist calls out a clue (“All of you with spikes are really young Pachycephalosaurus!”), and players who fit must switch to the new name. Whoever forgets their current name when called sits out. Talk afterward about why scientists keep the oldest valid name.

Scripture. “And take the helmet of salvation, and the sword of the Spirit, which is the word of God:” (Ephesians 6:17, KJV)

Pachycephalosaurus wore a helmet of bone. Paul tells Christians to put on a better helmet, the salvation God gives, and to carry His Word.

Practice: answers

1. “Thick-headed lizard.”
2. Gilmore named the first dome *Troodon wyomingensis* in 1931, after Wyoming where it was found; when the dome was moved into *Pachycephalosaurus*, it kept that species name.
3. $110 \div 5 = 22$ domes.
4. Almost all its fossils are skulls, so the body is worked out from smaller relatives with more complete skeletons.
5. A series of skulls from the same rocks showing in-between shapes: small domes with long spikes, then larger domes with shorter spikes; bone showing signs of youth (still-growing tissue) in the *Dracorex* and *Stygimoloch* skulls; and no fully grown flat-headed or spiky adults.

1.10 ARGENTINOSAURUS: ONE OF THE BIGGEST

OBJECTIVES

- Tell how Argentinosaurus was found and named, and which bones are actually known.
- Explain how scientists estimate the size of a giant from only a few bones, and why the estimates vary.
- Compare Argentinosaurus with a blue whale, a school bus and other giants using numbers.

Warm-up. One back bone of Argentinosaurus was about 1.6 meters (over 5 feet) tall. Stand against a wall and have someone mark 1.6 meters. Is one backbone of this animal taller than you?

Video slot. Video coming. Argentinosaurus and the titanosaurs of Patagonia; how scientists estimate dinosaur size. Search approved channels (Museo Carmen Funes, Fernbank Museum of Natural History, American Museum of Natural History “The Titanosaur”); preview first.

KEY TERMS

titanosaur

A group of sauropods, many of them giants, found especially in South America. Argentinosaurus and Patagotitan are titanosaurs.

vertebra

One bone of the backbone (plural: vertebrae).

fibula

The thinner of the two bones in the lower leg.

scaling

Working out the size of a whole animal by comparing the bones you have with the same bones in a better-known relative.

Patagonia

The southern part of South America, in Argentina and Chile, known for its windy plains and many giant fossils.

CORE IDEAS

A rancher’s “petrified log.” In 1987 Guillermo Heredia, a rancher near the town of Plaza Huincul in Neuquén Province, Argentina, noticed what looked like a huge piece of petrified wood on his land. It was a bone, part of a lower leg. Workers from the local Carmen Funes Museum and paleontologists from Buenos Aires dug at the site and found more giant bones. In 1993 José Bonaparte and Rodolfo Coria named the animal *Argentinosaurus huinculensis*, “Argentine lizard from Huincul.”

What was actually found. Only a small part of the skeleton has ever been found: several back **vertebrae**, part of the hip, a few pieces of rib and part of a leg bone, the **fibula**, about 1.55 meters (5.1 feet) long. But those bones are enormous. One back vertebra stands about 1.59 meters (5.2 feet) tall, taller than many adults. No skull, neck or tail of *Argentinosaurus* has been found.

Estimating a giant. How can scientists judge the size of an animal from a few bones? They use **scaling**: they compare each bone with the same bone in a better-known **titanosaur** and multiply up. Because the comparison animals and methods differ, the answers differ. Most estimates put *Argentinosaurus* at about 30 to 35 meters (100 to 115 feet) long, longer than three school buses end to end, and about 65 to 80 metric tons. Some estimates go lower and some higher. That spread is honest: the fewer bones you have, the less certain the answer.

Biggest of all? *Argentinosaurus* is one of the largest land animals ever found, but it has rivals. *Patagotitan*, named in 2017 from Chubut Province farther south in Argentina, is known from far more of its skeleton and was probably a little smaller. Other giants are known from even fewer bones, so no one can yet say for sure which was the biggest. For comparison, the largest blue whales are about 30 meters long and may weigh around 150 tons or more: as long as *Argentinosaurus*, and heavier, because water helps hold up a whale's weight. On land, nothing living comes close; the African elephant tops out around 6 to 7 tons.

From tiny eggs. In 1997 an expedition in Patagonia found a huge nesting ground of titanosaur eggs at a place now called Auca Mahuevo, with thousands of eggs, many about 13 to 15 centimeters (5 to 6 inches) across, some with embryos and scaly baby skin inside. A titanosaur hatchling was far smaller than you are, yet grew to giant size. Museums place *Argentinosaurus* in the Late **Cretaceous** rocks of the Huincul Formation. When God asked Job, "Where wast thou when I laid the foundations of the earth?" He reminded Job that the Creator's works are far greater than our understanding.

PICTURE STUDY



Brontosaurus, Charles R. Knight, 1897 · Watercolor (shown here as printed in the New-York Tribune, 1919) · American Museum of Natural History, New York
Wikimedia Commons · Public domain

No one living in Knight's day had ever heard of *Argentinosaurus*, but Knight painted the giant sauropods that scientists knew: *Brontosaurus* in the water and *Diplodocus* on the land. In 1897 most experts believed these animals were so heavy that they spent much of their time in swamps and lakes, where water would hold up their weight. Fossil footprints found later showed that sauropods walked on dry land, and even the 70-ton titanosaurs carried their own weight on pillar-like legs.

Look closely

- Find the *Brontosaurus* in the water. How much of its body is hidden below the surface?
- Find the *Diplodocus* on the shore. How is it holding its tail?
- Look at the legs you can see. Do they look like pillars, or bent like a lizard's?

Talk about it

1. Why did scientists in 1897 think sauropods needed water? What evidence changed their minds?
2. If Knight could have seen *Argentinosaurus* bones, how might he have painted it differently?

HANDS-ON: PACE OFF A GIANT

Mark out the length of *Argentinosaurus* outdoors and compare it with other giants, then make a scale diagram for your notebook.

You will need

- A long tape measure, or a 10-meter rope with a knot every meter
- Five markers (cones, sticks or shoes) and sidewalk chalk if on pavement
- A park, field or long sidewalk at least 40 meters long
- A clipboard and pencil

Steps

1. Place a marker at the start. Measure 12 m and place a second marker: that is a T. rex.
2. Measure from the start to 20 m (Brachiosaurus, about 18 to 22 m) and to 30 m (a large blue whale). Place markers.
3. Measure to 35 m and place the last marker: the upper estimate for Argentinosaurus.
4. Walk the length heel to toe and count your steps. Then count how many of your family members, lying head to toe, it would take to fill it.
5. Write down: the four lengths, your step count and your conclusion.

Check your work

- I marked T. rex, Brachiosaurus, a blue whale and Argentinosaurus.
- I counted my steps along the full length.
- I can explain why Argentinosaurus's length is given as a range.

FIELD NOTEBOOK

1. **Diagram.** On one long page, draw these to the same scale (1 cm = 2 m): Argentinosaurus (30–35 m, so 15–17.5 cm), a blue whale (30 m), Brachiosaurus (about 20 m), T. rex (12 m), an African elephant (about 6 m) and a person (1.7 m). Shade in a different color the bones of Argentinosaurus that have actually been found (backbones, hip, ribs, part of a leg) and leave the rest as a dashed outline.
2. **Notebook entry.** Write a paragraph explaining how scientists estimate the size of Argentinosaurus. Use the words “scaling” and “estimate,” give the range of length and weight, and explain why a range is more honest than a single number.

Did you know? A full-size reconstruction of Argentinosaurus stands at the Carmen Funes Municipal Museum in Plaza Huincul, Argentina, and another dominates the great hall of the Fernbank Museum of Natural History in Atlanta, Georgia. At the American Museum of Natural History in New York, a cast of Patagotitan is so long that its head pokes out of the gallery doorway.

Map or diagram. On a map of South America, find Argentina and shade Patagonia. Mark Plaza Huincul in Neuquén Province (Argentinosaurus), the Auca Mahuevo egg site (also in Neuquén), and the La Flecha ranch area in Chubut Province (Patagotitan). Add Buenos Aires and a scale bar, and measure the distance from Buenos Aires to Plaza Huincul.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** “Argentinosaurus lived about 95 million years ago, in the Late Cretaceous.” **What we observe:** a few gigantic bones (backbones, hip, ribs and a fibula) lying in the sandstones and mudstones of the Huincul Formation in Neuquén Province, Argentina, along with fossils of other dinosaurs. **How Christians read it:** the date comes from matching these layers with others dated by radioactive minerals, which rests on assumptions about starting amounts, constant decay rates and closed systems. Young-earth Christians, the position of this course, read the giant’s burial in thick layers of sediment as part of the rapid, large-scale deposition of the Flood year, thousands of years ago; other Christians accept the long ages. All agree on what is seen: the bones, their size, and the layers that hold them.

Goes deeper in. Geography, South America and Patagonia (coming soon); Arithmetic, scale drawings and ranges; Life Science, how large animals carry their weight. On this track, Stop A4 (Brachiosaurus), Trail C, Stop C2 (Eggs and nests) and Stop C9 (Sauropod necks).

For families. Heredia’s find was in 1987; Bonaparte and Coria named the species in 1993. Bone sizes follow Bonaparte and Coria (1993) and later restudies; length and mass estimates vary widely (some as low as about 30 m and 50–60 t, some over 90 t). *Patagotitan* is Carballido et al. (2017). Auca Mahuevo was reported by Chiappe and colleagues (1998). Blue-whale weights are approximate. Knight’s painting is commonly dated 1897 and described as a watercolor; please confirm with the AMNH record if exactness matters. The Job quotation is Job 38:4.

PRACTICE

1. **EASY** Who found the first Argentinosaurus bone, and what did he first think it was?
2. **EASY** Name three kinds of Argentinosaurus bones that have been found, and one that has not.
3. **MEDIUM** A school bus is about 12 m long. How many buses long is a 35 m Argentinosaurus? How many is a 30 m one?
4. **MEDIUM** An African elephant weighs about 6 tons. If Argentinosaurus weighed 72 tons, how many elephants would balance it?
5. **CHALLENGE** Why can a blue whale be heavier than Argentinosaurus even though they are about the same length? Why did scientists in 1897 think sauropods lived in water?

Make it a game • Biggest to Smallest. Write these on cards: Argentinosaurus, blue whale, Brachiosaurus, T. rex, Triceratops, African elephant, Velociraptor, you. Shuffle them. Race a timer to line them up by length from longest to shortest, then by weight from heaviest to lightest. Check with the numbers from this trail. Which order changes between the two lines?

Scripture. “Where wast thou when I laid the foundations of the earth? declare, if thou hast understanding.” (Job 38:4, KJV)

God spoke these words to Job to show him how great the Creator is. Standing beside an Argentinosaurus backbone, we can feel a little of what Job felt: our God made giants, and He is greater still.

Practice: answers

1. Guillermo Heredia, a rancher near Plaza Huincul, Argentina, in 1987. He thought it was a piece of petrified wood.
2. Found: back vertebrae, part of the hip, ribs, part of the fibula (any three). Not found: skull, neck or tail (any one).
3. $35 \div 12 \approx 2.9$ buses; $30 \div 12 = 2.5$ buses.
4. $72 \div 6 = 12$ elephants.
5. Water holds up much of a whale’s weight, so a whale can be bulkier than any land animal; a land giant must carry all its weight on its legs. In 1897 scientists thought sauropods were too heavy to walk on land and needed water for support; fossil trackways later showed they walked on dry ground.

TRAIL 1 BADGE QUIZZES

The badge quizzes are optional. The student answers in writing, in full sentences, without looking back at the stops. Four right out of five earns each badge. Badges and the certificate are earned by doing the stops, not by scores.

Badge quiz 1 (Stops 1–5)

1. Give the length of a grown T. rex and two pieces of evidence that it could crush bone.
2. What mistake did O. C. Marsh make with the first Triceratops horns, and how was it corrected?
3. How many plates and tail spikes did Stegosaurus have, and how were the plates arranged?
4. Why is Brachiosaurus called the “arm lizard”?
5. Give the real size of Velociraptor and the evidence that it had feathers.

Badge quiz 2 (Stops 6–10)

6. What was the Ankylosaurus tail club made of, and name two things it may have been used for.
7. What happened to Stromer’s original Spinosaurus bones, and name two features that suggest it ate fish.
8. What ran inside the Parasaurolophus crest, and what may it have been used for?
9. Give one piece of evidence for and one against the idea that Pachycephalosaurus butted heads.
10. Only a few bones of Argentinosaurus are known. How do scientists estimate its size, and why is the answer given as a range?

TRAIL CERTIFICATE: MY DINOSAUR FIELD NOTEBOOK AND TRAIL A CERTIFICATE

Gather the Field Notebook pages from this trail into one booklet with a cover: “My Dinosaur Field Notebook: Meet the Dinosaurs,” your name and the dates you started and finished. Each stop should have its labeled diagram or map and its paragraph entry.

Add a final two-page spread: a scale chart of all ten dinosaurs drawn to the same scale (1 cm = 1 m works for all but the two giants; use 1 cm = 2 m for the whole chart if you prefer), with a person for comparison, and a table listing each dinosaur, who named it, the year and one measured fact.

Add one museum sign, real or from a museum website, marked in two colors: what is observed and what is interpreted.

When the booklet is done, a parent signs the Trail A certificate.

- **Ten stops:** Each stop has a dated, labeled diagram or map and a paragraph of at least five sentences.

- **Accuracy and numbers:** Facts, names, years and measurements are correct, and estimates are written as estimates or ranges.
- **Scale chart:** All ten dinosaurs and a person are drawn to one stated scale with a title and a scale bar.
- **Observation and interpretation:** The marked museum sign correctly separates what is observed from what is interpreted, including any date.

Answer key

1. About 12 m. Any two: thick, banana-shaped teeth and huge jaw muscles (bite estimated near 35,000 newtons); a tyrannosaur coprolite full of crushed bone; a Triceratops hip bone with T. rex tooth marks.
2. In 1887 he thought they came from a giant bison (*Bison alticornis*). Better skulls with a beak, three horns and a frill showed they belonged to Triceratops, which he named in 1889.
3. 17 plates in two staggered (alternating) rows, and four tail spikes.
4. Its humerus (upper front leg bone) was longer than its thighbone, so its front legs were longer and its back sloped up like a giraffe's.
5. About 2 m long, about 0.5 m tall at the hips, about 15 to 20 kg. Quill knobs on its forearm bone show where large feathers were anchored.
6. Large osteoderms (bony skin plates) fused together. Defense against predators such as tyrannosaurs, and contests with other ankylosaurs.
7. They were destroyed in a bombing raid on Munich in April 1944. Any two: long narrow snout; conical, interlocking teeth; nostrils far back; dense bones; found with many large fish.
8. Hollow nasal passages looping up to the tip and back. It may have made deep, resonating calls and helped the animals recognize one another.
9. For: healed lesions on the tops of about one in five domes. Against: the dome bone is spongy and rounded, so head-on blows would glance off (some scientists think domes were mainly for display).
10. By scaling: comparing its bones with the same bones of better-known titanosaurs. Different relatives and methods give different answers, so the size (about 30–35 m, 65–80 tons) is given as a range.

DINOSAURS TRAIL B: DINOSAUR HUNTERS

The second trail of the Dinosaurs track follows the people who found the dinosaurs, from Mary Anning on the beach at Lyme Regis (1811) to Mary Schweitzer at her microscope (2005). Along the way come William Buckland and Megalosaurus, the Mantells and Iguanodon, Richard Owen and the word “Dinosauria,” Hawkins’ Crystal Palace models, the Bone Wars of Cope and Marsh, Barnum Brown’s T. rex, Roy Chapman Andrews and the Gobi eggs, and SUE. Each stop is a true story with dates and numbers, a picture study, a hands-on project, a map or diagram, a notebook entry, five practice questions, a game and a verse of Scripture.

This is the  **Ranger** level, written for ages 10 to 13. The student reads each stop alone, in about 25 to 35 minutes, and keeps a Field Notebook with a labeled map or diagram and a paragraph for every stop. A parent can check the practice answers and the notebook. Every stop stands on its own. The track is creation-friendly: period names such as **Jurassic** and **Cretaceous** are taught as museum words, and dates in millions of years are labeled as interpretations. Stop B10 has the  box: *What the sign says / What we observe / How Christians read it.*

The hunters on this trail were gifted and flawed. They made mistakes and corrected them, worked with great diligence and sometimes fell into pride and envy. Their stories show how knowledge grows: careful looking, honest correction and patience. Five stops earn the **Dinosaur Hunter badge, part 1**; ten earn part 2 and the **Trail B certificate**. The badge quizzes are at the end of the trail and are optional.

BEFORE YOU BEGIN

- Read a page of about 500 words alone and write a paragraph of five or six sentences about it.
- Know what a fossil is and the six days of creation from Genesis 1 (Trail A, or read them together first); be able to find England, the United States, Belgium and Mongolia on a map.

MASTERY CHECKLIST

- ☐ I can name the ten dinosaur hunters on this trail in order with their years and tell what each one found or did.
- ☐ I can explain how scientists corrected early mistakes, such as Iguanodon’s nose horn and the “egg thief” Oviraptor.
- ☐ I can tell what Richard Owen meant by “Dinosauria” and the features he used to define the group.
- ☐ I can draw and label a map of at least three discovery sites, in England, the American West and Mongolia.

- ☐ I can sort a museum sign into observations and interpretations and explain why a date in millions of years is an interpretation.

OPTIONAL BOOKS AND RESOURCES

- **Natural History Museum, London** (<https://www.nhm.ac.uk>): Free articles on Mary Anning, Megalosaurus, Iguanodon and Richard Owen, who founded the museum.
- **Friends of Crystal Palace Dinosaurs** (<https://www.cpdinosaurs.org>): Photos, history and a map of the 1854 models, which still stand in a London park (Stop B5).
- **Field Museum (Chicago): SUE the T. rex** (<https://www.fieldmuseum.org>): SUE's story, bone facts and photos for Stop B9.
- **Biodiversity Heritage Library** (<https://www.biodiversitylibrary.org>): Free scans of the original books and papers, such as Buckland's 1824 Megalosaurus paper and Mantell's *Wonders of Geology*, for students who want to see the first pictures.

2.1 MARY ANNING (1811)

OBJECTIVES

- Tell how Joseph and Mary Anning found the first complete ichthyosaur known to science, and list three more of Mary’s finds with their years.
- Explain why a careful collector without schooling became an expert whom professors visited.
- Draw and label a cliff diagram that shows how fossils weather out of the Lyme Regis cliffs.

Warm-up. Look at a flight of stairs or a stack of books from the side. Each step or book is a layer. If the bottom of the stack crumbled away, what would happen to the books above it? That is what the sea does to the cliffs at Lyme Regis every winter.

Video slot. Video coming. Mary Anning, Lyme Regis and the Jurassic Coast; ichthyosaur and plesiosaur fossils. Search approved channels (Natural History Museum London, Lyme Regis Museum, Smithsonian, Answers in Genesis once vetted); preview first.

KEY TERMS

fossil

The remains or trace of a once-living thing preserved in rock, such as a bone, shell, footprint or leaf print.

ichthyosaur

A dolphin-shaped sea reptile with a long snout and huge eyes; the name means “fish lizard” (say “ICK-thee-o-sore”). It was not a dinosaur.

plesiosaur

A sea reptile with a broad body, four flippers and, in many kinds, a very long neck; the name means “near to a lizard.” It was not a dinosaur.

coprolite

Fossilized dung. Coprolites show what an animal ate.

landslip

A sudden slide of earth and rock down a cliff or slope, often after heavy rain.

CORE IDEAS

A girl on the beach. Mary Anning was born on May 21, 1799, in Lyme Regis, a small seaside town in Dorset, England. Her father, Richard, was a cabinetmaker who sold “curiosities” from the beach to summer visitors. When he died in 1810, he left his family poor and in debt. Mary and her older brother Joseph kept hunting the crumbling cliffs, because a good fossil could pay for bread and rent.

The fish lizard. In 1811, Joseph found a long skull with sharp teeth sticking out of the cliff east of town. The next year, Mary, now about twelve, found the rest of the skeleton. It was about 17 feet (5.2 m) long. Scholars did not know what it was: part fish, part lizard, part dolphin. It was later named **Ichthyosaurus**, “fish lizard.” The lord of the manor bought it for about £23, and it ended up in the British Museum in London.

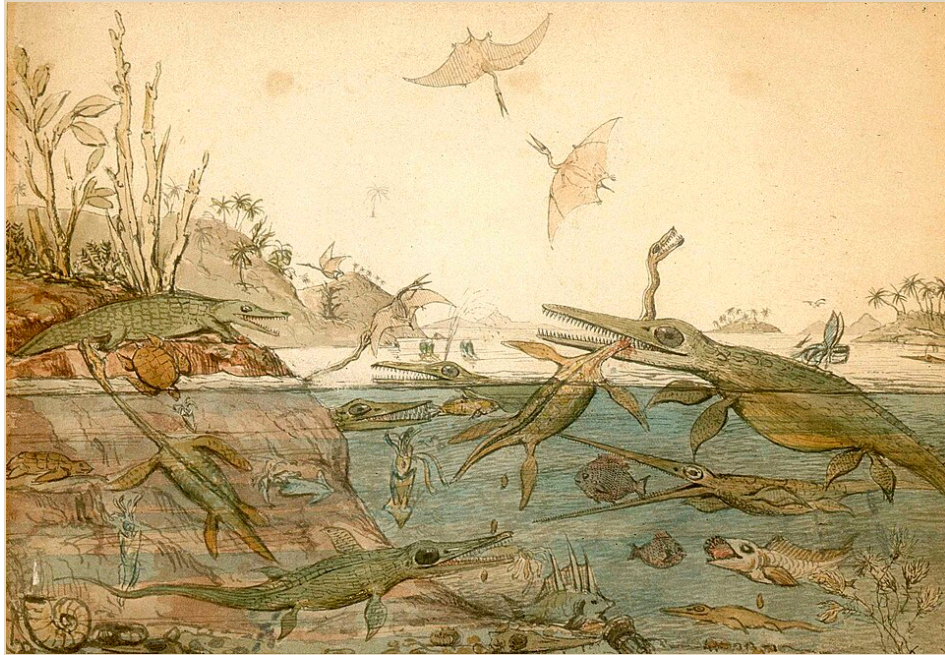
Dangerous work. The best fossils came out in winter, when storms and rain caused **landslips** that broke open the cliffs. Mary walked the beach between the tides with a hammer, a basket and her little dog, Tray. In 1833 a landslip killed Tray only a few feet from her. She had to know the rocks well, work fast before the sea washed a skeleton away, and dig it out without breaking it.

More firsts. In December 1823 Mary found the first nearly complete **plesiosaur**, a creature with a neck so long that the great French scientist Georges Cuvier first suspected it was a fake. When he studied it more, he agreed it was real. In 1828 she found the first British pterosaur, a flying reptile later named Dimorphodon. She also noticed that some “bezoar stones” held tiny fish bones and scales. She had found fossil dung, which William Buckland named **coprolites** in 1829.

An expert without a degree. Mary had little schooling, but she taught herself anatomy by dissecting fish and cuttlefish and copying scientific papers by hand. Professors came to her shop to learn from her. The Geological Society of London did not admit women in her day, and the scientists who described her finds often did not mention her name. Some of her friends spoke up for her, and in 1838 they arranged a yearly income to help her.

Faith and remembrance. Mary grew up in a Dissenting (Congregational) chapel and later joined the Church of England. She died on March 9, 1847. Three years later, friends from the Geological Society placed a stained-glass window in her memory in St. Michael’s Church, Lyme Regis. Its pictures show the works of mercy, a fitting memorial for a woman who worked hard and kept her family going.

PICTURE STUDY



Duria Antiquior (A More Ancient Dorset), Henry De la Beche, 1830 · Watercolor (later printed as a lithograph by George Scharf) · National Museum Wales, Cardiff (the watercolor)
Wikimedia Commons · Public domain

Henry De la Beche grew up in Lyme Regis and hunted fossils with Mary Anning as a young man. In 1830 he painted this scene of the sea creatures she had found, alive and in action. Prints of it were sold, and the money went to help Mary. It is one of the first pictures ever made of a scene from the deep past.

Look closely

- Find an ichthyosaur (dolphin-shaped, long snout) and a plesiosaur (long neck, four flippers). How many of each can you count?
- Find the line where the water meets the air. Why do you think the artist showed both above and below the water at once?
- Look at the bottom of the sea. What is falling or lying there? (Hint: look for something that could become a coprolite.)

Talk about it

1. De la Beche had only skeletons to work from. Which parts of the painting are observations from the bones, and which parts are guesses?
2. Why would selling this print be a good way to help Mary Anning?

HANDS-ON: A CLAY FOSSIL IN LAYERS

Make a small “cliff” in layers with a fossil hidden inside, then let a friend uncover it the way Mary did: slowly, from the side.

You will need

- Modeling clay or salt dough in two or three colors
- A small shell, chicken bone (boiled clean) or plastic toy skeleton
- A plastic knife, a paintbrush and a toothpick
- A tray

Steps

1. Press a flat layer of one color on the tray. Lay your “fossil” on it.
2. Cover it with a second color, then a third, pressing each layer flat.
3. Trade cliffs with someone. Using the toothpick and brush, uncover the fossil from the side only, as a cliff face is exposed.
4. Stop as soon as you see a bit of the fossil. Sketch it before you dig more, as a real collector records a find before moving it.

Check your work

- My cliff has at least three layers.
- I uncovered the fossil without breaking it.
- I sketched the find before removing it.

FIELD NOTEBOOK

1. **Diagram.** Draw a side view of the cliff and beach at Lyme Regis. Label: the cliff layers (blue-gray clay and limestone bands), a landslip at the top, a fossil skeleton showing in the cliff face, the beach, the high-tide line and the sea. Add an arrow showing where winter storms strike. Under it write one sentence: “Fossils appear when”
2. **Notebook entry.** Write a paragraph of five or six sentences: “Mary Anning’s Finds.” Name at least three fossils and the years she found them, and tell which quality of hers (patience, courage, hard work or curiosity) you think mattered most, and why.

Did you know? When Mary was a baby in 1800, a lightning bolt struck a tree under which a neighbor was holding her during a fair. The three women under the tree were killed, but baby Mary lived. Townspeople later said that was why she grew up so bright and lively. In 2024 a bronze statue of Mary and Tray was put up in Lyme Regis, paid for by gifts from around the world.

Map or diagram. On a map of Great Britain, find Dorset on the south coast and mark Lyme Regis. Then mark London, where her ichthyosaur went to the British Museum, and Oxford, where William Buckland taught (Stop B2).

Goes deeper in. Earth Science, the fossils and rock layers units; and History, “Britain in the 1800s” (coming soon). Trail E, Stops E1 and E2, meet the ichthyosaurs and plesiosaurs.

For families. Sources disagree slightly on dates: most give Joseph's skull as 1811 and Mary's skeleton as 1812; this stop follows the Natural History Museum, London. The plesiosaur (1823) was described by William Conybeare in 1824; the pterosaur (1828) was named *Dimorphodon* by Richard Owen in 1859. The annuity (1838) was arranged with Buckland's help. Mary's exclusion from the Geological Society is stated as a fact of the time; the Society first admitted women in 1904. The museum word "Jurassic Coast" names the rocks of this shoreline; this stop does not use dates.

PRACTICE

1. **EASY** What does "ichthyosaur" mean, and who found the first skull?
2. **EASY** Put these finds in order: pterosaur, ichthyosaur, plesiosaur.
3. **MEDIUM** Why did Mary hunt fossils mostly in winter, and why was it dangerous?
4. **MEDIUM** How did Mary discover what coprolites are?
5. **CHALLENGE** Mary Anning had almost no schooling. Give two ways she became an expert anyway, and one reason scientists of her day may have left her name out of their papers.

Make it a game • Beat the Tide. Scatter 10 paper "fossils" (drawn bones) across a room or yard. One player is the Tide and counts slowly to 30 with eyes closed. The Collector must pick up the fossils one at a time, gently, without bending them, and carry them to the "shop" (a basket) before the Tide reaches 30. Bent fossils don't count. Switch roles.

Scripture. "Or speak to the earth, and it shall teach thee: and the fishes of the sea shall declare unto thee." (Job 12:8, KJV)

Mary Anning learned by going to the earth itself and looking closely. God's creation, even a crumbling cliff, has much to teach a patient student.

Practice: answers

1. "Fish lizard." Mary's brother Joseph found the skull in 1811; Mary found the rest of the skeleton about a year later.
2. Ichthyosaur (1811-1812), plesiosaur (1823), pterosaur (1828).
3. Winter storms and rain caused landslips that broke open the cliffs and exposed new fossils. Falling rock and fast tides could kill; a landslip killed her dog Tray in 1833.
4. She noticed that some "bezoar stones" found inside or near ichthyosaur skeletons held fish bones and scales, so they were fossil dung. Buckland named them coprolites in 1829.
5. She taught herself anatomy by dissecting fish and cuttlefish and by copying scientific papers by hand; she also handled more fossils than almost anyone. Scientific societies did not admit women then, and the custom was to credit the gentleman who described a fossil, not the collector who found it.

2.2 WILLIAM BUCKLAND NAMES MEGALOSAURUS (1824)

OBJECTIVES

- Tell how William Buckland described Megalosaurus in 1824, the first dinosaur to get a scientific name.
- Explain how Buckland reasoned from a jaw and a few bones to the size and diet of the whole animal.
- Label a diagram of the Megalosaurus jaw and its teeth.

Warm-up. Look at a steak knife and a butter knife. Which one has a sawtooth (serrated) edge? What is it for? Buckland looked at the teeth in a fossil jaw and saw tiny saw edges too. What do you think that told him?

Video slot. Video coming. Megalosaurus and William Buckland at Oxford; the first named dinosaur. Search approved channels (Oxford University Museum of Natural History, Natural History Museum London, Smithsonian); preview first.

KEY TERMS

Megalosaurus

“Great lizard,” a large meat-eating dinosaur from near Oxford; the first dinosaur given a scientific name (1824).

geology

The study of the earth: its rocks, layers, minerals and fossils.

serrated

Having a saw-like edge of tiny points, as on a steak knife or a meat-eater’s tooth.

anatomy

The study of the parts of a body and how they fit and work together.

scientific name

A Latin or Greek name given to a kind of living thing, such as *Megalosaurus bucklandii*, so scientists everywhere use the same name.

CORE IDEAS

A teacher of rocks. William Buckland was born in 1784 in Axminster, Devon, only a few miles from Lyme Regis, the son of a clergyman. As a boy he walked with his father and picked up fossil shells. He became a clergyman himself and a teacher at Oxford University, where in 1818 he became the first Reader in Geology. His lectures were famous: he waved bones in the air, acted out how animals moved and took students on horseback to look at rocks in the open air.

Bones from the slate pits. At Stonesfield, a village about 12 miles from Oxford, workmen dug thin stone slabs for roofing. In the slabs they sometimes found huge bones. By the early 1820s Buckland had collected several: a piece of lower jaw with teeth, some backbones, part of a hip, a thighbone and a shoulder blade. They were too big for any known lizard.

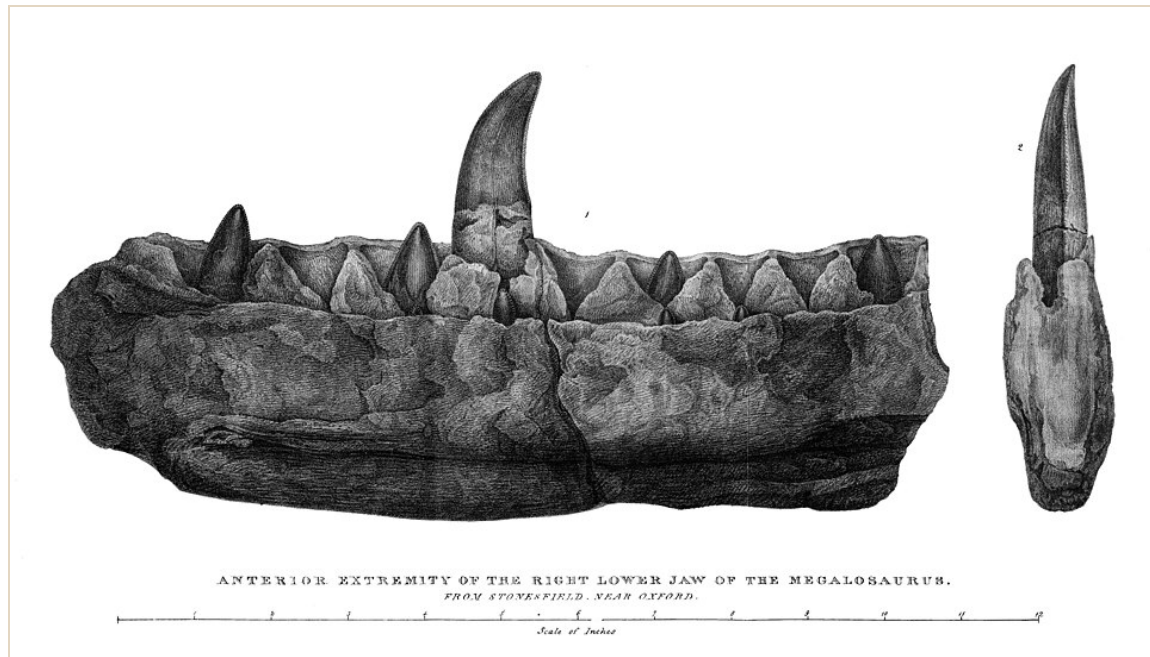
Reasoning from a jaw. Buckland studied the jaw with care. Its curved teeth were flattened like blades and **serrated** along their edges. New teeth were growing up from below to replace old ones, as in lizards and crocodiles. These were teeth for slicing meat. Comparing the thighbone with a lizard's, he estimated the animal at more than 40 feet (12 m) long. That guess was too big. Today it is thought to have been about 20 to 30 feet (6 to 9 m), but his reasoning from the teeth was sound.

The name. On February 20, 1824, Buckland read his paper "Notice on the Megalosaurus or great Fossil Lizard of Stonesfield" to the Geological Society of London. **Megalosaurus** means "great lizard." It was the first time anyone gave a scientific name to an animal we now call a dinosaur. In 1827 Gideon Mantell added the species name *bucklandii* in Buckland's honor. The word "dinosaur" did not exist yet; it came in 1842 (Stop B4).

Faith and the rocks. Buckland believed that the study of rocks would show the wisdom of the Creator. In 1823 he wrote a book about bones in caves that he thought were left by the Flood. Later he changed his mind about those caves and taught that the earth was very old, with the Flood as a more recent event. His 1836 book *Geology and Mineralogy Considered with Reference to Natural Theology* argued that the design seen in fossils points to God. Christians today read the rocks in different ways, and Buckland's life shows a man trying to do both science and faith honestly.

An unusual man. Buckland was cheerful and odd. He kept animals in his house, tried to taste nearly every kind of animal there was, and became Dean of Westminster Abbey in 1845. His wife, Mary Buckland, drew many of his fossil pictures and helped mend specimens. He died in 1856. The Megalosaurus jaw is still in the Oxford University Museum of Natural History.

PICTURE STUDY



The lower jaw of Megalosaurus, plate from Buckland's 1824 paper, Plate made for William Buckland, 1824 · Lithograph · Transactions of the Geological Society of London; the jaw itself is in the Oxford University Museum of Natural History · Wikimedia Commons · Public domain

This print shows the jaw that Buckland described in 1824. Before photography, careful drawings were the only way to share a fossil with scientists in other cities and countries. The artist had to draw exactly what was there, not what he expected to see.

Look closely

- Count the teeth you can see in the jaw. Are they all the same size?
- Find a tooth that is only partly grown. Where is it?
- Look at the shape of one tooth: is it round like a peg or flat like a blade?

Talk about it

1. What clues in this one jaw told Buckland the animal ate meat?
2. Why was a careful drawing so important in 1824?

Safety first. A grown-up handles the steak knife; touch only the flat side, never the edge.

HANDS-ON: TOOTH DETECTIVE

Use real teeth (or good pictures) to practice Buckland's method: read the diet from the teeth.

You will need

- Pictures of teeth: a cow or horse, a dog or cat, a crocodile and a human (books or museum websites)
- A steak knife and a butter knife (with a grown-up) to compare edges
- A magnifying glass and your Field Notebook

Steps

1. Look at each set of teeth. Sort them: flat grinding teeth, pointed stabbing teeth, or blade-like slicing teeth.
2. With a grown-up, run a fingertip gently along the flat side (not the edge) of the steak knife and look at its saw edge with the magnifying glass.
3. Draw one Megalosaurus tooth from the picture study, full size if you can, and add its serrations.
4. Write a sentence for each animal: "Its teeth are ... so it probably ate"

Check your work

- I sorted at least four kinds of teeth.
- I drew a Megalosaurus tooth with its serrations.
- I can explain how teeth tell diet.

FIELD NOTEBOOK

1. **Diagram.** Draw the Megalosaurus jaw from the picture study. Label: jawbone, a full-grown tooth, a replacement tooth coming up, the serrated edge (draw a close-up circle), and the front and back of the jaw. Add a scale line: "real jaw about 1 foot long."
2. **Notebook entry.** Write a paragraph: "How Buckland Read a Jaw." Tell what he observed, what he concluded about diet and size, which conclusion was right, and which turned out to be too big.

Did you know? Megalosaurus may have been found long before Buckland. In 1677 Robert Plot, also of Oxford, drew the end of a huge thighbone and thought it might be from a giant man. That bone is now lost, but from Plot's drawing many scientists think it was a Megalosaurus. Buckland also gave the name "coprolite" to the fossil dung Mary Anning found (Stop B1).

Map or diagram. On a map of southern England, mark Oxford and Stonesfield (northwest of Oxford), London, where the paper was read, and Axminster and Lyme Regis on the south coast, where Buckland grew up near Mary Anning's beach.

Goes deeper in. Life Science, "Teeth and diet" (coming soon), and Trail C, Stop C1 "Teeth tell diet"; Earth Science, the history of geology.

For families. Buckland's paper was read February 20, 1824 and printed in the *Transactions of the Geological Society of London*. James Parkinson had printed the name "Megalosaurus" in 1822 without a description, so Buckland's 1824 paper counts as the

naming. Modern length estimates for Megalosaurus vary (roughly 6–9 m); this stop gives a range. Buckland's *Reliquiae Diluvianae* (1823) read the Kirkdale Cave bones as Flood evidence; by the 1830s he had given up that reading and held an old earth. The stop states both positions without mocking either. His eating of unusual animals is well documented; the stop mentions it lightly.

PRACTICE

1. **EASY** What does Megalosaurus mean, and in what year was it named?
2. **EASY** Where did the Megalosaurus bones come from?
3. **MEDIUM** Name two things about the teeth that showed Megalosaurus ate meat.
4. **MEDIUM** Buckland estimated more than 40 feet; today's estimate is about 20 to 30 feet. Is a length estimate an observation or an interpretation? Why?
5. **CHALLENGE** Megalosaurus was named in 1824, but the word "dinosaur" came in 1842. What does that tell you about how science names things?

Make it a game • Whose Teeth?. One player describes teeth without naming the animal: "Flat and wide for grinding," "Long, pointed and curved," "Blades with saw edges." The others guess a diet (plants, meat, fish, both) and then an animal. Score a point for the right diet and a bonus for a good animal guess.

Scripture. "The works of the LORD are great, sought out of all them that have pleasure therein." (Psalm 111:2, KJV)

Buckland took great pleasure in seeking out God's works in the rocks. Studying creation carefully is one way to honor the Creator.

Practice: answers

1. "Great lizard"; 1824.
2. The Stonesfield slate pits, near Oxford, England.
3. They were curved and flattened like blades, and their edges were serrated like a steak knife.
4. An interpretation. No one measured a whole animal; the length was worked out from a few bones by comparing them with other animals, so it can change when more bones are found.
5. Single kinds of animals are found and named first; a group name comes later, after several kinds are known and scientists see what they have in common (Owen grouped Megalosaurus, Iguanodon and Hylaeosaurus as Dinosauria).

2.3 GIDEON AND MARY ANN MANTELL'S IGUANODON

OBJECTIVES

- Tell how the Mantells' fossil teeth led to the naming of Iguanodon in 1825.
- Explain how comparing fossils with living animals helped and also misled scientists (the "horn" that was a thumb).
- Draw and label a comparison of Mantell's Iguanodon and the Iguanodon known today.

Warm-up. Think of a jigsaw puzzle with no picture on the box and most of the pieces missing. You have only a few pieces with teeth on them. What could you guess about the whole picture? That was Gideon Mantell's puzzle.

Video slot. Video coming. Gideon Mantell and the discovery of Iguanodon; the Iguanodons of Bernissart. Search approved channels (Natural History Museum London, Royal Belgian Institute of Natural Sciences, Smithsonian); preview first.

KEY TERMS

Iguanodon

"Iguana tooth," a large plant-eating dinosaur with a spiked thumb, named by Gideon Mantell in 1825; the second dinosaur to be named.

comparative anatomy

Learning about an animal by comparing its body parts with those of other animals.

reconstruction

A drawing, model or skeleton showing what scientists think a whole animal looked like from the parts found.

naturalist

A person who studies plants, animals, rocks and fossils by careful observation.

Wealden

The name of the layers of clay and sandstone in southeast England where Iguanodon was found; from the Weald, a region of Sussex and Kent.

CORE IDEAS

A doctor and his helper. Gideon Mantell was born in 1790 in Lewes, Sussex, the son of a shoemaker. He trained as a surgeon and became a busy country doctor, delivering babies and setting bones by day. At night and on his rounds he collected fossils. In 1816 he married Mary Ann Woodhouse. She learned to draw fossils with great skill, and the many plates in his first book, *The Fossils of the South Downs* (1822), are her work.

The teeth. In the early 1820s the Mantells obtained some strange teeth from a quarry in Tilgate Forest, near Cuckfield in Sussex. A famous family story says Mary Ann found the first

one in a pile of road stones while her husband visited a patient. Mantell himself told the story in different ways later, so no one knows for certain who picked up the first tooth. What is certain is that the teeth were worn flat on top, like the teeth of an animal that chews plants, yet they were found in rock with reptile bones.

“Rhinceros teeth.” Mantell showed the teeth to experts. Most were not impressed. Georges Cuvier, the greatest anatomist in Europe, at first said they were from a rhinceros and that the bones came from a large fish. Mantell kept looking. In 1824, at the Hunterian Museum in London, Samuel Stutchbury showed him the skeleton of an iguana lizard. Its little teeth looked just like Mantell’s fossils, only about twenty times smaller.

The name. In 1825 Mantell published his find in the *Philosophical Transactions of the Royal Society*. On a friend’s advice he called it **Iguanodon**, “iguana tooth.” Megalosaurus (1824) had been a meat-eater; Iguanodon was the first known giant plant-eating reptile. Cuvier now agreed that it was something new. Mantell scaled up an iguana and guessed his animal was enormous, far bigger than we now know it was.

The horn that was a thumb. In 1834 a quarry near Maidstone, Kent, produced part of a skeleton, and friends bought it for Mantell for £25. Among the bones was a cone-shaped spike. Mantell placed it on the nose, like a rhinceros horn, and drew a long, lizard-like animal. Then in 1878, coal miners at Bernissart, Belgium, found more than thirty Iguanodon skeletons deep underground. Louis Dollo studied them and showed that the spike belonged on the thumb.

A costly love of fossils. Mantell spent so much on fossils that he fell into debt. In 1838 he sold his collection to the British Museum. His marriage became unhappy, and he and Mary Ann separated in 1839. He kept writing popular books, like *The Wonders of Geology* (1838), until he died in 1852. Mantell also named Hylaeosaurus in 1833, one of the three animals Richard Owen would soon group together as dinosaurs (Stop B4).

PICTURE STUDY



The Country of the Iguanodon, John Martin, 1837 · Watercolor (engraved as the frontispiece of Mantell's *The Wonders of Geology*, 1838) · Natural History Museum, London
Wikimedia Commons · Public domain

John Martin was famous for huge, stormy paintings of Bible scenes, such as the Flood and the fall of Babylon. Mantell asked him to paint the creatures of the Sussex rocks as they might have looked. Martin's Iguanodons look like giant iguanas, because that is how Mantell imagined them in 1837.

Look closely

- Find the Iguanodons. How do they stand: like a lizard, or upright like a bird?
- Look at the light and the sky. What feeling does Martin give the scene?
- Find a plant that looks like a palm or fern. Why might the artist have chosen tropical plants?

Talk about it

1. Compare this painting with De la Beche's *Duria Antiquior* (Stop B1). Which looks more like a scientific picture, and which more like a dramatic story?
2. Which parts of Martin's Iguanodon would scientists change today?

HANDS-ON: THEN AND NOW IGUANODON

Draw two Iguanodons side by side: the one Mantell imagined around 1834 and the one scientists describe today. Seeing them together shows how science corrects itself.

You will need

- A large sheet of paper folded in half
- Pencil, eraser and colored pencils
- A ruler
- Pictures of a modern Iguanodon reconstruction (museum website or library book)

Steps

1. Title the left half “Mantell, about 1834” and the right half “Today.”
2. Left side: draw a long, low, lizard-like body sprawling on four legs, with a horn on its nose.
3. Right side: draw the modern Iguanodon, with a heavy body held level, a stiff tail, strong back legs, and arms that could walk or reach, with a spike on each thumb.
4. Label on both: head, thumb spike or “horn,” tail, back legs. Draw an arrow from the nose horn on the left to the thumb on the right and write “moved in 1878.”

Check your work

- Both drawings are labeled.
- I showed where the spike went in each.
- I can tell who moved the spike and what evidence he used.

FIELD NOTEBOOK

1. **Diagram.** Draw an iguana tooth and an Iguanodon tooth side by side. Make the Iguanodon tooth about twenty times bigger (if the iguana tooth is 2 mm, the Iguanodon tooth is 40 mm). Label the ridges and the worn, flat top.
2. **Notebook entry.** Write a paragraph: “Being Wrong and Being Corrected.” Tell two mistakes made about Iguanodon (rhinoceros teeth, nose horn), who corrected them, and what new evidence did it.

Did you know? The Iguanodons of Bernissart were found more than 1,000 feet (over 300 m) underground in a coal mine. Workers spent about three years digging them out. Several were mounted standing upright, and they can still be seen in a tall glass hall at the Royal Belgian Institute of Natural Sciences in Brussels. The town of Maidstone later put an Iguanodon on its coat of arms.

Map or diagram. On a map of southeast England and Belgium, mark Lewes, Cuckfield (Tilgate Forest), Maidstone and London. Across the Channel, mark Brussels and Bernissart (near Mons). Draw a line from the nose-horn town (Maidstone, 1834) to the thumb-spike town (Bernissart, 1878).

Goes deeper in. Art, “Drawing from observation” (coming soon), for Mary Ann Mantell’s fossil plates; and Life Science, comparative anatomy. Trail A meets more plant-eating dinosaurs.

For families. Historian Dennis Dean and others doubt the roadside story of Mary Ann finding the first tooth; Mantell's own accounts differ, and the stop says so. The 1825 paper appeared in *Philosophical Transactions*; William Conybeare is usually credited with suggesting the name. The Maidstone specimen (1834) is known as the "Mantel-piece." The Bernissart find was in 1878; Louis Dollo's studies followed in the 1880s. The Mantells' separation (1839) is mentioned only as a fact. Mantell's size estimates varied over the years; the stop avoids a single figure.

PRACTICE

1. **EASY** What does Iguanodon mean, and why was it given that name?
2. **EASY** What did Mary Ann Mantell do for her husband's first book?
3. **MEDIUM** What did Cuvier first say about the teeth, and what changed his mind?
4. **MEDIUM** Where did Mantell put the Iguanodon's spike, and where does it really belong? What find settled it?
5. **CHALLENGE** If an iguana tooth is 2 mm tall and Iguanodon's tooth is about 20 times bigger, how tall is the Iguanodon tooth? Why was it a mistake to use the same scale for the whole animal?

Make it a game • Where Does It Go?. Draw an animal outline (a horse, a bird, a dog) and cut out one part, such as an ear, a tail or a hoof. Players take turns, eyes open, trying to place the part in the right spot and explaining their reason. Then show a real picture. Everyone who gave a good reason scores, even if wrong, just as Mantell reasoned well with the bones he had.

Scripture. "And whatsoever ye do, do it heartily, as to the Lord, and not unto men;" (Colossians 3:23, KJV)

Mary Ann's careful drawings and Gideon's long hours over the bones were hard, patient work. Christians are called to do every task heartily, as to the Lord.

Practice: answers

1. "Iguana tooth." Its teeth looked like an iguana's teeth, only much larger.
2. She drew the fossil plates (illustrations) for *The Fossils of the South Downs* (1822).
3. He said they were rhinoceros teeth. After Mantell compared them with an iguana's teeth and showed more evidence, Cuvier agreed they came from a new kind of large plant-eating reptile.
4. He put it on the nose like a horn. It belongs on the thumb. The many complete skeletons found at Bernissart, Belgium, in 1878 showed it.
5. About 40 mm (4 cm). Different animals have different proportions; a plant-eater can have small teeth for its body size, so scaling an iguana's whole body up twenty times made Iguanodon seem far too long.

2.4 RICHARD OWEN COINS “DINOSAURIA” (1842)

OBJECTIVES

- Explain what the word “Dinosauria” means and the three animals Richard Owen first grouped under it.
- Name the features Owen used to set dinosaurs apart from lizards.
- Make a labeled chart that sorts reptiles by how their legs meet the body.

Warm-up. Get down on the floor in a push-up position with your elbows bent out to the sides, like a lizard. Now straighten your arms so they are right under your shoulders. Which way is easier to hold up a heavy body? Richard Owen noticed the same thing in dinosaur bones.

Video slot. Video coming. Richard Owen, the word “dinosaur” and the founding of the Natural History Museum in London. Search approved channels (Natural History Museum London, Royal College of Surgeons Hunterian Museum, Smithsonian); preview first.

KEY TERMS

Dinosauria

The group name Richard Owen made in 1842 from Greek *deinos*, “terrible” or “fearfully great,” and *sauros*, “lizard.”

classification

Sorting living things into groups by the features they share.

sacrum

The bones of the backbone that join the hips. Owen saw that dinosaurs had five of them fused together, while lizards have two.

upright posture

Standing with the legs straight under the body, like an elephant or a bird, rather than sprawling out to the side like a lizard.

anatomist

A scientist who studies the structure of bodies, often by dissection and by comparing skeletons.

CORE IDEAS

A young anatomist. Richard Owen was born in 1804 in Lancaster, England. He trained as a surgeon and went to work at the Hunterian Museum of the Royal College of Surgeons in London, caring for thousands of skeletons and preserved specimens. He was hard-working and brilliant at comparing bones. By his thirties he was the most famous **anatomist** in Britain.

The big report. The British Association for the Advancement of Science asked Owen to describe all the fossil reptiles found in Britain. He studied hundreds of specimens and read the second part of his report at Plymouth in August 1841. When the report was printed in April 1842, it contained a new word: **Dinosauria**. Owen made it from two Greek words, *deinos*, “terrible” or “fearfully great,” and *sauros*, “lizard.”

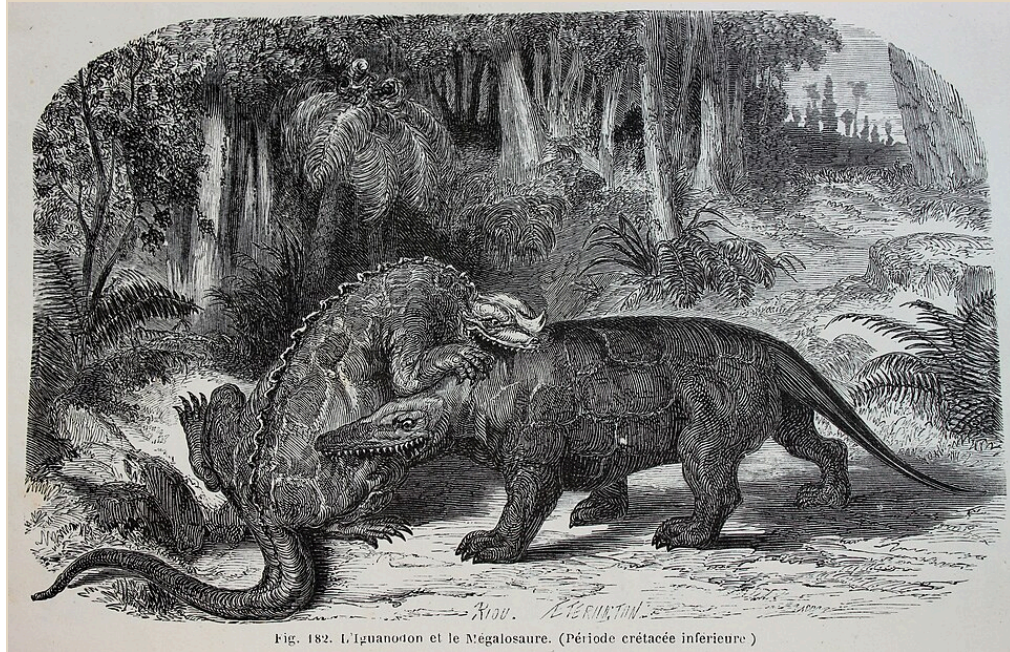
Three animals, one group. In 1842 only three kinds were well enough known to group together: Buckland’s *Megalosaurus* (1824), Mantell’s *Iguanodon* (1825) and Mantell’s *Hylaeosaurus* (1833). Owen listed what they shared. They had five vertebrae fused to the hips (lizards have two). Their legs stood straight under the body, not sprawling out to the side. And they were much bigger than any living reptile. These were not just big lizards, Owen said; they were a separate group.

Owen’s picture of a dinosaur. Because the legs stood upright, Owen pictured dinosaurs as heavy, four-legged animals built like elephants or rhinoceroses. He shrank Mantell’s *Iguanodon* to a more reasonable size, under 30 feet (about 9 m). Later finds showed that many dinosaurs walked on two legs, so parts of his picture were wrong, but his main point was right: dinosaurs stood upright. Scientists still use his word.

A builder of museums. Owen named many other animals, including the giant moa of New Zealand, which he predicted in 1839 from a single piece of bone before whole skeletons were found. He described *Archaeopteryx* in 1863. As head of the natural history collections of the British Museum from 1856, he pushed for a new building where ordinary people could see God’s creatures. The Natural History Museum in South Kensington opened in 1881, with carvings of animals all over its walls.

Gifts and faults. Owen believed nature showed a wise plan, and he opposed Charles Darwin’s idea of natural selection. He was also proud. He often failed to give credit to others, especially Gideon Mantell, and many of his colleagues came to distrust him. Owen’s life shows that great gifts and great faults can live in the same person. He died in 1892.

PICTURE STUDY



The Iguanodon and the Megalosaurus, from The World Before the Deluge, Édouard Riou, 1863 · Wood engraving (book illustration) · From Louis Figuier, La Terre avant le déluge (Paris, 1863)
Wikimedia Commons · CC BY 2.0

Édouard Riou, who also drew pictures for Jules Verne's adventure novels, made this engraving for a popular French book about the earth's history. He drew Iguanodon and Megalosaurus the way Richard Owen described them: heavy, four-legged and built like giant mammals. Iguanodon still has its horn on its nose.

Look closely

- Count the legs of each animal. How do they stand?
- Find the horn on the Iguanodon. Where does it really belong (Stop B3)?
- Look at the background: the water, the rocks and the plants. What kind of place did Riou imagine?

Talk about it

1. Which part of Owen's idea does this picture get right, and which part has science changed?
2. Why would a popular book want an exciting fight scene rather than a quiet one?

HANDS-ON: HOW DO YOU STAND? A LEG CHART

Owen noticed that dinosaur legs stood straight under the body. Test it yourself with simple models, then make a chart.

You will need

- Modeling clay
- Eight pipe cleaners or craft sticks
- A small book or block (the “weight”)
- Paper and colored pencils

Steps

1. Make two clay bodies the same size.
2. Model 1 (sprawling): push four pipe cleaners into the sides and bend them out and down, like a lizard’s legs.
3. Model 2 (upright): push four pipe cleaners straight down from under the body, like an elephant’s legs.
4. Gently set the same small weight on each. Which one sags first?
5. Make a chart with two columns, “Sprawling” and “Upright.” Draw a front view of each and list animals: lizard, crocodile (in between), elephant, horse, Iguanodon, Megalosaurus, bird.

Check your work

- I built and tested both models.
- My chart has front views and at least six animals.
- I can name Owen’s three features of dinosaurs.

FIELD NOTEBOOK

1. **Diagram.** Draw a simple hip-and-backbone diagram from the side. On a lizard, color two hip vertebrae; on a dinosaur, color five fused together. Label: backbone, hip bone, fused vertebrae (sacrum), leg. Title it “Owen’s Clue.”
2. **Notebook entry.** Write a paragraph: “Why Owen Needed a New Word.” Explain the three animals he grouped, what they shared, and one thing he got wrong about how they looked.

Did you know? Owen’s moa prediction came from a single broken thighbone brought from New Zealand in 1839. He told the Zoological Society it came from a large bird, heavy like an ostrich, that could not fly. Within a few years crates of moa bones arrived that proved him right. Some kinds of moa stood about 12 feet (3.6 m) tall with their necks stretched up.

Map or diagram. Make a “word tree.” Write *Dinosauria* at the top. Draw two branches: *deinos* (terrible, fearfully great) and *sauros* (lizard). Add other words that use them: *Megalosaurus*, *ichthyosaur*, *Plesiosaurus*, *Deinonychus*.

Goes deeper in. Life Science, “Classifying living things” (coming soon); Literature, Greek and Latin roots in science words. Trail D, Stop D10 “Fearfully made” returns to Owen’s word.

For families. Owen's report was read in August 1841 at Plymouth; the printed version (April 1842) is where "Dinosauria" first appears, and most historians date the word to 1842. Owen's Greek *deinos* is often translated "terrible," but he meant "fearfully great." The Natural History Museum opened in 1881. Owen's quarrels with Mantell and Darwin are well documented; the stop names his pride plainly without judging him by modern standards. He opposed natural selection but accepted some development of living things over time; the stop keeps to the simpler fact that he opposed Darwin's theory.

PRACTICE

1. **EASY** What does "Dinosauria" mean, and when did it first appear in print?
2. **EASY** Name the three animals Owen grouped as dinosaurs.
3. **MEDIUM** Give two features Owen used to separate dinosaurs from lizards.
4. **MEDIUM** What did Owen get wrong about how dinosaurs looked, and why did he make that mistake?
5. **CHALLENGE** Owen was brilliant and also proud. Give one example of each from his life, and explain why it matters to know both.

Make it a game • Greek Word Builder. Write these on cards: *deinos* (terrible), *sauros* (lizard), *megalo* (great), *ichthys* (fish), *tri* (three), *keras* (horn), *ops* (face), *stego* (roof), *tyrannos* (tyrant). Players draw two or three cards, build a creature name, say what it means and draw the creature. Real names (like Triceratops) score a bonus.

Scripture. "And out of the ground the LORD God formed every beast of the field, and every fowl of the air; and brought them unto Adam to see what he would call them: and whatsoever Adam called every living creature, that was the name thereof." (Genesis 2:19, KJV)

Naming animals is one of the first jobs God gave to man. Scientists like Owen continue that work when they study creatures carefully and give them fitting names.

Practice: answers

1. "Terrible" or "fearfully great lizards"; April 1842, in Richard Owen's report on British fossil reptiles.
2. Megalosaurus, Iguanodon and Hylaeosaurus.
3. Any two: five vertebrae fused to the hips (lizards have two); legs held straight under the body; much larger size than any living reptile.
4. He pictured them all as heavy four-legged animals like elephants. Upright legs reminded him of large mammals, and the few bones known did not yet show that many dinosaurs walked on two legs.
5. Brilliant: he named the Dinosauria, predicted the moa from one bone, or founded the Natural History Museum. Proud: he failed to credit others, especially Mantell. Knowing both shows that great gifts don't make a person faultless, and that we should judge ideas by evidence, not only by who said them.

2.5 HAWKINS' CRYSTAL PALACE DINOSAURS (1854)

OBJECTIVES

- Tell how Benjamin Waterhouse Hawkins built the first life-size dinosaur models, with Richard Owen as adviser, for the Crystal Palace park in 1854.
- Explain how the models show what scientists knew in 1854 and what they did not yet know.
- Draw a labeled diagram of how a large model is built from the inside out.

Warm-up. Shape a small animal from clay without anything inside. Now try to make one the size of your hand stand on thin legs. What happens? A model as big as a bus needs a skeleton of its own. Today you will see how Hawkins built one.

Video slot. Video coming. The Crystal Palace dinosaurs in Sydenham, London; Benjamin Waterhouse Hawkins' 1854 sculptures. Search approved channels (Friends of Crystal Palace Dinosaurs, Natural History Museum London, Historic England); preview first.

KEY TERMS

sculptor

An artist who makes figures in three dimensions from stone, metal, clay or other materials.

life-size

Made the same size as the real thing.

armature

The inner frame that holds up a sculpture, like a skeleton inside a body.

mold

A hollow form shaped like an object; material poured or pressed into it takes that shape.

Crystal Palace

A huge building of iron and glass first built for the Great Exhibition of 1851 in London, then moved to Sydenham in south London.

CORE IDEAS

A palace of glass. In 1851 London held the Great Exhibition in the Crystal Palace, a building of iron and nearly 300,000 panes of glass. When the exhibition closed, the palace was taken down and rebuilt, even bigger, on a hill at Sydenham in south London. Its owners wanted a park that would teach visitors as well as delight them. They decided to include something no one had ever seen: life-size models of the animals known only from fossils.

The sculptor and the scientist. The job went to Benjamin Waterhouse Hawkins, born in London in 1807, a sculptor and natural history artist known for his careful animal drawings.

Richard Owen, who had named the Dinosauria (Stop B4), advised him. Hawkins studied the bones in museums, worked out the size of each animal and made small clay models for Owen to check. Then he scaled them up in his workshop on the park grounds.

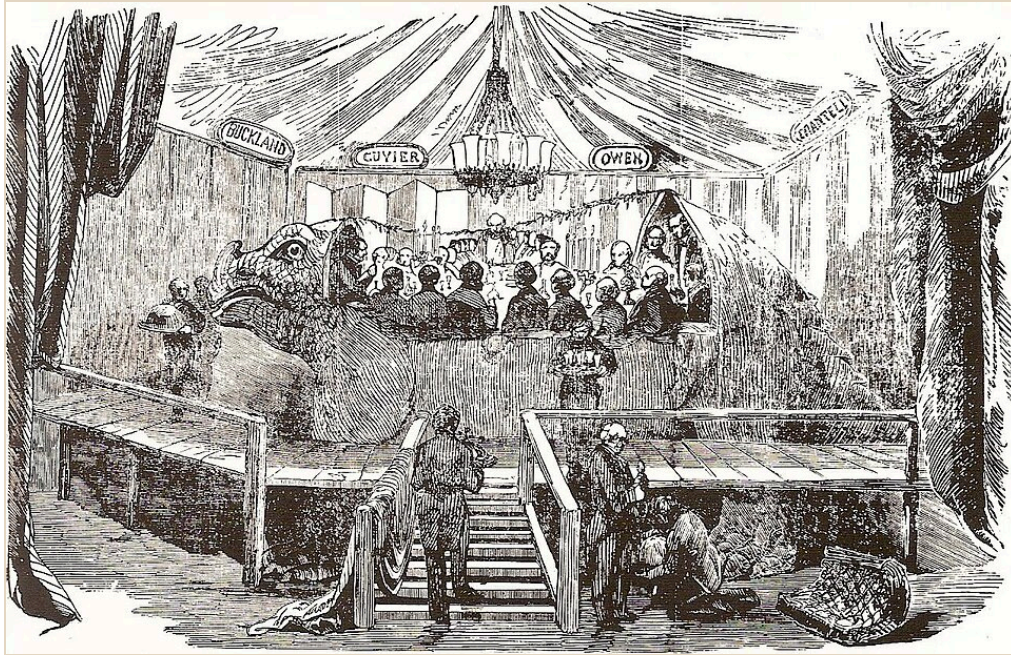
How to build a monster. A model as big as an Iguanodon could not be solid clay. Hawkins built each one on a strong brick base with iron columns and bars inside, like a skeleton, and covered it with tiles and cement, then shaped the skin by hand. For the large Iguanodon, he said, he used about 600 bricks, 650 drain tiles, 900 plain tiles and 38 casks of cement. In all he made more than 30 figures, among them ichthyosaurs, plesiosaurs, pterosaurs and Ice Age mammals such as the giant ground sloth and the Irish elk.

Dinner in a dinosaur. To get the public excited, Hawkins held a famous dinner on New Year's Eve, 1853. Twenty-one guests, with Owen at the head, sat at a table inside the mold of the Iguanodon. The invitations were written on drawings of a pterosaur's wing. Newspapers loved it. On June 10, 1854, Queen Victoria opened the new Crystal Palace, and crowds came to stare at the beasts around the lake.

Right and wrong. The models show what scientists knew in 1854. Hawkins and Owen gave Iguanodon and Megalosaurus four heavy legs like rhinoceroses, and they put Iguanodon's thumb spike on its nose. After later discoveries (Stop B3), visitors could see that some of the figures were wrong. Yet the marine reptiles, made from Mary Anning's kind of skeletons, were close to what scientists think today. The models are a snapshot of knowledge at one moment.

Still standing. The Crystal Palace itself burned down in 1936, but the models survived. In 2007 they were listed as Grade I, the highest protection for a historic structure in England. Hawkins later went to America. In 1868, in Philadelphia, he helped mount the skeleton of Hadrosaurus, the first dinosaur skeleton ever mounted standing up for the public.

PICTURE STUDY



Dinner in the Iguanodon Model at the Crystal Palace, Sydenham, Unknown engraver for the Illustrated London News, January 7, 1854 · Wood engraving in a newspaper · The Illustrated London News
Wikimedia Commons · Public domain

A week after the famous dinner, the *Illustrated London News* printed this picture. Most people in 1854 had never seen a photograph in a newspaper; engravings like this one were how news was shown. The banners above the table carried the names of famous scientists, among them Buckland, Mantell and Cuvier.

Look closely

- Find the table and the guests. Where exactly are they sitting?
- Look for the banners. Can you read any names?
- Look at the shape around the table. Which part of the Iguanodon do you think it is?

Talk about it

1. Why would a dinner inside a model be good for getting people to visit the park?
2. If you were inviting guests to a dinner in a dinosaur today, which dinosaur would you choose, and why?

HANDS-ON: BUILD AN ARMATURE DINOSAUR

Build a small dinosaur the way Hawkins built his big ones: a frame first, then a skin.

You will need

- Aluminum foil and a few pipe cleaners or a length of soft craft wire
- Masking tape

- Air-dry clay or salt dough
- A piece of cardboard for a base
- Paint (optional)

Steps

1. Twist pipe cleaners into a simple skeleton: a backbone, four (or two) legs and a tail.
2. Tape the legs to the cardboard base so it stands.
3. Wrap crumpled foil around the frame to bulk up the body (this saves clay, like Hawkins' tiles and bricks).
4. Cover it with a thin skin of clay. Shape the head, toes and skin texture. Let it dry and paint it.
5. Decide: will you build it the 1854 way (four heavy legs, nose horn) or the modern way? Write a museum label telling which.

Check your work

- My model has a frame, a filling and a skin.
- It stands without falling over.
- My label says whether it is an 1854 or a modern reconstruction.

FIELD NOTEBOOK

1. **Diagram.** Draw a cutaway of Hawkins' Iguanodon, as if sliced down the middle. Label: brick base, iron columns, iron bars, tiles, cement skin, and the opening where the dinner table went. Add a scale line: about 30 feet (9 m) long.
2. **Notebook entry.** Write a paragraph: "What the Crystal Palace Models Got Right and Wrong." Name two mistakes and one success, and explain why a model can only show what is known at the time it is made.

Did you know? Hawkins began a second set of models for a "Paleozoic Museum" in New York's Central Park in 1868, but the city stopped the project and the unfinished models were broken up and buried in 1871. Pieces may still lie under the park. In Philadelphia his Hadrosaurus skeleton drew so many visitors that the Academy of Natural Sciences had to charge admission to control the crowds.

Map or diagram. Sketch a plan of the Crystal Palace park lake as a long oval with islands. Put the sea reptiles in the water, the dinosaurs on the largest island and the Ice Age mammals on the far side, the way Hawkins arranged them to show different "ages" of the rocks. Add a compass rose and the palace at the top of the hill.

Goes deeper in. Art, sculpture and modeling (coming soon); History, "Victorian Britain" and the Great Exhibition of 1851. Trail E, Stop E10 "Build a museum display" uses the same skills.

For families. The dinner was held December 31, 1853, and pictured in the *Illustrated London News* of January 7, 1854. The materials list comes from Hawkins' own 1854 lecture to the Society of Arts. The park opened June 10, 1854; the palace burned November 30, 1936; the models were upgraded to Grade I listing in 2007. The Friends of Crystal Palace Dinosaurs (cpdinosaurs.org) have good photos. Hawkins arranged the models by geological "periods"; the stop presents that as his arrangement and does not add dates.

PRACTICE

1. **EASY** Who made the Crystal Palace dinosaurs, and who advised him?
2. **EASY** What happened on New Year's Eve, 1853?
3. **MEDIUM** What is an armature, and why did Hawkins need one?
4. **MEDIUM** Name two things about the Crystal Palace Iguanodon that scientists would change today.
5. **CHALLENGE** The Crystal Palace models are wrong in places, yet they are protected as treasures. Give two reasons they are still worth keeping.

Make it a game • Then or Now? A leader reads a description: "Iguanodon with a horn on its nose," "Megalosaurus walking on two legs," "Iguanodon with a spike on its thumb." Players stand up for "1854" and sit down for "Today." Anyone who can give the reason earns a point.

Scripture. "For now we see through a glass, darkly; but then face to face: now I know in part; but then shall I know even as also I am known." (1 Corinthians 13:12, KJV)

Hawkins and Owen knew only part, and their models show it. All our knowledge in this life is partial; God alone knows all things fully, and that makes us humble and eager to keep learning.

Practice: answers

1. Benjamin Waterhouse Hawkins, a sculptor, with Richard Owen as scientific adviser.
2. Twenty-one guests, with Owen at the head, ate dinner at a table inside the mold of the Iguanodon model.
3. The inner frame of a sculpture. His models were so large and heavy that they needed iron and brick inside to hold them up.
4. The spike should be on the thumb, not the nose; and it should not look like a heavy rhinoceros on four thick legs. Today it is shown with a level body, strong back legs and a stiff tail.
5. They were the first life-size models of extinct animals ever made, and they show exactly what scientists believed in 1854, so they teach how knowledge grows and changes. They are also fine works of art and a part of history.

2.6 THE BONE WARS: COPE AND MARSH

OBJECTIVES

- Tell how Edward Drinker Cope and Othniel Charles Marsh went from friends to rivals, and name dinosaurs each one named.
- Find the main Bone Wars quarries on a map of the American West.
- Weigh the good and the harm of the rivalry, and name the sin at its heart.

Warm-up. Have you ever wanted something just because someone else had it? Think of a time (no names needed). How did it feel? Two of the greatest fossil hunters in history let that feeling run their lives for twenty years.

Video slot. Video coming. The Bone Wars of Edward Drinker Cope and Othniel Charles Marsh; Como Bluff and the Morrison dinosaurs. Search approved channels (Yale Peabody Museum, Academy of Natural Sciences of Drexel University, Smithsonian, PBS American Experience); preview first.

KEY TERMS

Bone Wars

The bitter race between Cope and Marsh, roughly 1872–1892, to find and name more fossil animals than the other.

paleontologist

A scientist who studies fossils (say “pay-lee-on-TOL-o-jist”).

quarry

A pit where stone is dug; fossil hunters also call their dig sites quarries.

type specimen

The fossil a scientist uses to describe and name a new kind of animal; the name is tied to it.

envy

Sorrow or anger at another person’s good, and the wish to take it away from them.

CORE IDEAS

Two gifted men. Edward Drinker Cope was born in 1840 into a wealthy Quaker family in Philadelphia. He was quick, restless and brilliant; he wrote his first scientific paper at eighteen. Othniel Charles Marsh was born in 1831 in New York State. His rich uncle, George Peabody, paid for his education and, in 1866, founded the Peabody Museum at Yale, where Marsh became the first professor of paleontology in the United States. Marsh was slow, careful and secretive.

Friends turn rivals. The two met in Berlin in 1864 and were friendly at first; they even named fossils after each other. Then trouble began. In 1868 Marsh visited Cope's marl pits in New Jersey and quietly arranged for the workers to send fossils to him. In 1870 Cope was embarrassed when Joseph Leidy pointed out that Cope had put the head of his sea reptile *Elasmosaurus* on the end of its tail. Marsh made sure people heard about it. Neither man ever forgave the other.

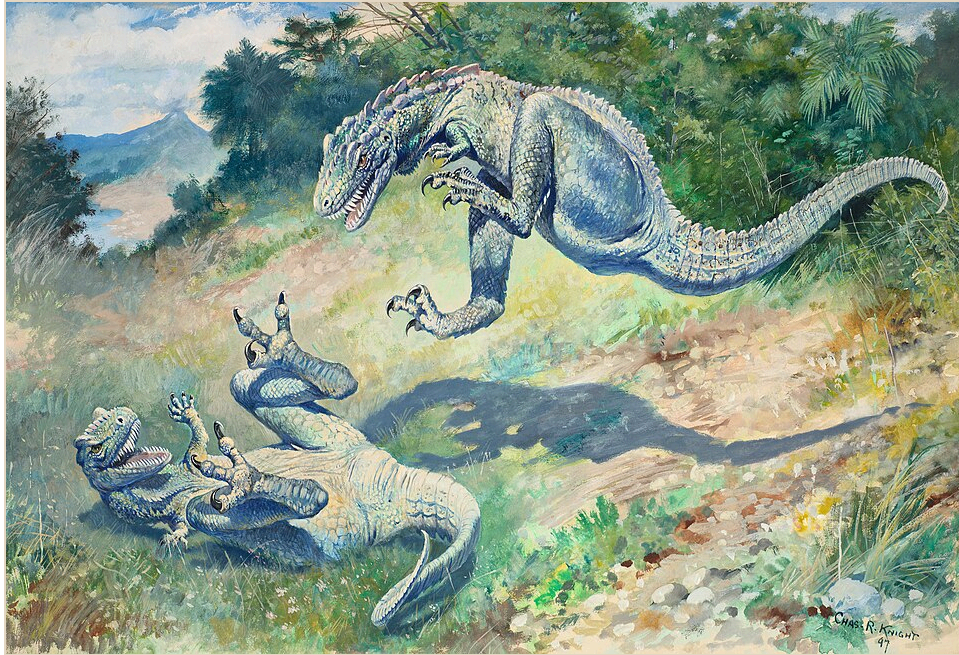
The race west. After the Civil War, railroads opened the West. In 1877 huge bones were found near Morrison and Cañon City, Colorado, and at Como Bluff, Wyoming, beside the Union Pacific Railroad. Cope and Marsh hired crews, paid them to keep secrets and raced to describe each find first. Their crews spied on each other, and some workers smashed bones rather than leave them for the other side. New names were sent east by telegraph, sometimes from fragments too poor to describe well.

A flood of names. Together the two men named more than 130 kinds of dinosaurs (about 80 by Marsh and 56 by Cope), along with many other fossil animals. Some names were later found to be the same animal named twice. Marsh named *Stegosaurus*, *Allosaurus*, *Apatosaurus*, *Brontosaurus*, *Diplodocus* and *Triceratops*. Cope named *Camarasaurus* and *Coelophysis*. Many skeletons in museums today came from their quarries.

A sad ending. In 1890 Cope gave his complaints against Marsh to the *New York Herald*, and for weeks the two men attacked each other in the newspaper. Both lost much of their fortunes and reputations. Cope died in 1897 and Marsh in 1899, both with far less money than they had begun with. Their work moved science forward, but their quarrel wasted money and time and destroyed fossils that might have taught us much.

The root of it. The Bible calls envy "the rottenness of the bones" (Proverbs 14:30). Cope and Marsh each wanted not only to find dinosaurs but to beat the other man. Pride and envy turned good work into a war. The lesson is old and simple: a gift from God used to tear down a neighbor brings little joy.

PICTURE STUDY



Leaping Laelaps, Charles R. Knight, 1897 · Watercolor · American Museum of Natural History, New York
Wikimedia Commons · Public domain

Charles R. Knight was a young artist when he painted this scene under Cope's direction, the same year Cope died. Cope had named *Laelaps* in 1866 from bones found in New Jersey. Marsh pointed out that the name had already been given to a kind of mite, and in 1877 he renamed the animal *Dryptosaurus*. Knight's dinosaurs are lively and quick, very different from Hawkins' heavy beasts (Stop B5).

Look closely

- Look at the leaping dinosaur. Which parts of its body are off the ground?
- Compare these animals with Hawkins' Megalosaurus. How are they different?
- Find the light and the shadows. Where does the light come from?

Talk about it

1. Why do you think Cope wanted his dinosaurs shown as fast and active?
2. Even the name of this dinosaur was part of the Bone Wars. What does that tell you about how deep the rivalry ran?

HANDS-ON: A BONE WARS MAP

Map the race from the eastern museums to the western quarries.

You will need

- An outline map of the United States (print one or trace from an atlas)
- Two colored pencils, one for Cope and one for Marsh

- A ruler

Steps

1. Mark and label the two home bases: Philadelphia (Cope, Academy of Natural Sciences) and New Haven, Connecticut (Marsh, Yale Peabody Museum).
2. Mark the 1877 quarries: Morrison and Cañon City in Colorado, and Como Bluff in southeastern Wyoming.
3. Draw the Union Pacific Railroad as a line across southern Wyoming. Draw the Missouri River from Montana to St. Louis.
4. Draw an arrow in Cope's color from Philadelphia to Cañon City and one in Marsh's color from New Haven to Como Bluff.
5. Add a key, a compass rose and the title "The Bone Wars, 1877."

Check your work

- My map has both home cities and three quarries.
- It has a key, a compass rose and a title.
- I can tell why the railroad mattered.

FIELD NOTEBOOK

1. **Map.** Copy your Bone Wars map into the Field Notebook, or glue it in, with all labels.
2. **Notebook entry.** Write a paragraph: "Was the Bone Wars Good or Bad for Science?" Give one good result and one harmful result, then explain how Proverbs 14:30 applies.

Did you know? Marsh named *Apatosaurus* in 1877 and *Brontosaurus* in 1879. In 1903 another scientist decided they were the same animal, so the older name, *Apatosaurus*, won and "Brontosaurus" was dropped. Then in 2015 a large study argued they were different enough to be separate after all, and many scientists now use both names again.

Map or diagram. Make a two-column chart, "Cope" and "Marsh." In each column list: born, city, museum, character (quick or careful), and three animals each named. Underline the dinosaurs you have met in Trail A.

Goes deeper in. History, "America after the Civil War: railroads and the West" (coming soon); Geography, the Rocky Mountain states. Trail A, Stops A2 and A3 meet *Triceratops* and *Stegosaurus*, both named by Marsh.

For families. Counts vary by source; the commonly cited figures are about 80 new dinosaur species for Marsh and 56 for Cope, many later merged. Leidy's correction of *Elasmosaurus* came in 1870 (Cope had described it in 1868-69); accounts that Marsh first noticed the error come from Marsh himself. The *New York Herald* articles appeared in January 1890. Cope and Marsh both worked for the U.S. Geological Survey at different times, and the Survey funding quarrel was part of the 1890 dispute; the stop leaves out

the political details. The often-told story that Cope left his skull to science to compare brain sizes with Marsh is popular but poorly documented, so it is omitted.

PRACTICE

1. **EASY** Which museum did Marsh work for, and which city was Cope's home?
2. **EASY** Name three dinosaurs that Marsh named.
3. **MEDIUM** What mistake did Cope make with *Elasmosaurus*, and who pointed it out?
4. **MEDIUM** Why did the 1877 finds in Colorado and Wyoming start a race?
5. **CHALLENGE** If together they named 136 kinds of dinosaurs and Marsh named 80, how many did Cope name? Then give one reason a big number of names is not the same as a big amount of good science.

Make it a game • Quarry Race, Played Fair. Hide 20 paper "bones" in two areas. Two teams race to collect them. Round 1: any bone you find is yours. Round 2: teams must share each find aloud and build one skeleton together. Afterward, talk: which round built a better skeleton, and which was more fun?

Scripture. "A sound heart is the life of the flesh: but envy the rottenness of the bones." (Proverbs 14:30, KJV)

Two men who spent their lives digging up bones were eaten up inside by envy. A heart at peace is life; envy rots what is good.

Practice: answers

1. Marsh: the Peabody Museum at Yale (New Haven, Connecticut). Cope: Philadelphia.
2. Any three: *Stegosaurus*, *Allosaurus*, *Apatosaurus*, *Brontosaurus*, *Diplodocus*, *Triceratops*.
3. He put the head on the end of the tail. Joseph Leidy pointed it out in 1870.
4. Huge new dinosaur bones were found in several places at once, near railroads; each man wanted to dig them and name them first, so they sent crews and paid for secrecy.
5. $136 - 80 = 56$. Some names were given in a hurry from poor fragments, and some were the same animal named twice, so many names had to be dropped later.

2.7 BARNUM BROWN FINDS T. REX (1902)

OBJECTIVES

- Tell how Barnum Brown found the first *Tyrannosaurus rex* skeleton in Montana in 1902 and how it was named in 1905.
- Describe the steps of a dinosaur dig, from prospecting to the museum floor.
- Draw a labeled map of the route from Hell Creek, Montana, to New York.

Warm-up. Get a sheet of newspaper, a bowl of water and some flour. (If you can't make a mess today, just imagine it.) How could you wrap a cracked, crumbly bone so it will travel a thousand miles without falling apart? Fossil hunters still use Barnum Brown's answer.

Video slot. Video coming. Barnum Brown and the first *Tyrannosaurus rex*; the American Museum of Natural History dinosaur halls. Search approved channels (American Museum of Natural History, Carnegie Museum of Natural History, Smithsonian); preview first.

KEY TERMS

Tyrannosaurus rex

"Tyrant lizard king," a huge meat-eating dinosaur named by Henry Fairfield Osborn in 1905 from the skeleton Barnum Brown found in 1902.

prospecting

Walking and searching the land for signs of fossils (or minerals) on the surface.

badlands

Dry, rough land cut by gullies and bare cliffs, where rain wears away soft rock and uncovers fossils.

field jacket

A hard wrap of burlap strips dipped in plaster that protects a fossil on its way to the museum.

holotype

The single specimen chosen as the official example when a new kind of animal is named.

CORE IDEAS

A farm boy with a famous name. Barnum Brown was born in 1873 in Carbondale, Kansas, and named after the circus showman P. T. Barnum. He picked up fossil shells in the fields his father plowed. After studying at the University of Kansas, he joined the American Museum of Natural History in New York in 1897. Henry Fairfield Osborn, head of the museum's fossil department, wanted great dinosaurs for New York, and he sent Brown west to find them.

Hell Creek, 1902. In the summer of 1902, Brown rode into the **badlands** of Hell Creek, near the little town of Jordan in eastern Montana. Prospecting along the gullies, he found bones of a huge meat-eater weathering out of a sandstone hill. The rock was so hard that he used dynamite to clear the top layers and then picks, chisels and brushes for the bones themselves. The work went on into the next summers.

Getting it home. Brown's crew wrapped each bone in a **field jacket** of burlap and plaster. Horses and wagons hauled the heavy jackets more than a hundred miles to the railroad at Miles City, and trains carried them to New York. At the museum, workers called preparators spent months chipping the rock away.

A name for a king. In 1905 Osborn described the skeleton and named it **Tyrannosaurus rex**, "tyrant lizard king." In the same paper he named another meat-eater from a find Brown made in Wyoming in 1900, *Dynamosaurus*. Both turned out to be the same kind of animal, and because *Tyrannosaurus rex* appeared first in the paper, it is the name we use. The 1902 skeleton became the holotype, the official example of the species.

The second skeleton. In 1908 Brown found a better *T. rex* in Montana with a nearly complete skull. In 1915 the museum mounted it standing almost straight up, its tail dragging on the ground like a kangaroo's, with a skull about 4 feet (1.2 m) long. Crowds lined up to see it. Decades later, scientists studying footprints and bones concluded that *T. rex* held its body level and its tail in the air, and in the 1990s the skeleton was remounted that way. In 1941 the museum sold the 1902 holotype to the Carnegie Museum in Pittsburgh, where it stands today.

Mr. Bones. Brown hunted fossils for sixty years, from Canada to India. He floated down Alberta's Red Deer River on a flatboat, digging along its banks, and he named *Ankylosaurus* in 1908. Reporters called him "Mr. Bones." He was famous for dressing neatly even in the field, sometimes in a suit and tie, and for wearing a long fur coat on cold digs. He died in 1963, a week before his 90th birthday.

PICTURE STUDY



Skeleton of Tyrannosaurus, American Museum of Natural History photograph, 1915 · Black-and-white photograph, printed in a book · Published in the Annual Report of the American Museum of Natural History for 1915

Wikimedia Commons · No restrictions

This photograph shows Barnum Brown's 1908 T. rex as it was first mounted in 1915. The museum printed it in its yearly report, with a caption saying the animal stood 18½ feet high and was 47 feet long. The pose shows what scientists thought then: that T. rex stood tall like a kangaroo and dragged its tail. Look closely and you can learn both about the dinosaur and about the people who built the mount.

Look closely

- Find the skull. The caption says the skeleton is 18½ feet tall. About how many of you, standing on each other's heads, would reach it?
- Follow the tail. Where does it touch the floor?
- Find the small arms. How many fingers did the builders give each hand?

Talk about it

1. Why would scientists later decide this pose was wrong? What evidence could change it?
2. The builders gave this T. rex three fingers on each hand, but later finds showed it had only two. Why would a museum have to guess at parts it had not found?

Safety first. Plaster of Paris gets warm as it sets; a grown-up mixes it, and never let it set around hands or fingers. Flour paste is the safe choice for younger helpers.

HANDS-ON: MAKE A FIELD JACKET

Wrap a “fossil” the way Brown’s crew did, then open it like a museum preparator.

You will need

- A chicken bone (boiled clean) or a cardboard “bone”
- A tray of damp sand
- Paper towels or tissue (the separator)
- Strips of newspaper or old cotton cloth, and a paste of flour and water (or plaster of Paris with a grown-up)
- Scissors

Steps

1. Bury the bone halfway in damp sand so the top shows, as Brown would find it on a hillside.
2. Cover the bone with damp paper towel so the jacket will not stick to it.
3. Dip strips in the paste and lay them over the bone and some of the sand around it, crossing them in layers. Let it dry overnight.
4. Flip the jacket over with the sand inside, jacket the bottom too, and label it with a number, place and date.
5. Next day, cut it open carefully with scissors and brush out the sand. Did the bone survive?

Check your work

- My jacket has at least three layers of strips.
- I labeled it with a number, place and date.
- The bone came out unbroken.

FIELD NOTEBOOK

1. **Map.** Draw a map of the northern United States. Mark Hell Creek near Jordan, Montana; Miles City and the railroad; Carbondale, Kansas, where Brown grew up; Pittsburgh, where the 1902 skeleton is now; and New York City. Draw the bones’ journey with arrows and label each step: wagon, train, museum.
2. **Notebook entry.** Write a paragraph: “Five Steps of a Dinosaur Dig.” Explain prospecting, uncovering, jacketing, shipping and preparing, using Brown’s 1902 T. rex as your example.

Did you know? When the U.S. entered World War II, many people feared bombing raids on American cities. The museum’s sale of the first T. rex to Pittsburgh in 1941 kept the only two good skeletons in two different cities. Brown also spied for the U.S. government during both World Wars, using his travels and maps.

Map or diagram. Draw a side-by-side diagram of the 1915 mount (upright, tail on the ground) and the modern pose (body level, tail straight out). Label the head, backbone, hips, tail and feet. Draw a dotted line for the backbone in each and write how its angle changed.

Goes deeper in. Earth Science, “How fossils are dug and prepared” (coming soon); Geography, the Great Plains. Trail A, Stop A1 meets T. rex itself; Stop B9 tells the story of SUE.

For families. Brown found the holotype (AMNH 973, now CM 9380) in 1902 near Jordan, Montana; excavation continued into 1903–1904. Osborn’s paper naming *Tyrannosaurus rex* and *Dynamosaurus imperiosus* appeared in the AMNH Bulletin in 1905. The 1908 specimen (AMNH 5027) was mounted in 1915 and remounted in a horizontal pose in the 1990s. Carnegie bought the holotype in 1941; the wartime reason is often given but the museum also needed money, so the stop calls it “sold.” His wartime intelligence work is documented in Dingus and Norell’s biography *Barnum Brown* (2010). Photographs show his neat field dress and his fur coat on winter digs.

PRACTICE

1. **EASY** Where and when did Barnum Brown find the first T. rex skeleton?
2. **EASY** What does *Tyrannosaurus rex* mean, and who named it?
3. **MEDIUM** Why do fossil hunters put bones in field jackets?
4. **MEDIUM** *Dynamosaurus* and *Tyrannosaurus* were named in the same paper but were the same animal. Why do we say *Tyrannosaurus*?
5. **CHALLENGE** The 1915 mount stood upright with its tail on the ground; today T. rex is shown level. Is the pose an observation or an interpretation? What kinds of evidence changed it?

Make it a game • Prospector. A grown-up hides 10 small objects (beads, buttons, pebbles painted white) half-buried in a sandbox, a garden bed or a box of rice. Players “prospect” by walking slowly and looking only, no digging, and call out each find. Then they uncover it carefully with a paintbrush. The player who finds the most without breaking or moving anything wins.

Scripture. “Seest thou a man diligent in his business? he shall stand before kings; he shall not stand before mean men.” (Proverbs 22:29, KJV)

Barnum Brown was diligent: he walked thousands of miles of badlands and worked for sixty years. His diligence led him, in a sense, to stand before a “king,” the tyrant lizard king.

Practice: answers

1. At Hell Creek, near Jordan, Montana, in 1902.
2. “Tyrant lizard king”; Henry Fairfield Osborn, in 1905.

3. Fossils are often cracked and crumbly; a hard jacket of burlap and plaster holds them together so they are not broken on the long trip to the museum.
4. When two names are given to the same animal, the first one published is kept; *Tyrannosaurus rex* appeared first in Osborn's paper.
5. An interpretation. Evidence such as trackways without tail-drag marks, the shape of the hip and tail bones, and comparison with birds led scientists to conclude that *T. rex* held its body level with its tail off the ground.

2.8 ROY CHAPMAN ANDREWS AND THE GOBI EGGS (1923)

OBJECTIVES

- Tell the story of the Central Asiatic Expeditions and the first nests of dinosaur eggs recognized by science (1923).
- Explain how *Oviraptor* was wrongly called an “egg thief” and how later evidence corrected the name’s meaning.
- Draw a labeled map of the expedition route from Peking (Beijing) to the Flaming Cliffs.

Warm-up. Hold a chicken egg (gently!). Feel its weight and its shell. Now imagine finding an egg made of stone, lying in a nest in a desert where no one has lived for a very long time. What questions would you ask first?

Video slot. Video coming. Roy Chapman Andrews, the Central Asiatic Expeditions and the dinosaur eggs of the Flaming Cliffs, Mongolia. Search approved channels (American Museum of Natural History, Smithsonian, National Geographic); preview first.

KEY TERMS

expedition

A long, organized journey with a purpose, such as exploring or collecting fossils.

Gobi Desert

A large, cold, dry desert across southern Mongolia and northern China.

Protoceratops

A sheep-sized plant-eating dinosaur with a beak and a bony frill, found by the hundreds at the Flaming Cliffs.

Oviraptor

“Egg seizer,” a toothless, beaked dinosaur found on a nest in 1923 and named in 1924 as if it were stealing eggs.

embryo

A baby animal in its earliest stage of growth, before hatching or birth.

CORE IDEAS

From mopping floors to the desert. Roy Chapman Andrews was born in 1884 in Beloit, Wisconsin. As a boy he roamed the woods and taught himself to stuff animals. In 1906 he arrived at the American Museum of Natural History in New York and asked for a job; the only opening was mopping floors in the taxidermy department, and he took it. He worked his way up by studying whales, writing and leading expeditions to Asia.

A bold plan. Andrews believed Central Asia held the fossils of many unknown animals. He planned the largest land expedition the museum had ever sent out. Between 1922 and 1930

the Central Asiatic Expeditions crossed the Gobi Desert of Mongolia five times. They used a new idea: automobiles. A line of Dodge cars carried the scientists, while a caravan of camels went ahead carrying gasoline, food and supplies. Walter Granger led the fossil work, and geologists, mapmakers and photographers came too.

The Flaming Cliffs. In 1922 the team found a place of red sandstone cliffs that glowed like fire in the evening sun, at Bayanzag. Andrews named them the Flaming Cliffs. They found the skull of a new beaked dinosaur, named **Protoceratops** in 1923. When they returned in July 1923, George Olsen, a member of the team, found something even more surprising: a nest of fossil eggs. They were long, about 6 inches (15 cm), lying in a circle. These were the first dinosaur eggs to be recognized by science.

The “egg thief.” Near the eggs lay the skeleton of a small, toothless dinosaur with a beak. Since the team thought the eggs belonged to Protoceratops, they guessed this animal had died while robbing the nest. In 1924 Henry Fairfield Osborn named it **Oviraptor philoceratops**, “egg seizer, lover of ceratopsians.” Osborn himself warned that the name might mislead. The same year he named another small hunter from the Flaming Cliffs: Velociraptor.

The truth comes out. In 1993, about seventy years later, another museum team led by Mark Norell returned to the Gobi. They found an egg of the same kind with a tiny skeleton, an **embryo**, inside it. It was not a Protoceratops; it was an oviraptor-like dinosaur. Then they found an oviraptorid fossil sitting on top of its nest with its arms spread over the eggs, like a hen brooding her chicks. The “thief” was really a parent. Under scientific rules the name Oviraptor stays, but its meaning has been turned on its head.

Later years. The expeditions ended in 1930 because of wars and unrest in China and Mongolia. Andrews wrote popular books about his adventures, such as *On the Trail of Ancient Man* (1926), and served as director of the American Museum from 1935 to 1942. He died in 1960.

PICTURE STUDY



Members of the Third Asiatic Expedition at camp, Irden Manha, Mongolia, Unknown expedition photographer, American Museum of Natural History, About 1923 · Black-and-white photograph · Published in Natural History magazine, vol. 24 (1924), American Museum of Natural History, New York
Wikimedia Commons · Public domain

This group portrait was taken at the expedition's camp at Irden Manha in Mongolia. Seated in front are Roy Chapman Andrews, the paleontologist Walter Granger, the geologist Frederick Morris, the fossil collector Peter Kaisen and Henry Fairfield Osborn, president of the museum, who came to visit. Standing behind are other team members, including George Olsen, who found the first nest of eggs, and the Mongolian and Chinese interpreters and helpers the expedition depended on.

Look closely

- Count the people. How many are sitting and how many are standing?
- Look at the clothes and hats. What do they tell you about the weather and the work?
- Look at the land behind them. What kind of place is it?

Talk about it

1. An expedition needs many kinds of workers: diggers, drivers, cooks, guides and scientists. Which job would you want, and why?
2. Why do you think the expedition photographed its whole team, and not only the fossils?

HANDS-ON: EXPEDITION SUPPLY LIST

Plan your own desert expedition the way Andrews did: in detail, before you leave.

You will need

- Paper and pencil
- A map of Mongolia and northern China (atlas or online)
- A calculator (optional)

Steps

1. Your team has 5 cars and 10 people. You will be gone 100 days. Each person needs 3 liters of water a day. How many liters of water for the whole trip? (Show your work.)
2. Each car can carry 200 liters. Will the cars alone carry all the water? If not, how many camel loads of 150 liters each would you need for the rest?
3. List ten other things you must bring (tools, plaster, burlap, maps, medicine, spare tires ...) and give a reason for each.
4. Mark on the map your starting city, Peking (Beijing), and your goal, the Flaming Cliffs.

Check your work

- I worked out the water: $10 \times 3 \times 100 = 3,000$ liters.
- I found that the cars carry 1,000 liters and 2,000 liters need about 14 camel loads (13.3, rounded up).
- My supply list has ten items with reasons.

FIELD NOTEBOOK

1. **Map.** Draw Mongolia and northern China. Label Peking (Beijing), Kalgan (Zhangjiakou), the Great Wall, Urga (Ulaanbaatar), the Gobi Desert and the Flaming Cliffs (Bayanzag) in the south of Mongolia. Draw the expedition route with a dashed line and add a camel and a car symbol to your key.
2. **Notebook entry.** Write a paragraph: “The Egg Thief Who Wasn’t.” Tell what the 1923 team observed, what they concluded, what the 1993 team found and how it changed the story.

Did you know? To raise money for the 1924 expedition, Andrews auctioned one of the eggs in 1923. It sold for \$5,000 and is now at Colgate University in New York. The sale made the Mongolian and Chinese governments think the eggs were worth a fortune, and it made the later expeditions much harder to arrange. Eggs had been found in France in 1869, but no one recognized them as dinosaur eggs at the time.

Map or diagram. Draw an oviraptorid brooding on its nest as seen from above: a ring of long eggs set in pairs, pointing outward, with the parent’s body in the middle and its arms spread over the eggs. Label the eggs, arms, body, legs and tail.

Goes deeper in. Geography, “Mongolia and China” (coming soon); Arithmetic, word problems with supplies and rates. Trail C, Stops C2 “Eggs and nests” and C8 “Babies and growth” go further.

For families. Andrews' dates: born 1884, joined AMNH 1906, expeditions 1922–1930, director 1935–1942, died 1960. The eggs were found at Bayanzag in July 1923 (George Olsen is credited). The embryo was described by Norell et al. in *Science* (1994); the brooding oviraptorid in *Nature* (1995), later named *Citipati*. The often-repeated claim that Andrews inspired Indiana Jones is unconfirmed and is left out. The expeditions ended amid political turmoil in China and Mongolia; the stop does not go into the politics. Expedition photographs are credited to the American Museum of Natural History; Shackelford took most of the 1922–1925 field pictures.

PRACTICE

1. **EASY** What did the Central Asiatic Expeditions find at the Flaming Cliffs in 1923?
2. **EASY** What two ways of travel did the expedition use?
3. **MEDIUM** What does Oviraptor mean, and why was it given that name?
4. **MEDIUM** What two finds in the 1990s showed that Oviraptor was a parent, not a thief?
5. **CHALLENGE** Separate the observation from the interpretation: “A small skeleton lay on a nest of eggs” and “The animal died stealing the eggs.” Then explain why the first scientists jumped to the wrong one.

Make it a game · Thief or Parent?. One player describes a scene in two sentences: “A dog is lying next to a broken flowerpot.” The others must give two different explanations (the dog knocked it over; the dog was sleeping there when the wind did it), then ask a question that could test which is true. Take turns. The best testing question scores a point.

Scripture. “Judge not according to the appearance, but judge righteous judgment.” (John 7:24, KJV)

Oviraptor looked like a thief, and for seventy years it was called one. Jesus teaches us not to judge by how things look at first, but to seek the truth and judge fairly.

Practice: answers

1. Nests of fossil dinosaur eggs, the first recognized by science, along with Protoceratops and Oviraptor.
2. Automobiles (Dodge cars) and camel caravans carrying gasoline and supplies.
3. “Egg seizer.” Its skeleton was found on eggs that scientists thought belonged to Protoceratops, so they guessed it was stealing them.
4. An embryo of an oviraptor-like dinosaur inside the same kind of egg, and an oviraptorid fossil sitting on its nest with its arms spread over the eggs.
5. The first sentence is an observation; the second is an interpretation. They assumed the eggs belonged to Protoceratops, the most common dinosaur there, so an animal on them seemed to be a thief. They had no embryo yet to show whose eggs they were.

2.9 SUE THE T. REX (1990)

OBJECTIVES

- Tell how Sue Hendrickson found SUE, the most complete T. rex then known, in South Dakota in 1990.
- Explain the question “Who owns a fossil?” and how the courts answered it for SUE.
- Draw SUE’s skeleton outline to scale with a scale bar and labels.

Warm-up. Lie down on the floor and have someone measure you from head to toe. SUE is about 40 feet long. How many of you, lying head to toe, would it take to equal SUE?

Video slot. Video coming. SUE the T. rex at the Field Museum: the discovery, the preparation and SUE’s bones. Search approved channels (Field Museum, Smithsonian, PBS NOVA); preview first.

KEY TERMS

complete (of a fossil)

How much of an animal’s skeleton was found. SUE is about 90 percent complete by bulk, which is very rare.

preparator

A museum worker who removes rock from a fossil and repairs and strengthens it.

pathology

A sign of injury or disease in a body. On a fossil, it shows as a healed break, a hole or a bump on the bone.

trust land

Land that the United States government holds for an owner, such as a member of an Indian tribe; it cannot be sold without government approval.

auction

A public sale where buyers bid against each other and the highest bid wins.

CORE IDEAS

A flat tire. On August 12, 1990, a team from the Black Hills Institute of Geological Research was finishing a summer of digging near Faith, South Dakota. That morning a tire on their truck was flat, and most of the team drove to town to fix it. Sue Hendrickson, a self-taught fossil hunter, stayed behind and walked with her dog, Gypsy, to a line of sandstone cliffs she had wanted to explore.

Bones in the cliff. At the foot of the cliff she found small pieces of bone. Looking up, she saw large backbones sticking out of the rock. When the team returned, the leader, Peter

Larson, saw at once that they were T. rex bones. The team worked for 17 days, digging away tons of rock and jacketing the bones. They named the skeleton SUE after its finder.

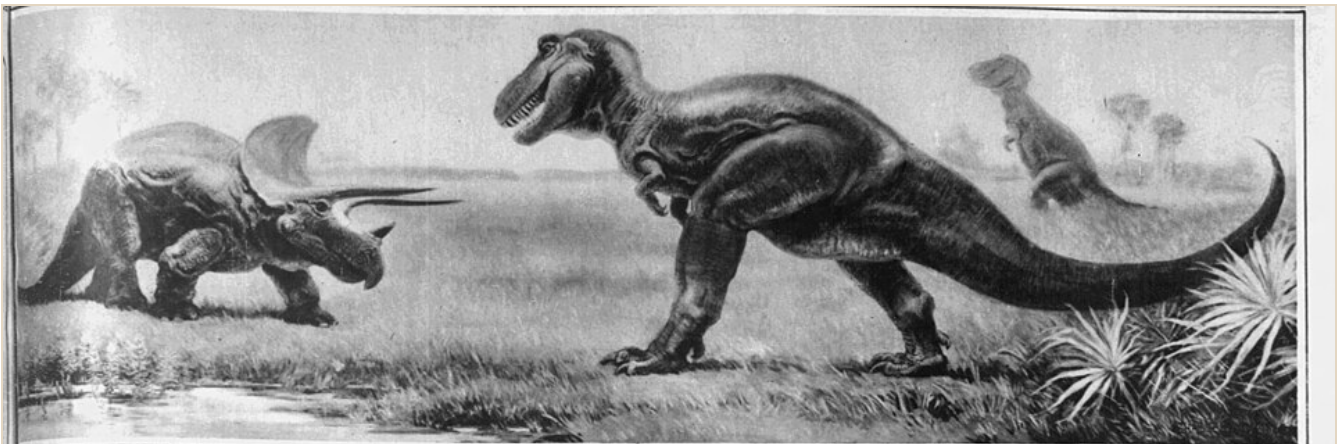
Who owns a fossil? The cliff was on the ranch of Maurice Williams, a member of the Cheyenne River Sioux Tribe, and the Institute paid him \$5,000 for the fossil. But his land was **trust land**, held for him by the U.S. government, and could not be sold without government approval. In 1992 federal agents took SUE from the Institute. After years in court, judges ruled that SUE belonged to Williams as part of his land. In the United States, fossils on private land belong to the landowner; fossils on public land belong to everyone and need a permit to collect.

A record sale. On October 4, 1997, SUE was sold at Sotheby's auction house in New York for \$8,362,500, at that time the most ever paid for a fossil. The buyer was the Field Museum in Chicago, helped by gifts from companies and others. Preparators spent tens of thousands of hours cleaning and repairing the bones, some of them in a glass lab where visitors could watch. On May 17, 2000, SUE was unveiled in the museum's great hall.

What SUE tells us. SUE is about 40.5 feet (12.3 m) long and 13 feet (4 m) tall at the hips, with a skull 5 feet (1.5 m) long. More than 250 bones were found. SUE's bones show many **pathologies**: broken and healed ribs, an injured shoulder, and holes in the jaw that may have come from an infection. Growth rings in the bones suggest SUE lived to about 28 to 33 years, old for a T. rex. No one knows whether SUE was male or female; the bones do not tell.

A new home. In 2018 SUE moved to a new room in the Field Museum with a better pose, adding the belly ribs (gastralia) that had been left off the first mount. Scientists from around the world still study the bones, and the skull is so heavy (about 600 pounds) that a lighter cast sits on the mount while the real one is kept in its own case.

PICTURE STUDY



Tyrannosaurus rex and Triceratops (Field Museum mural), Charles R. Knight, about 1927 · Oil on canvas mural · Field Museum of Natural History, Chicago
Wikimedia Commons · Public domain

Charles R. Knight (Stop B6) painted a series of 28 large murals for the Field Museum between 1926 and 1930. This is the most famous one. Seventy years later, SUE came to live

in the same museum. Knight painted T. rex standing upright with its tail on the ground, as scientists then believed.

Look closely

- Compare the T. rex here with SUE's modern pose. What is different about the back and the tail?
- Look at the Triceratops. How is it ready to defend itself?
- Look at the land and the sky. Is this a jungle, a desert or a plain?

Talk about it

1. This painting is still loved and shown, even though scientists have changed their minds about the pose. Why do you think it is still valuable?
2. If you could add SUE's injuries (from the bones) to this picture, where would you show them?

HANDS-ON: SUE LIFE-SIZE IN CHALK

Draw SUE full size on a driveway, sidewalk or playground: about 40 feet (12.3 m) long.

You will need

- Sidewalk chalk
- A tape measure (at least 25 feet) or a 10-foot string
- A helper
- Your scale drawing from the notebook (below)

Steps

1. Mark a straight line 40 feet long: the backbone from nose to tail tip.
2. Mark the hips about 18 feet from the nose. Draw one leg as a 13-foot line from the hips out to the side (that is SUE's hip height, laid flat on the ground).
3. Draw the skull at the front, 5 feet long. Draw the tiny arms, each about 3 feet long.
4. Lie down beside the skull and have someone outline you in another color.
5. Count how many of you fit along SUE's length.

Check your work

- My chalk SUE is about 40 feet long.
- The skull is 5 feet and the arms are about 3 feet.
- I compared my own size with SUE's.

FIELD NOTEBOOK

1. **Scale diagram.** On graph paper, let one square equal 1 foot. Draw SUE's side view: 40 squares long, hips 13 squares high, skull 5 squares long. Add a scale bar ("1 square =

1 foot”) and label skull, neck, backbone, ribs, gastralia (belly ribs), arms, hips, legs and tail. Draw a 5-foot person to the same scale.

2. **Notebook entry.** Write a paragraph: “Who Owns a Fossil?” Explain the difference between private and public land, what happened to SUE, and what you think a fair rule is, giving a reason.

Did you know? SUE’s arms are only about 3 feet (1 m) long, yet each could probably lift several hundred pounds. And SUE’s skull is so heavy that the real one is not on the skeleton at all: it sits in its own case nearby, and a lighter cast skull sits on the neck.

Map or diagram. On a map of the United States, mark Faith, South Dakota (where SUE was found), Hill City, South Dakota (the Black Hills Institute), New York City (the Sotheby’s auction) and Chicago (the Field Museum). Draw arrows for SUE’s travels and write a year on each arrow: 1990 (found), 1992 (taken by federal agents), 1997 (sold), 2000 (unveiled).

Goes deeper in. Small Business & Economics, “Property, ownership and auctions” (coming soon); Arithmetic, scale drawing and measurement. Stop B7 tells of the first T. rex; Trail A, Stop A1 meets T. rex itself.

For families. Facts follow the Field Museum: found August 12, 1990 by Sue Hendrickson; sold October 4, 1997 at Sotheby’s for \$8,362,500; unveiled May 17, 2000; moved to a new gallery in 2018. Age estimates vary (Erickson et al., 2004, gave 28; the Field Museum now says about 33), so a range is given. The Field Museum does not know SUE’s sex and uses no gendered words; this stop calls SUE “it” or uses the name. The legal case is summarized neutrally; a separate case against Institute members on other charges is not part of this stop. Museum signs give SUE an age in millions of years; this stop leaves the date out (see Stop B10 and Trail D, Stop D8).

PRACTICE

1. **EASY** Who found SUE, and why is the skeleton called SUE?
2. **EASY** Where is SUE today?
3. **MEDIUM** Why did the courts decide SUE belonged to Maurice Williams and not the Black Hills Institute?
4. **MEDIUM** SUE is 40.5 feet long. If a student is 5 feet tall, about how many students lying head to toe equal SUE’s length?
5. **CHALLENGE** Give two things scientists learned from SUE’s bones that a less complete skeleton might not show, and one question the bones cannot answer.

Make it a game • Bid for the Bones. Give each player 100 paper “dollars.” A leader auctions five pictures of fossils (a tooth, a skull, a full skeleton, an egg, a footprint). Players bid in steps of 5. Afterward, each buyer explains why that fossil was worth the

price to a museum. Play money only; the point is to talk about what makes a fossil valuable for learning.

Scripture. “The earth is the LORD’s, and the fulness thereof; the world, and they that dwell therein.” (Psalm 24:1, KJV)

People argued for years over who owned SUE. In the end, every rock and bone belongs to God, and men and women are stewards who must deal honestly and fairly with what He has made.

Practice: answers

1. Sue Hendrickson found it in 1990; the team named the skeleton after her.
2. The Field Museum in Chicago.
3. SUE was found on Williams’ land, which was trust land held by the U.S. government; it could not be sold without government approval, so the \$5,000 sale did not count and the fossil remained part of his land.
4. $40.5 \div 5 = 8.1$, so about 8 students.
5. Any two: healed injuries (ribs, shoulder), possible jaw infection, age from growth rings, the shape of the gastralia and wishbone, the true length and proportions. A question they cannot answer: whether SUE was male or female (or SUE’s color, voice and so on).

2.10 MARY SCHWEITZER'S SOFT TISSUE (2005)

OBJECTIVES

- Tell the steps by which Mary Schweitzer's team found soft, flexible tissue inside a T. rex thighbone (2005), and what later tests found.
- Separate the observations from the interpretations in the soft-tissue story, including the date on a museum sign.
- Draw and label a cross-section diagram of a bone showing where the tissue was found.

Warm-up. Drop a clean chicken bone into a jar of vinegar and leave it for three or four days. (Start it today; you will finish it as part of the project.) The vinegar slowly dissolves the hard minerals. What do you think will be left?

Video slot. Video coming. Mary Schweitzer and soft tissue in Tyrannosaurus rex bone (MOR 1125); demineralizing fossil bone. Search approved channels (North Carolina State University, Smithsonian, PBS NOVA; for creation-friendly framing, Answers in Genesis or Institute for Creation Research once vetted); preview first.

KEY TERMS

soft tissue

Body material that is not hard and mineral-filled, such as blood vessels, cells, skin and protein fibers.

demineralize

To remove the hard minerals from bone, here with a mild chemical, so only the non-mineral material remains.

collagen

A tough, stringy protein that gives bone, skin and tendons their strength; the most common protein in your body.

medullary bone

A special, short-lived layer of bone inside the leg bones of female birds that stores calcium for making eggshells.

hypothesis

A proposed explanation that can be tested by more observations or experiments.

CORE IDEAS

A late start. Mary Higby Schweitzer grew up in Helena, Montana. She studied to be a teacher and was a mother of three before she began, in her thirties, to sit in on dinosaur classes taught by Jack Horner at Montana State University. She went on to earn a doctorate. In the early 1990s, looking through a microscope at a thin slice of T. rex bone, she saw tiny

round red shapes inside the bone's channels. They looked like blood cells. She was surprised, and she was careful.

The bone from the cliff. In 2000 Bob Harmon, working with Horner's Museum of the Rockies team, found a T. rex in the Hell Creek badlands of Montana, specimen MOR 1125. A thighbone in its plaster jacket was too heavy for the helicopter, so the team broke it into pieces. Some pieces went to Dr. Schweitzer, by then at North Carolina State University. Inside was a layer of bone that looked unusual.

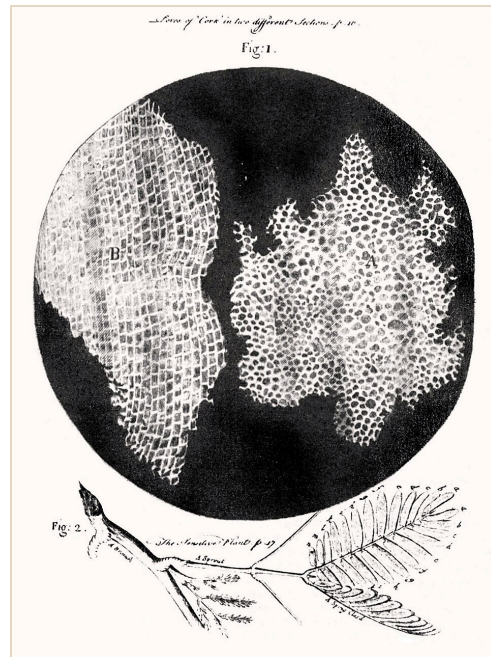
What was left. Her assistant placed bone fragments in a mild chemical that slowly **demineralizes** bone. Usually, fossil bone simply dissolves. This time, flexible material remained. Under the microscope there were clear, hollow, branching tubes that looked like blood vessels, with small round and branching shapes inside like cells. Stretched with tweezers, the material bent and sprang back. On March 25, 2005, the team published the find in the journal *Science*.

Testing and more testing. In June 2005 the team showed that the unusual layer looked like **medullary bone**, which female birds make before laying eggs; this T. rex was probably female. In 2007 and 2009 other tests found short pieces of **collagen** protein in MOR 1125 and in a duck-billed dinosaur. Some scientists offered another **hypothesis**: that the "vessels" were slime left by bacteria (a biofilm). Schweitzer's team ran more tests, and many researchers concluded that at least some original material is present. The debate pushed everyone to test more carefully.

Observe, then interpret. The observations are things anyone with the right tools can check: soft, stretchy material; branching tubes; protein fragments. The big question is how such material could last. Most scientists accept the museum date of about 68 million years, and in 2014 Dr. Schweitzer's team suggested that iron from blood may have preserved it. Many young-earth Christians conclude that the bones are only thousands of years old and were buried in the Flood. Both are interpretations, built on different starting assumptions.

A scientist of faith. Dr. Schweitzer has said publicly that she is a Christian and that she sees no conflict between her faith and her science; she holds an old-earth view and disagrees with young-earth uses of her work. Her story shows how a careful scientist handles a surprise: look again, test again, report honestly and let others check the work.

PICTURE STUDY



Cork cells, from Micrographia (Observation XVIII), Robert Hooke, 1665 · Engraving (book illustration) · From Robert Hooke, Micrographia (London, 1665) Wikimedia Commons · Public domain

Robert Hooke, an English scientist, looked at a thin slice of cork through his microscope and saw rows of tiny empty boxes. They reminded him of the small rooms (cells) in a monastery, and he called them “cells.” That is where the word comes from. Hooke’s picture is a reminder that a microscope can show things no one expected, as it did for Mary Schweitzer 340 years later.

Look closely

- Find the two round views. How are they different? (Hint: one is a slice across, one along.)
- Look at the shape of the little boxes. Are they all the same size?
- Find the plant sprig. Why might Hooke include it?

Talk about it

1. Hooke drew exactly what he saw. Why is a careful drawing or photograph important when you see something surprising?
2. Hooke’s cork cells were empty. What would it mean if he had found something soft still inside them?

Safety first. Use only cooked, cleaned chicken bones; wash hands after handling. Vinegar is safe but stings in the eyes.

HANDS-ON: THE RUBBER BONE AND THE SIGN SORT

Part 1 shows what “demineralize” means with a real bone. Part 2 practices sorting a museum sign into observations and interpretations.

You will need

- A clean chicken leg bone and a jar of white vinegar (started in the warm-up)
- A second clean chicken bone kept dry (for comparison)
- A museum sign (from a visit, a museum website or the sample in the 🕒 box below)
- Two colored pencils

Steps

1. After three or four days, take the bone out of the vinegar and rinse it. Try gently bending it. Compare it with the dry bone.
2. Write what you observe: color, feel, how far it bends.
3. Explain in a sentence: the vinegar dissolved the minerals; what is left is mostly collagen. A fresh bone has this; the surprise was finding something flexible in a dinosaur bone.
4. Copy the sample sign from the 🕒 box. Underline observations in one color and interpretations in another. Then do the same with a real museum sign.

Check your work

- My vinegar bone bends and I described it in writing.
- I can explain what demineralizing does.
- I marked two signs in two colors.

FIELD NOTEBOOK

1. **Diagram.** Draw a cross-section of a leg bone as a large circle. Label from outside in: outer compact bone with tiny channels for blood vessels; the medullary bone layer (draw it as a thin spongy ring just inside); the hollow marrow cavity in the middle. Draw a close-up circle beside it showing a branching vessel with small cells, and label it “what was seen after demineralizing.”
2. **Notebook entry.** Write a paragraph: “Observation or Interpretation?” List three observations from the MOR 1125 study and two interpretations of what they mean, and explain why scientists who agree on the observations can still disagree on the date.

Did you know? The chemical that Schweitzer’s lab used, called EDTA, does not burn the bone away like a strong acid. It gently pulls the calcium out over days or weeks. Before 2005 hardly anyone had tried this on dinosaur bone, because nearly everyone assumed there would be nothing left to find.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** “This Tyrannosaurus rex lived about 68 million years ago, in the Late Cretaceous.” **What we observe:** a T. rex thighbone (MOR 1125) from the Hell Creek rocks of Montana; after the minerals were removed, flexible material with branching, vessel-like tubes and cell-like shapes remained; later tests found fragments of collagen protein; the bone has a layer like the medullary bone of egg-laying birds. **How Christians read it:** many young-earth Christians read the soft tissue as evidence that the bone is thousands, not millions, of years old, buried in the Flood described in Genesis 6–9; the date on the sign rests on assumptions about how fast rock layers formed and how radioactive elements decayed. Dr. Schweitzer, a Christian with an old-earth view, accepts the sign’s date and proposes that iron from blood helped preserve the tissue. Christians hold both views. “Late Cretaceous” is a museum word naming the rock layer; the number is an interpretation, and the soft tissue is an observation everyone must account for.

Map or diagram. On a map of Montana, mark the Hell Creek area near Jordan (where both Barnum Brown’s T. rex of Stop B7 and MOR 1125 were found) and Bozeman (Museum of the Rockies). Then draw an arrow to Raleigh, North Carolina, where the bone was studied.

Goes deeper in. Life Science, “Cells and tissues” and “Proteins” (coming soon); Earth Science, the creation and dating units. Trail D, Stop D9 “Soft tissue and dating” takes up the dating question in full.

For families. This is a  stop. Key papers: Schweitzer et al., *Science* 307 (March 25, 2005), soft tissue in MOR 1125; Schweitzer, Wittmeyer and Horner, *Science* 308 (June 3, 2005), medullary bone; Asara et al., *Science* (2007), collagen peptides; Schweitzer et al., *Science* (2009), Brachylophosaurus; Kaye et al., *PLoS ONE* (2008), the biofilm hypothesis; Schweitzer et al., *Proc. R. Soc. B* (2014), iron. The early-1990s red structures were in a different T. rex (MOR 555). Dr. Schweitzer has described her Christian faith in interviews and has objected to young-earth uses of her findings; young-earth groups (Answers in Genesis, Institute for Creation Research, Creation Ministries International) read the finds as evidence of a young earth. The stop presents both views fairly and without mockery, following the course’s young-earth position while teaching what the sign claims.

PRACTICE

1.  **EASY** What did Schweitzer’s team find after demineralizing pieces of the T. rex thighbone?
2.  **EASY** Why was the thighbone broken into pieces in the first place?
3.  **MEDIUM** What is medullary bone, and what did finding it in MOR 1125 suggest?
4.  **MEDIUM** Sort these: (a) “The tissue stretches and springs back.” (b) “The tissue is 68 million years old.” (c) “Collagen fragments were detected.” (d) “Iron preserved the tissue.”

5. **CHALLENGE** Some scientists said the “vessels” were bacterial slime (biofilm). Why is a challenge like this good for science, and what kind of evidence would help settle it?

Make it a game · Sign Detective. A leader reads museum-style sentences aloud: “This skull is 5 feet long.” “This animal lived 66 million years ago.” “These teeth are serrated.” “It hunted in packs.” Players hold up a magnifying glass card (or make circles with their fingers) for an observation and a thought-bubble card (or tap their heads) for an interpretation. A player who explains why scores two points.

Scripture. “It is the glory of God to conceal a thing: but the honour of kings is to search out a matter.” (Proverbs 25:2, KJV)

God hid surprises in His creation, even inside a dinosaur bone. Searching them out with care and honesty is an honorable work, and every true discovery points back to the Creator.

Practice: answers

1. Flexible, stretchy material with clear, branching tubes like blood vessels and small shapes like cells.
2. In its plaster jacket it was too heavy for the helicopter to lift, so the team broke it.
3. A short-lived layer inside the leg bones of female birds that stores calcium for eggshells; it suggested this T. rex was female and ready to lay eggs.
4. Observations: (a) and (c). Interpretations: (b) and (d).
5. Challenges force more careful testing so mistakes are caught. Evidence that the material contains animal proteins such as collagen (not bacterial ones), reacts to antibodies made against animal proteins, and has the structure of vessels and cells would favor original tissue; evidence of only bacterial chemistry would favor biofilm.

TRAIL 2 BADGE QUIZZES

The badge quizzes are optional. The student answers in writing, in complete sentences; a parent checks with the answers given. Four right out of five earns the first badge; five right out of six earns the second. Badges and the certificate are earned by doing the stops, not by scores.

Badge quiz 1 (Stops 1–5)

1. Name two kinds of fossil sea reptiles Mary Anning (and her brother) found, with their years, and explain why winter was the best time to search.
2. What was the first dinosaur to get a scientific name, who named it, and what clues showed it ate meat?
3. Why was Iguanodon given its name, and what mistake about it did the Bernissart skeletons correct?
4. What does “Dinosauria” mean, and what three animals did Owen first place in the group?
5. What were the Crystal Palace models built on inside, and why are they still valuable even though some are wrong?

Badge quiz 2 (Stops 6–10)

6. Name one dinosaur named by Marsh and one by Cope, and one harm the Bone Wars did to science.
7. Where and when did Barnum Brown find the first T. rex, and what is a field jacket?
8. Why was Oviraptor called an “egg thief,” and what showed it was really a parent?
9. Who found SUE, and why did the courts rule that SUE belonged to Maurice Williams?
10. On a sign that says “This T. rex lived 68 million years ago; soft tissue was found in its bone,” which part is an observation and which is an interpretation? Explain.
11. Put these in order: SUE found; “Dinosauria” coined; first T. rex found; Megalosaurus named; Gobi eggs found.

TRAIL CERTIFICATE: MY DINOSAUR HUNTERS FIELD NOTEBOOK AND TRAIL B CERTIFICATE

Gather the Field Notebook pages from this trail into one booklet with a cover: “My Dinosaur Hunters Field Notebook,” your name and the dates you started and finished.

Add a timeline page across two facing pages with all ten discoveries in order, from Mary Anning (1811) to Mary Schweitzer (2005), with one sentence and a small drawing for each.

Add a world map page that marks every place on the trail: Lyme Regis, Oxford, Lewes, Sydenham, Bernissart, Philadelphia, New Haven, Como Bluff, Hell Creek, the Flaming Cliffs, Faith and Chicago.

Add one museum sign (real or from the  box) marked in two colors for observations and interpretations. When the booklet is done, a parent signs the Trail B certificate.

- **Ten stops:** A labeled map or diagram and a paragraph for each stop, each with a title and a date.
- **Timeline and map:** The ten discoveries are in the right order with their years, and the places are correctly marked on the world map.
- **Observe or interpret:** The student correctly sorts a museum sign and explains why a date in millions of years is an interpretation.
- **Care and accuracy:** Writing is in complete sentences, facts and spellings are correct, and drawings are neat and labeled.

Answer key

1. The ichthyosaur (1811–1812) and the plesiosaur (1823); also the first British pterosaur (1828). Winter storms caused landslips that broke open the cliffs and exposed new fossils.
2. Megalosaurus, named by William Buckland in 1824. Its teeth were curved, blade-like and serrated.
3. Its teeth looked like giant iguana teeth (“iguana tooth”). The spike Mantell put on its nose belonged on its thumb.
4. “Terrible” or “fearfully great lizards” (1842). Megalosaurus, Iguanodon and Hylaeosaurus.
5. Brick bases with iron columns and bars, covered with tiles and cement. They were the first life-size models of extinct animals and show exactly what scientists believed in 1854.
6. Marsh: Stegosaurus, Allosaurus, Apatosaurus, Brontosaurus, Diplodocus or Triceratops. Cope: Camarasaurus or Coelophysis. Harm: fossils were smashed, names were given in a hurry from poor fragments, and money and time were wasted.
7. Hell Creek, near Jordan, Montana, in 1902. A hard wrap of burlap and plaster that protects a fossil on its way to the museum.
8. It was found on eggs thought to belong to Protoceratops. In the 1990s an oviraptor-type embryo was found in the same kind of egg, and an oviraptorid was found sitting on its nest.
9. Sue Hendrickson, in 1990. It was found on his land, which was trust land held by the U.S. government and could not be sold without government approval, so the fossil remained his.
10. “Soft tissue was found in its bone” is an observation that can be tested. “68 million years ago” is an interpretation based on assumptions about rates in the past; young-earth Christians read the same bone as thousands of years old.
11. Megalosaurus named (1824); “Dinosauria” coined (1842); first T. rex found (1902); Gobi eggs found (1923); SUE found (1990).

DINOSAURS TRAIL C: HOW DINOSAURS LIVED

The third trail of the Dinosaurs track asks how dinosaurs actually lived: what their teeth say about food, how they laid eggs and built nests, what footprints and trackways record, whether they traveled in herds, how fast they could move, whether they were warm-blooded, what the feathered fossils really show, how babies grew up, how sauropods held their giant necks and what dinosaurs may have sounded like. Each stop works like a detective case, building an answer from several kinds of evidence and marking clearly where the evidence ends and the guessing begins.

This is the  **Ranger** level, for ages 10 to 13. The student reads each stop alone, in about 25 to 35 minutes, then does a hands-on project with real measurements, draws a labeled map or diagram, and writes a short paragraph in the Field Notebook. Every stop stands by itself. The track is creation-friendly: God made the beasts of the earth on the sixth day (Genesis 1:24-25). Period names such as **Jurassic** and **Cretaceous** are museum vocabulary, and where a date in millions of years comes up (Stop C7), the  box sets out *What the sign says / What we observe / How Christians read it*.

Five stops earn the **Dinosaur Life Ranger badge, part 1**, and ten stops earn part 2 and the **Trail C certificate**. The two badge quizzes at the end are optional; badges are earned by doing the stops and keeping the Field Notebook, not by scores.

BEFORE YOU BEGIN

- Read a page of about 500 words alone and tell back the main points; measure in meters and centimeters; multiply and divide with a calculator.
- Know what a fossil is and the difference between an observation and an interpretation (Trail B, Stop B10, or a parent's explanation).

MASTERY CHECKLIST

- ☐ I can explain at least five clues to how dinosaurs lived (teeth, eggs and nests, trackways, bonebeds, bone growth rings) and what each one can and cannot tell us.
- ☐ I can measure a trackway and use footprint length and stride to tell whether an animal was walking, trotting or running.
- ☐ I can give the evidence on both sides of an open question, such as warm-bloodedness, herds or sauropod neck posture.
- ☐ I can read a graph or draw a labeled diagram from numbers, such as a growth curve, a quarry map or a feeding envelope.
- ☐ I can separate observations from interpretations, including dates on museum signs, and tell how Christians read the evidence.

OPTIONAL BOOKS AND RESOURCES

- **Biodiversity Heritage Library** (<https://www.biodiversitylibrary.org>): Free scans of old books used on this trail, such as Edward Hitchcock's *Ichnology of New England* (1858) and O. C. Marsh's *The Dinosaurs of North America* (1896).
- **American Museum of Natural History** (<https://www.amnh.org>): Free pages and videos on dinosaur eggs, the Paluxy River trackway, feathered dinosaurs and Charles R. Knight's paintings.
- **Beneski Museum of Natural History, Amherst College** (<https://www.amherst.edu/museums/naturalhistory>): Home of Edward Hitchcock's collection of fossil footprints (Stop C3); the website has photos of the track slabs.

3.1 TEETH TELL DIET

OBJECTIVES

- Sort dinosaur teeth into three main shapes (blade, peg or leaf, and dental battery) and tell what each shape was good for.
- Explain three other clues to diet besides tooth shape: wear marks, tooth replacement and coprolites.
- Draw and label a diagram comparing a meat-eater's tooth with a plant-eater's dental battery.

Warm-up. Look in a mirror and find three kinds of teeth in your own mouth: thin front teeth for biting, pointed eyeteeth for gripping and flat back teeth for grinding. Bite a cracker with your front teeth, then chew it with your back teeth. Which teeth do which job? A dinosaur's teeth tell the same kind of story.

Video slot. Video coming. Dinosaur teeth and diet: serrated theropod teeth, hadrosaur and ceratopsian dental batteries, Nigersaurus tooth rows, tooth replacement. Search approved channels (American Museum of Natural History, Royal Tyrrell Museum, Smithsonian National Museum of Natural History, Natural History Museum London); preview first.

KEY TERMS

dental battery

A block of hundreds of teeth packed tightly in columns, worn together into one grinding or slicing surface, as in duck-billed and horned dinosaurs.

herbivore

An animal that eats plants.

carnivore

An animal that eats meat.

microwear

Tiny scratches and pits on the chewing surface of a tooth, seen under a microscope, left by the food the animal ate.

coprolite

Fossilized dung. Its contents can show what an animal had eaten.

CORE IDEAS

Tools in the jaw. Teeth are the hardest part of a vertebrate's body, so they are among the most common dinosaur fossils. Many dinosaurs are known only from a few teeth. A tooth is a tool, and a tool tells you the job. A carpenter can look at a saw, a chisel and a file and know what each was made for. A paleontologist does the same with teeth. Gideon Mantell's first

Iguanodon was named in 1825 from teeth that looked like giant iguana teeth, and those plant-eater teeth were the clue to the whole animal.

Blades for meat. Most **carnivores** among the dinosaurs, the theropods, had teeth shaped like curved, flattened blades with tiny saw-teeth called serrations along the front and back edges. They worked like a steak knife. Under a microscope, the serrations of some theropods have little grooves at their base that may have kept the edge from cracking. *Spinosaurus* had very different teeth: straight cones without strong serrations, much like a crocodile's, good for gripping slippery fish. The shape of a tooth points to the food.

Pegs, leaves and batteries for plants. Plant-eating dinosaurs, the **herbivores**, solved the problem in different ways. *Diplodocus* had a row of thin, pencil-like pegs only at the front of its jaws, good for stripping leaves off branches. *Stegosaurus* and *Ankylosaurus* had small, leaf-shaped teeth for chopping soft plants. The duck-billed hadrosaurs and the horned dinosaurs such as *Triceratops* built **dental batteries**: hundreds of teeth stacked in columns, with a new tooth waiting under each working one. In *Edmontosaurus* the jaws could hold more than a thousand teeth at once. The surface wore down like a file as the animal chewed, and new teeth kept rising to take the place of the old.

New teeth all the time. You get two sets of teeth in your life. Dinosaurs, like crocodiles today, replaced their teeth again and again. Scientists can count the daily growth lines inside a tooth, the way we count rings in a tree, to find how long each tooth lasted. A 2013 study found that *Diplodocus* replaced each tooth about every 35 days. The small sauropod *Nigersaurus*, from Niger in Africa, had about 500 teeth in a wide, straight-edged mouth like a vacuum-cleaner head, and replaced each one about every 14 days. It was likely a ground-level grazer, mowing low plants.

Other clues. Shape is only the first clue. **Microwear**, the scratches and pits on a tooth, shows whether an animal chewed gritty plants, tough stems or bone. Stomach contents are rare but precious: a few fossils have been found with seeds, leaves or fish scales where the stomach was. **Coprolites** show what actually went through the animal. Putting the clues together is like solving a detective case: no single clue settles it, but several clues pointing the same way make a strong answer.

“Every green herb for meat.” Genesis 1:30 says that in the beginning God gave “every green herb for meat” to the beasts of the earth. Many Christians read this to mean that animals, dinosaurs too, ate plants before the Fall, and that sharp teeth and claws came to be used for killing after sin entered the world. Scripture tells us what God did; the teeth tell us how the animals were eating when they were buried.

PICTURE STUDY



Triceratops, Charles R. Knight, 1901 · Painting · Painted for the American Museum of Natural History, New York
Wikimedia Commons · Public domain

Charles R. Knight painted this *Triceratops* in 1901, working closely with scientists at the American Museum of Natural History. Look past the horns and frill to the front of the face. The beak and the great jaws hold the clues to how this animal ate.

Look closely

- Find the beak at the front of the mouth. What living animals have a beak like this?
- Look at the cheeks and the deep jaws behind the beak. What would be hidden inside them?
- Look at the plants around the animal. Did Knight paint anything that Triceratops might be eating?

Talk about it

1. Triceratops had a toothless beak at the front and a dental battery at the back. Why might an animal need both?
2. What parts of this painting come from fossil bones, and what parts did Knight have to imagine?

Safety first. Use plastic or butter knives only, and cut on a plate, away from your fingers. Ask a grown-up before using a grater.

HANDS-ON: TOOTH DETECTIVE LAB

Test how tooth shape matches food, then draw a labeled diagram of three kinds of dinosaur teeth.

You will need

- A slice of bread, a piece of cooked meat or cheese, and a handful of lettuce leaves
- A plastic serrated knife and a plastic smooth knife (or a butter knife)
- A fork (for raking leaves, like peg teeth) and a cheese grater or emery board (like a dental battery)
- A paper plate, a pencil, colored pencils and your Field Notebook

Steps

1. Cut the meat or cheese with the smooth knife, then with the serrated knife. Which cuts more easily? Write down what you notice.
2. Pull the fork through the lettuce like a comb. This is how a sauropod with peg teeth may have stripped leaves from a branch.
3. Rub a crust of bread on the grater or emery board. This is how a dental battery ground tough plants into small pieces.
4. In your Field Notebook, draw a diagram with three panels: (1) a theropod tooth, curved and blade-like, with labels for the crown, root, serrations and tip; (2) a row of Diplodocus peg teeth at the front of a jaw, labeled “peg teeth, front only”; (3) a Triceratops or Edmontosaurus dental battery, drawn as stacked columns, labeled “working tooth,” “replacement teeth” and “grinding surface.”
5. Under each panel, write the food that tooth was best for and the kitchen tool you used to test it.

Check your work

- I tested all three tools and wrote what I noticed.
- My diagram has three panels with at least eight labels in all.
- I can explain what a dental battery is and why new teeth were always waiting underneath.

FIELD NOTEBOOK

1. **Diagram.** If you did not draw it in the project, draw the three-panel tooth diagram now, with labels and the food each tooth suited.
2. **Notebook entry.** Write a paragraph of five to seven sentences: “How can a scientist tell what a dinosaur ate?” Name at least three kinds of clues (tooth shape, microwear, replacement rate, stomach contents, coprolites) and give one dinosaur example.

Did you know? Paleontologists can sometimes tell what kind of dinosaur a single tooth came from just by the size and shape of its serrations. Shed theropod teeth are common

in some fossil beds because the animals lost and replaced them so often, and they are often found near the bones of plant-eaters, a sign of where the meat-eaters had been feeding.

Goes deeper in. Life Science, the units on animal design, food chains and teeth (coming soon). On this track, Trail A, Stop A1 (Tyrannosaurus rex) gives T. rex's teeth and bite in detail, and Trail B, Stop B3 tells how Iguanodon was found from its teeth.

For families. Tooth-replacement rates are from D'Emic et al., *PLoS ONE* (2013), and Sereno et al., *PLoS ONE* (2007), which described the jaws of Nigersaurus. Counts of teeth in dental batteries vary by species and by how they are counted; "more than a thousand" for Edmontosaurus is a commonly cited figure and should be read as approximate. The reading of Genesis 1:29–30 as describing an original plant-eating creation is common among young-earth Christians; Christians differ on how much it says about animal diets, and the stop presents it as a reading of the text.

PRACTICE

1. **EASY** Match each tooth to its diet: (a) curved blade with serrations; (b) straight cone without strong serrations; (c) dental battery.
2. **EASY** What is a coprolite, and what can it tell us?
3. **MEDIUM** Diplodocus replaced each tooth about every 35 days. About how many times would one tooth position be replaced in a year?
4. **MEDIUM** Nigersaurus had about 500 teeth and replaced each one about every 14 days. About how many new teeth did it grow in a year?
5. **CHALLENGE** A scientist finds a jaw with only peg teeth at the front and none at the back. Under a microscope the teeth have many fine scratches but few pits. What would you suggest the animal ate and how?

Make it a game · Whose Tooth?. One player draws a tooth shape on a card without showing anyone (a blade with serrations, a cone, a peg, a leaf shape or a battery of columns). The others ask yes-or-no questions ("Does it have serrations?" "Is it at the front only?") and then guess the diet and, for a bonus, a dinosaur. The correct guesser draws next.

Scripture. "And to every beast of the earth, and to every fowl of the air, and to every thing that creepeth upon the earth, wherein there is life, I have given every green herb for meat: and it was so." (Genesis 1:30, KJV)

In the King James Version, "meat" means food. God provided food for every creature He made, and He still does (Psalm 145:15).

Practice: answers

1. (a) meat, slicing flesh (theropods); (b) fish, gripping slippery prey (Spinosaurus); (c) tough plants, grinding or slicing (hadrosaurs and horned dinosaurs).
2. Fossilized dung. Its contents (bone bits, plant pieces, fish scales) show what the animal actually ate.
3. $365 \div 35 \approx 10.4$, so about 10 times a year.
4. Each position: $365 \div 14 \approx 26$ times a year. $500 \times 26 \approx 13,000$ new teeth a year.
5. It was probably a plant-eater that stripped or cropped leaves with its front teeth and swallowed without chewing. Many fine scratches suggest it ate soft or gritty plants rather than hard seeds or bone, which tend to leave pits. A good answer says this is a careful guess from several clues, not a certainty.

3.2 EGGS AND NESTS

OBJECTIVES

- Describe dinosaur eggs: their shapes, sizes, shells and colors, with numbers.
- Explain three kinds of nesting evidence: nest colonies, buried clutches and brooding adults.
- Draw a scaled map of a Maiasaura nesting colony.

Warm-up. Hold a chicken egg in your palm, wrap your fingers around it and squeeze evenly (over a bowl, just in case). Most people cannot break it this way. An eggshell is a thin dome, and domes are strong. Now think: how thick would a shell need to be to hold up a dinosaur sitting on it?

Video slot. Video coming. Dinosaur eggs and nests: Maiasaura at Egg Mountain, Montana; titanosaur eggs at Auca Mahuevo, Argentina; brooding oviraptorosaurs. Search approved channels (Museum of the Rockies, American Museum of Natural History, Royal Tyrrell Museum, Natural History Museum of Los Angeles County); preview first.

KEY TERMS

clutch

A set of eggs laid together in one nest.

embryo

A baby animal still developing inside its egg.

pore

A tiny hole in an eggshell that lets air in and moisture out so the embryo can breathe.

colony

A place where many animals of one kind nest close together.

brooding

Sitting on eggs to warm and protect them, as a hen does.

CORE IDEAS

Hard-shelled eggs. All dinosaurs, as far as anyone knows, laid eggs. Fossil eggs have now been found on every continent, in many thousands. Their shells are made of calcite, the same mineral as a chicken egg, and under a microscope the shell crystals and **pores** have patterns that help scientists sort eggs into groups. Some are round like a grapefruit; others are long and narrow, like a stretched hen's egg. The longest known dinosaur eggs reach about 45 to 60 centimeters (18 to 24 inches), but most were much smaller.

Why not bigger? Even the giant sauropods, some over 30 meters long, laid eggs only about 13 to 15 centimeters across, smaller than an ostrich egg. There is a good reason. As an egg

grows larger, its shell must grow thicker to keep from breaking. But a thick shell lets less air through its pores, and a baby must still be able to break out. God designed the egg with a limit, and the biggest dinosaurs kept their eggs small and laid many of them.

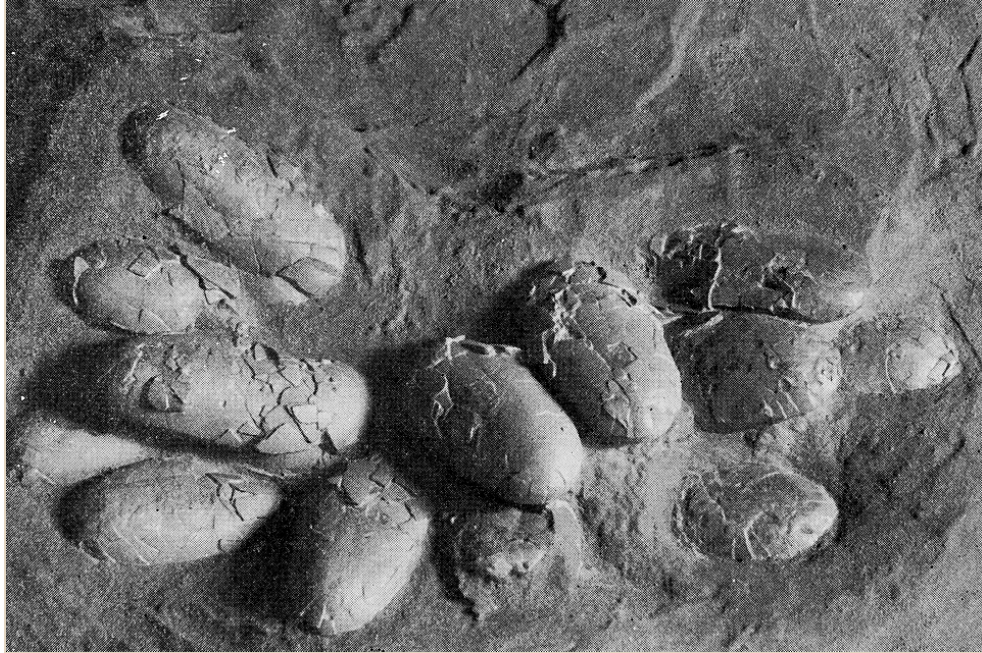
A field of eggs. In 1997 a team led by Luis Chiappe and Rodolfo Coria found a hillside in Patagonia, Argentina, covered with titanosaur eggs. They named the site Auca Mahuevo, a play on the Spanish word for egg. Some eggs held tiny **embryos** with patches of fossil skin showing small, bumpy scales, the first sauropod embryos ever found. The eggs lay in **clutches** of about 15 to 40. Like crocodiles and turtles today, sauropods seem to have laid their eggs in holes or mounds and let the warm soil do the work.

A good mother lizard. In 1978 Jack Horner and Bob Makela were shown a few tiny bones in a rock shop in Montana. That led them to a hill they called Egg Mountain, where they found bowl-shaped nests, each about 2 meters across, spaced about 7 meters apart, roughly the length of an adult. It was a **colony**, like a modern seabird colony. In one nest lay the bones of babies too big to be newly hatched, with worn teeth. Horner thought the parents brought food to the nest, so in 1979 he named the dinosaur *Maiasaura*, "good mother lizard." Not every scientist agrees the babies were fed in the nest, but the colony showed that these dinosaurs nested together and returned to the same place.

Sitting on the nest. In the Gobi Desert of Mongolia, several skeletons of oviraptorosaurs, feathered relatives of *Oviraptor*, have been found crouched on top of rings of eggs with their arms spread over them, just as a bird **broods**. The eggs were arranged in a circle, pointed ends inward, leaving room for the parent's body. In 2018 scientists tested the shells of some oviraptorosaur eggs and found traces of pigment: the eggs were probably blue-green, like a robin's. Other studies of growth lines in embryo teeth suggest that some dinosaur eggs took about three to six months to hatch, longer than most bird eggs.

Reading the nests. Eggs and nests are fragile. To be preserved they must be buried quickly, often by mud or sand. Many creation geologists point out that nests on several stacked levels, some with eggs still unhatched, fit with sudden burials during a time of upheaval such as the Flood year; other geologists read the same sites as seasons of floods over many years. The careful observation is the same: whole nests, with eggs in place, covered fast.

PICTURE STUDY



Eggs of the dinosaur Protoceratops as found in the Gobi Desert, American Museum of Natural History photograph, reproduced in Charles Schuchert, Outlines of Historical Geology, Eggs found 1923; book printed 1937 · Photograph, printed in a book · Wellcome Collection, London
Wikimedia Commons · CC BY 4.0

In 1923 Roy Chapman Andrews' expedition found the first dinosaur eggs to become famous around the world, at the Flaming Cliffs in Mongolia. Photographs of them soon appeared in schoolbooks; the caption of this one says each egg is about 5 inches long. (Trail B, Stop B8 tells the story of the expedition.) The scientists first thought the eggs belonged to Protoceratops; much later, eggs like these were found to belong to Oviraptor. Here, study the eggs themselves as evidence.

Look closely

- Count the eggs you can see. Are they round or long?
- Look at how they lie. Are they scattered, or arranged in a pattern?
- The caption says each egg is about 5 inches long. Hold your hands that far apart. Is that bigger or smaller than a chicken's egg?

Talk about it

1. Scientists once said whose eggs these were, and later changed their minds. What kind of evidence could show who laid an egg?
2. What would have to happen for a nest of eggs to stay whole and become a fossil?

Safety first. Raw eggs can carry germs: wash your hands and the work surface after handling them, and ask a grown-up to help with the scissors.

HANDS-ON: EGGSHELL DOMES AND A COLONY MAP

First, test the strength of eggshell domes. Then draw a scaled map of a Maiasaura nesting colony.

You will need

- Four raw eggs, small scissors and a strip of masking tape
- A stack of hardback books of the same size
- Graph paper, a ruler, a pencil and colored pencils

Steps

1. Wrap a strip of tape around the middle of each egg. Gently tap a small hole in the narrow end, pour out the inside into a bowl (save it for cooking), and carefully cut around each egg along the tape to make four half-shells with even edges. Rinse them.
2. Set the four half-shells, domed side up, in a rectangle the size of one book. Gently lay one book on top, then another, and another. Count how many books the domes hold before one cracks. Record the number.
3. **Colony map.** On graph paper, let 1 square = 1 meter. Draw an area 30 squares by 20 squares and title it "Maiasaura nesting colony, Egg Mountain, Montana."
4. Draw 8 to 10 nests as circles 2 squares across, each about 7 squares from its nearest neighbor. Inside some nests draw small ovals for eggs; in one draw small baby skeletons.
5. Add a scale bar (0, 5, 10 meters), a north arrow, and a key: nest, eggs, hatchling bones, adult (draw one adult about 7 meters long beside a nest).

Check your work

- I recorded how many books my eggshell domes held.
- My map uses a scale of 1 square = 1 meter and has nests about 7 meters apart.
- My map has a title, scale bar, north arrow and key.

FIELD NOTEBOOK

1. **Diagram.** Draw a cross-section of a dinosaur egg. Label the shell, a pore, the air space, the yolk and the embryo. Beside it draw a top view of an oviraptorosaur nest: a ring of long eggs with the pointed ends inward and an outline of the parent's spread arms over them.
2. **Notebook entry.** Write a paragraph: "What do eggs and nests tell us about how dinosaurs lived?" Use at least two numbers and name two sites (Egg Mountain, Auca Mahuevo or the Gobi).

Did you know? Many of the eggs once thought to belong to *Protoceratops* in the Gobi turned out to be oviraptorosaur eggs. In 1993 an expedition found one with a tiny

oviraptorosaur embryo curled inside. That single embryo changed how scientists read the whole Gobi nesting story.

Map or diagram. On a world map, mark three famous egg sites: Egg Mountain (Choteau, Montana, USA), the Flaming Cliffs (Gobi Desert, Mongolia) and Auca Mahuevo (Neuquén Province, Argentina). Draw a small egg symbol at each and add a key.

Goes deeper in. Life Science, units on birds, reptiles and life cycles (coming soon); Gardening & Animals, for chickens and egg-laying. On this track, Trail B, Stop B8 (the Gobi eggs) and Trail C, Stop C8 (Babies and growth).

For families. Auca Mahuevo: Chiappe et al., *Nature* (1998). Egg Mountain and Maiasaura: Horner and Makela, *Nature* (1979). Brooding oviraptorosaur (Citipati): Norell et al., *Nature* (1995). Blue-green eggs: Wiemann, Yang and Norell, *Nature* (2018). Incubation times from embryo teeth: Erickson et al., *PNAS* (2017). Whether Maiasaura parents fed babies in the nest is debated. The paragraph on burial gives the young-earth Flood reading beside the conventional one without naming dates.

PRACTICE

1. **EASY** What does *Maiasaura* mean, and why did Jack Horner choose the name?
2. **EASY** What are the pores in an eggshell for?
3. **MEDIUM** Why did even giant sauropods lay fairly small eggs?
4. **MEDIUM** Maiasaura nests were about 7 meters apart. In a row 63 meters long, with a nest at each end, how many nests would fit?
5. **CHALLENGE** Give one piece of evidence that some dinosaurs brooded their eggs like birds and one that others buried them like crocodiles.

Make it a game • Guard the Nest. Put six soft balls (the eggs) in a ring on the floor. One player is the parent and crouches over the nest with arms spread. The others try to tiptoe in and touch an egg without being tagged. The parent may not leave the nest. After three tags, switch parents.

Scripture. “Which leaveth her eggs in the earth, and warmeth them in dust, And forgetteth that the foot may crush them, or that the wild beast may break them.” (Job 39:14-15, KJV)

God asked Job about the ostrich, which leaves its eggs warming in the ground. Some dinosaurs did the same; others sat on their nests. God gave each kind its own way, and His care reaches every nest.

Practice: answers

1. “Good mother lizard.” Babies with worn teeth were found in a nest, so he thought the parents cared for and fed them.

2. They let air in and moisture out so the embryo can breathe.
3. A bigger egg needs a thicker shell, and a very thick shell lets too little air through and is too hard for the baby to break. So there is a limit to egg size.
4. $63 \div 7 = 9$ spaces, so 10 nests.
5. Brooding: oviraptorosaur skeletons found sitting on rings of eggs with arms spread over them. Burying: sauropod eggs at Auca Mahuevo and elsewhere laid in clutches in pits or mounds with no adult, warmed by soil.

3.3 FOOTPRINTS AND TRACKWAYS

OBJECTIVES

- Explain what a trace fossil is and what a trackway can tell that bones cannot.
- Tell the story of the Connecticut Valley tracks, from Pliny Moody (1802) to Edward Hitchcock (1858).
- Measure and label a trackway diagram: footprint length, pace, stride and trackway width.

Warm-up. Walk across a sandy patch, a muddy spot or a sheet of paper with damp feet. Look back at your prints. Can you tell where you walked slowly and where you hurried? Did you walk in a straight line? Your footprints are telling a story without a single bone.

Video slot. Video coming. Dinosaur footprints and trackways: Dinosaur State Park (Connecticut), the Hitchcock track collection at Amherst College, the Paluxy River tracks at Dinosaur Valley State Park (Texas). Search approved channels (Amherst College Beneski Museum, Texas Parks and Wildlife, National Park Service, American Museum of Natural History); preview first.

KEY TERMS

trace fossil

A fossil of something an animal did, such as a footprint, burrow, nest or bite mark, rather than of its body.

trackway

A line of footprints made by one animal walking or running.

ichnology

The study of trace fossils (from the Greek *ichnos*, “track”).

pace

The distance from one footprint to the next print of the opposite foot.

stride

The distance from one footprint to the next print of the same foot (two paces).

CORE IDEAS

Noah’s raven. In 1802 a farm boy named Pliny Moody was plowing his family’s field in South Hadley, Massachusetts, when he turned up a slab of red sandstone with a line of three-toed prints across it. They looked like the tracks of a giant bird. Some neighbors joked that they were the tracks of “Noah’s raven.” The slab was set up as a doorstep. No one yet knew the word “dinosaur”; it would not be coined for another forty years.

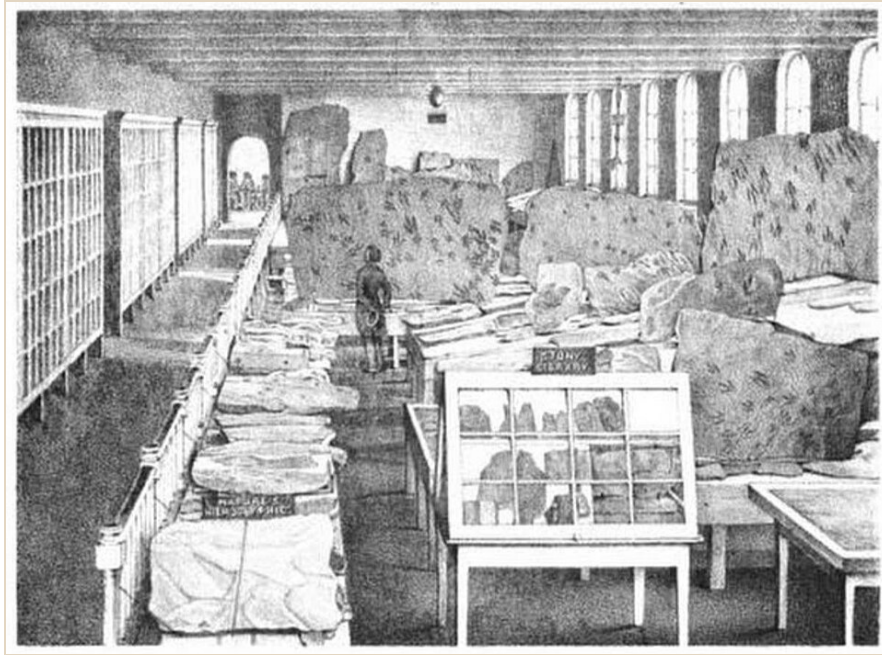
The minister-geologist. In 1835 Edward Hitchcock, a Congregational minister and professor of geology who later became president of Amherst College, began to study the tracks seriously. He spent the rest of his life collecting them, thousands of prints from quarries all along the Connecticut River valley. In 1858 he published *Ichnology of New England*, with page after page of careful drawings. Hitchcock thought most of the three-toed tracks were made by huge birds. Today most paleontologists say they were made by two-legged dinosaurs such as theropods, whose feet were very like birds' feet. His collection is still on display at Amherst College.

What tracks can tell. Bones show what an animal was built like. Tracks show what it did. A **trackway** can show (1) what kind of foot made it, three-toed, four-toed or a round sauropod pad; (2) how big the animal was, because hip height is roughly four times the length of the footprint in many two-legged dinosaurs; (3) how fast it was moving, from the length of the **stride**; (4) whether it walked alone or in a group; and (5) how it stood. Dinosaur trackways are narrow, with the feet placed nearly under the body, not sprawled out like a lizard's. Tail-drag marks are rare, so dinosaurs usually carried their tails off the ground.

Famous trackways. In 1966 a bulldozer clearing ground for a state building in Rocky Hill, Connecticut, uncovered about 2,000 footprints. The site became Dinosaur State Park, and most of the tracks were reburied to protect them, with about 500 left under a dome for visitors. In 1938 Roland T. Bird of the American Museum of Natural History dug up a long sauropod trackway from the bed of the Paluxy River near Glen Rose, Texas, with the prints of a three-toed meat-eater following along the same path. Part of that trackway was set up beneath a sauropod skeleton in New York.

How do footprints last? A footprint in wet mud usually dries, crumbles or is washed away within days. To become a fossil, it must be covered by a new layer of sediment soon after it is made, gently enough not to erase it. Creation geologists point out that many trackways are found on layer after layer, which fits animals walking on freshly laid sediment while the waters were rising and falling during the Flood year. Other geologists read them as tidal flats and lake shores over long ages. Either way, each print records one real moment: one animal, one step, in soft ground.

PICTURE STUDY



Fossil footmarks, a plate from Ichnology of New England, Edward Hitchcock, 1858 · Lithograph plate in a printed book · Ichnology of New England (Boston, 1858); copies in the Biodiversity Heritage Library
Wikimedia Commons · Public domain

Edward Hitchcock filled his 1858 book with exact drawings of the tracks he collected. He thought they were made by giant birds, and he named many kinds of tracks. Look at this plate the way he did: as a careful record, drawn so that others could check his work.

Look closely

- Count the toes on each print. Are there claw marks at the tips?
- Find two prints in a row. Can you tell which is the left foot and which is the right?
- Look for numbers, scale lines or labels on the plate. Why would they matter?

Talk about it

1. Hitchcock thought birds made these tracks. Was that a reasonable guess from what he could see? Why?
2. What could a scientist learn from this drawing, even without seeing the real stone?

HANDS-ON: MAKE AND MEASURE A TRACKWAY

Make your own trackway, measure it the way an ichnologist does, and draw a labeled trackway diagram.

You will need

- A long strip of butcher paper or several sheets taped together (at least 4 meters), or a patch of damp sand

- A shallow tray of water (or washable paint and a grown-up's permission)
- A tape measure, a pencil and your Field Notebook

Steps

1. Measure your hip height (floor to the top of your hip bone) and your footprint length. Write both down.
2. Wet your bare feet and walk normally along the paper or sand. Then make a second trackway beside it, this time running (on sand or grass only; paper is slippery).
3. For each trackway, measure: footprint length; **pace** (left print to the next right print); **stride** (left print to the next left print); and trackway width (the distance across from the outer edge of the left prints to the outer edge of the right).
4. Check the rule of thumb: is your hip height about four times your footprint length? (People often come out a little different from dinosaurs; write what you find.)
5. Draw a trackway diagram in your Field Notebook: six three-toed footprints in a narrow zigzag. Draw a dashed midline. Label one footprint length, one pace, one stride and the trackway width with arrows. Add a scale bar and the title "Theropod trackway (diagram)."

Check your work

- I made a walking and a running trackway.
- I measured footprint length, pace, stride and trackway width.
- My diagram has six prints, a midline, four labeled measurements and a scale bar.

FIELD NOTEBOOK

1. **Diagram.** Complete the trackway diagram from the project if you have not already.
2. **Notebook entry.** Write a paragraph: "Five things a trackway can tell us that a skeleton cannot." Use the Connecticut Valley or the Paluxy River as your example.

Did you know? Trace fossils get their own names, separate from the animals that made them, because it is usually impossible to know exactly which species left a print. The most common large three-toed track in Connecticut is called *Eubrontes*, a name Hitchcock gave it. The state of Connecticut made *Eubrontes* its state fossil in 1991.

Map or diagram. On a map of New England, trace the Connecticut River from Vermont and New Hampshire south to Long Island Sound. Mark South Hadley and Amherst in Massachusetts and Rocky Hill in Connecticut, and draw a small three-toed track beside each.

Goes deeper in. Earth Science, the units on sedimentary rock and how fossils form (coming soon); Arithmetic, measuring and scale drawings. On this track, Trail C, Stop C5 (How fast could they run?) uses trackway measurements to find speed.

For families. Pliny Moody's find is traditionally dated 1802; Hitchcock's first paper on the tracks was 1836, and *Ichnology of New England* appeared in 1858. Dinosaur State Park's figures (about 2,000 tracks found in 1966, about 500 under the exhibit dome) are from the park. R. T. Bird excavated the Paluxy trackway in 1938–1940; a section is displayed at the American Museum of Natural History. Some older creationist books claimed human footprints beside the Paluxy dinosaur tracks; leading creationist organizations withdrew that claim in the 1980s, and this course does not use it. The "hip height $\approx 4 \times$ foot length" rule is a rough guide; scientists use different ratios for different dinosaurs.

PRACTICE

1. **EASY** What is the difference between a body fossil and a trace fossil? Give one example of each.
2. **EASY** What is the difference between a pace and a stride?
3. **MEDIUM** A three-toed footprint is 40 cm long. Using the rule of thumb, about how tall was the dinosaur at the hip?
4. **MEDIUM** Why are tail-drag marks rare in dinosaur trackways, and what does that tell us?
5. **CHALLENGE** Edward Hitchcock thought the three-toed tracks were made by giant birds. Name one observation that supports his idea and one later discovery that changed most scientists' minds.

Make it a game • Track Detectives. One player leaves the room. The others make a short trail of chalk marks or paper cut-out footprints on the floor that tells a story (walking, then running, then stopping, then two animals meeting). The detective returns and reads the story from the tracks alone.

Scripture. "Thy way is in the sea, and thy path in the great waters, and thy footsteps are not known." (Psalm 77:19, KJV)

We can follow a dinosaur's footprints in stone, but God's ways are deeper than we can trace. The psalmist remembered how God led His people through the sea, even when no one could see the path.

Practice: answers

1. A body fossil is part of the animal (bone, tooth, shell); a trace fossil is a sign of what it did (footprint, nest, burrow, bite mark).
2. A pace is from one foot's print to the next print of the other foot; a stride is from one foot's print to the next print of the same foot, two paces.
3. $4 \times 40 \text{ cm} = 160 \text{ cm}$, or about 1.6 meters.
4. Because dinosaurs usually held their tails up off the ground, balancing the body over the hips. Older pictures that show dragging tails are not supported by the tracks.
5. Support: the prints have three slender toes with claw marks, very like bird tracks. Later: skeletons of two-legged dinosaurs (theropods) were found with feet that match the prints, and

no birds of that size were found in those rocks.

3.4 HERDS

OBJECTIVES

- Name two kinds of evidence that some dinosaurs lived in groups: bonebeds and parallel trackways.
- Describe three famous sites: Bernissart (Belgium), the Davenport Ranch trackway (Texas) and the *Albertosaurus* bonebed (Alberta).
- Draw a grid quarry map of a bonebed and weigh more than one explanation for it.

Warm-up. Look out a window or think of a park. Which animals do you usually see in groups (geese, deer, cows, sparrows) and which alone (a hawk, a cat)? Why might an animal be safer, or find food more easily, in a group?

Video slot. Video coming. Dinosaur herds and bonebeds: the Bernissart *Iguanodons* in Brussels, *Centrosaurus* and *Albertosaurus* bonebeds in Alberta, sauropod trackways in Texas. Search approved channels (Royal Belgian Institute of Natural Sciences, Royal Tyrrell Museum, American Museum of Natural History, Texas Parks and Wildlife); preview first.

KEY TERMS

herd

A group of animals of the same kind that live, feed and travel together.

bonebed

A layer of rock packed with the bones of many animals, often of one kind.

quarry map

A careful drawing, made on a grid, that shows exactly where each bone lay as it was dug up.

taphonomy

The study of what happens to an animal's body between death and becoming a fossil (from Greek words meaning "burial law").

parallel trackways

Several trackways side by side, heading the same way, as if a group walked together.

CORE IDEAS

A coal mine full of dinosaurs. In 1878 coal miners at Bernissart, Belgium, broke into a pocket of clay about 322 meters underground and found bones. It was the start of one of the greatest dinosaur finds in history: the remains of more than thirty *Iguanodon*, many of them nearly complete. Workers drew careful **quarry maps** of each skeleton, cut the bones out in plaster-covered blocks and carried them to Brussels. There Louis Dollo and his helpers spent years mounting them, standing upright in a row inside a chapel. Several of them still stand

together in a great glass case in the museum today. So many animals of one kind in one place made people ask: did *Iguanodon* live in herds?

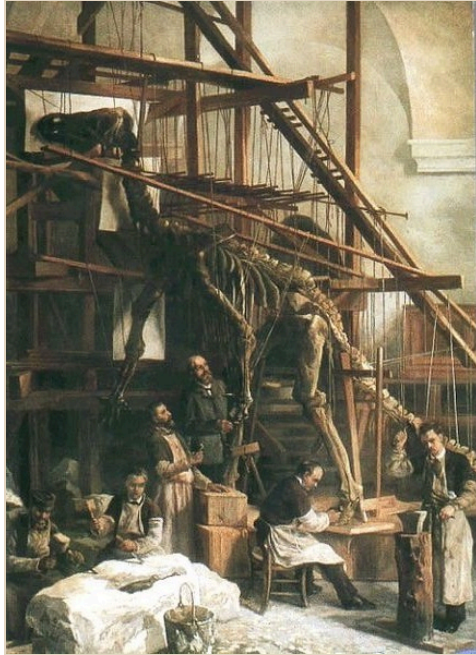
Bonebeds. Since then many **bonebeds** have been found. In Alberta, Canada, some *Centrosaurus* bonebeds hold the bones of hundreds or even thousands of animals, from young to old. In Montana, a bonebed of *Maiasaura* has been estimated to hold thousands of individuals. At Ghost Ranch, New Mexico, a quarry opened in 1947 yielded hundreds of skeletons of the small, slender *Coelophysis*. When one kind of animal of many ages is found together in one layer, many scientists read it as a herd caught by a disaster.

Hunters in groups? In 1910 Barnum Brown dug a bonebed at Dry Island in Alberta with the bones of several *Albertosaurus*, a smaller cousin of T. rex. Philip Currie re-found the quarry in 1997, and further work raised the count to at least 26 individuals, from young to adult. Some scientists think tyrannosaurs may have lived or hunted in groups. Others answer that predators can gather at a carcass or a waterhole without being a pack, the way Komodo dragons crowd around one meal. This is a good example of an open question.

Walking together. Trackways give a different kind of evidence, because they record living animals, not dead ones. At the Davenport Ranch in Texas, Roland T. Bird mapped about two dozen sauropod trackways running side by side in the same direction. Bird and later Robert Bakker suggested the small ones walked in the middle, protected by adults; later studies doubted that, but agreed the animals were traveling together. Parallel trackways of duck-billed and horned dinosaurs, and even of small theropods, have been found in other places.

Careful reasoning. A bonebed alone does not prove a herd. Floodwaters can wash many bodies together from different places, and bones can pile up in a river bend. Scientists study **taphonomy**: are the bones broken or whole? Sorted by size, as moving water sorts pebbles? All facing one way, as a current would leave them? Many creation geologists read great bonebeds as animals swept up and buried in the Flood, which fits mass burial, sorting and the huge numbers. Others read them as droughts or river floods. The wise student keeps the observations clear and holds the explanation more loosely.

PICTURE STUDY



Louis De Pauw supervising the mounting of the first Iguanodon of Bernissart, Léon Becker, 1884 (showing work done in 1882) · Painting · Royal Belgian Institute of Natural Sciences, Brussels
Wikimedia Commons · Public domain

After the Bernissart find, the museum in Brussels needed a room tall enough to put the skeletons together. It used the old Chapel of Saint George. The artist Léon Becker painted the work in progress. Louis De Pauw, the museum's chief preparator, and his team hung the bones from ropes to set them in place, standing upright like kangaroos, as Louis Dollo and the scientists of the day thought best.

Look closely

- Find the ropes and the wooden frame. What are they doing?
- Look at the workers. How tall is the skeleton compared with them?
- Look at the tail. Does it rest on the ground or is it held up?

Talk about it

1. Today scientists think Iguanodon often walked on all fours with its tail held out straight. Why might the 1880s team have stood it upright?
2. What would you want to know about how the Bernissart skeletons lay in the ground before deciding they were a herd?

HANDS-ON: MAP A BONEBED

Paleontologists map every bone before they move it. Make your own bonebed and a quarry map, then decide what story it tells.

You will need

- A bedsheet or a patch of floor about 2 meters by 2 meters
- String or tape to make a grid of 50 cm squares (4 by 4)
- About 20 “bones”: craft sticks, pasta, twigs or paper cut-outs in large and small sizes
- Graph paper, a ruler, a pencil and a helper

Steps

1. Lay out the grid. Label the columns A-D and the rows 1-4, so each square has a name such as B3.
2. Ask your helper to scatter the bones in one of two ways, without telling you which: (1) “herd caught together”: big and small bones mixed in clumps, pointing every which way; or (2) “washed by a current”: bones sorted with small ones together at one end and long bones mostly lined up in the same direction.
3. On graph paper, draw the same grid (1 square = 50 cm). Draw each bone in its square, at its true angle. Number each bone.
4. Add a title (“Quarry map, [your name]’s bonebed”), a north arrow, a scale bar and a key (long bone, short bone, skull).
5. Study your map. Are the bones sorted by size? Do the long bones line up? Write which story you think it tells, and why. Then ask your helper which way they set it up.

Check your work

- My quarry map has a labeled grid, every bone numbered, a north arrow, a scale bar and a key.
- I looked for sorting by size and lining up of long bones.
- I wrote my explanation and the evidence for it before checking the answer.

FIELD NOTEBOOK

1. **Diagram.** Draw the Davenport Ranch idea: five or six sauropod trackways as rows of round prints, side by side, all heading the same way, with an arrow showing direction. Label “large prints” and “small prints,” and add a scale bar.
2. **Notebook entry.** Write a paragraph: “Did dinosaurs live in herds?” Give one piece of evidence from bones, one from trackways, and one reason to be careful before deciding.

Did you know? The Bernissart *Iguanodon* skeletons were the first nearly complete dinosaur skeletons ever found. Before 1878, the famous Crystal Palace *Iguanodon* of 1854 had been built from scraps and showed the thumb spike as a horn on the nose. Bernissart showed where the spike really belonged.

Goes deeper in. Earth Science, units on fossils, sediments and the Flood (coming soon); Life Science, animal behavior; Geography, maps and grids. On this track, Trail D, Stop D5 (Fossil graveyards and the Flood).

For families. Bernissart: the find was made in 1878 at a depth of 322 m; counts of individuals vary by source (commonly “at least 38” individuals including partial ones, about 29 or more fairly complete); the stop says “more than thirty.” Dry Island *Albertosaurus* bonebed: Currie et al. (2005) and later work (at least 26 individuals reported by 2014). Davenport Ranch: Bird (1944); Bakker (1968) proposed the young-in-the-middle idea; Lockley and others doubted it. Group hunting in tyrannosaurs and dromaeosaurs remains debated. The Flood reading of bonebeds is presented as the course’s young-earth position, beside the conventional view.

PRACTICE

1. **EASY** Name two kinds of evidence that some dinosaurs lived in groups.
2. **EASY** Where and when were the Iguanodons of Bernissart found, and by whom?
3. **MEDIUM** Why are trackways sometimes better evidence of herds than bonebeds?
4. **MEDIUM** In a bonebed, the small bones are all at one end and most long bones point the same way. What might this suggest?
5. **CHALLENGE** At Dry Island, at least 26 *Albertosaurus* of different ages were found together. Give one reason to think they lived as a group and one reason to be cautious.

Make it a game · Herd or Alone?. Players stand in a group as a herd of plant-eaters. One player is a predator who may tag only a player standing more than an arm’s length from everyone else. The herd must move from one side of the yard to the other. Then play again with everyone spread out. Talk about which way kept more of the herd safe.

Scripture. “And if one prevail against him, two shall withstand him; and a threefold cord is not quickly broken.” (Ecclesiastes 4:12, KJV)

Solomon saw that together is stronger than alone. God made many creatures to live in groups, and He made people for family, friendship and the church.

Practice: answers

1. Bonebeds (many animals of one kind buried together) and parallel trackways (several animals walking side by side in the same direction).
2. In a coal mine at Bernissart, Belgium, in 1878, by coal miners.
3. Trackways were made by living animals moving together; bonebeds show only where bodies ended up, and water could have carried them together after death.
4. That moving water sorted and lined up the bones, so the animals may not have died together as a herd in that spot.
5. Group: many of one kind and of many ages in one layer, which is unusual for predators. Caution: predators may gather at a food source or waterhole without living together, and water could have brought bodies together.

3.5 HOW FAST COULD THEY RUN?

OBJECTIVES

- Use footprint length and stride length to tell whether a dinosaur was walking, trotting or running.
- Explain two other ways scientists estimate speed: leg proportions and computer models of muscles and bones.
- Give honest, evidence-based speed estimates for T. rex and for fast theropods, and say why the numbers differ.

Warm-up. Walk 20 steps across a yard and count. Now run the same distance and count again. Did you take fewer steps when you ran? Your stride grew longer as you went faster. Dinosaurs left the same clue in their trackways.

Video slot. Video coming. How fast could dinosaurs run: speed from trackways, R. McNeill Alexander's formula, T. rex running models, ostrich and emu running. Search approved channels (Royal Veterinary College, Natural History Museum London, American Museum of Natural History, Smithsonian); preview first.

KEY TERMS

hip height

The height from the ground to the hip joint. In many two-legged dinosaurs it was about four times the footprint length.

relative stride

Stride length divided by hip height. It shows whether an animal was walking, trotting or running, whatever its size.

biomechanics

The study of how bodies move, using the rules of physics for levers, forces and muscles.

tibia

The shin bone. A long shin compared with the thigh is a sign of a fast runner.

estimate

A careful best guess worked out from evidence and a model.

CORE IDEAS

A zoologist's formula. In 1976 the British zoologist R. McNeill Alexander noticed something about living animals, from people to ostriches to elephants. If you divide the length of an animal's **stride** by its **hip height**, you get a number, the **relative stride**, that tells you its gait. Below about 2.0 the animal is walking. Between about 2.0 and 2.9 it is trotting. Above about 2.9 it is running. Alexander also wrote a formula that turns stride and

hip height into an actual speed. Because footprints give both numbers (hip height is about four times the footprint length), a fossil trackway becomes a speedometer.

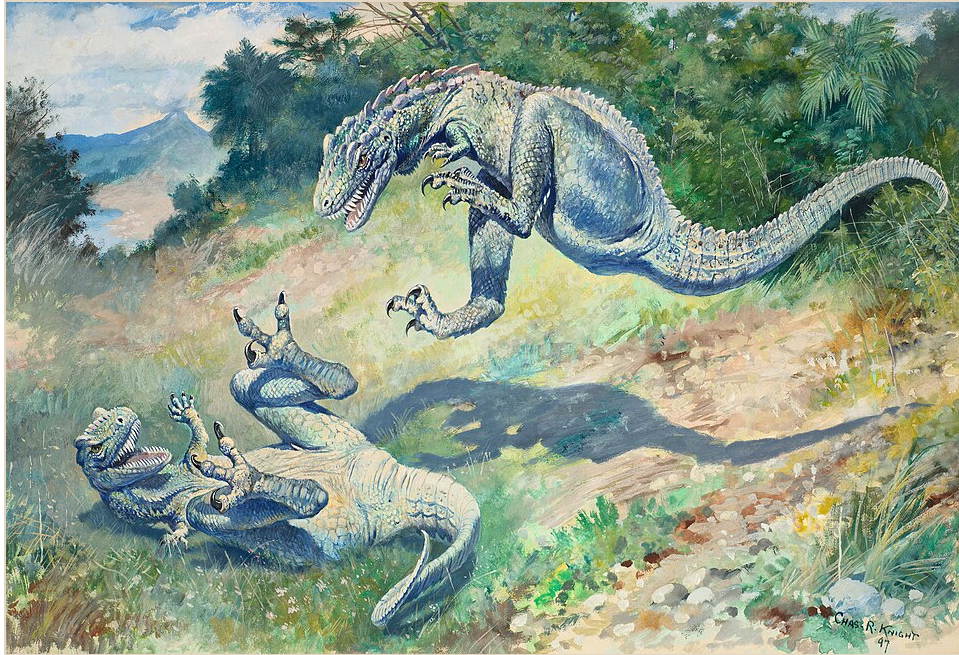
What the tracks say. When scientists measured hundreds of dinosaur trackways, they found that nearly all show walking, usually at about 3 to 8 kilometers an hour (2 to 5 miles an hour), the speed of a person on a walk. That makes sense: animals spend most of their time walking, and running animals often slip or leave blurred prints. A few trackways show real running. In 2021 scientists described two theropod trackways in La Rioja, Spain, made by medium-sized meat-eaters running at about 45 kilometers an hour (28 miles an hour), among the fastest dinosaur speeds ever measured from footprints.

Built for speed. Bones give a second clue. Fast runners today, such as ostriches, horses and deer, have long, slim lower legs and feet compared with their thighs, and they stand on their toes. The ostrich-like ornithomimids, with long **tibias** and slender feet, were probably among the fastest dinosaurs. An ostrich can run about 70 kilometers an hour (43 miles an hour); some scientists think ornithomimids came close, though no trackway has yet proved it. Big, heavy animals with short, thick lower legs, such as sauropods and ankylosaurs, were built for steady walking, not sprinting.

Could T. rex catch a jeep? In a famous 1993 movie, a T. rex chases a jeep at highway speed. Real scientists tested that idea with **biomechanics**. In 2002 John Hutchinson and Mariano Garcia calculated that for a 6-ton T. rex to run 72 kilometers an hour (45 miles an hour), more than 40 percent of its body weight would have to be muscle in each leg, which is impossible. In 2017 a team using a computer model of T. rex's bones and muscles found that if it tried to run fast, the bones of its feet would break. Their best estimate for a full-grown T. rex was a fast walk of about 20 kilometers an hour (12 miles an hour). Young, lighter tyrannosaurs, with longer legs for their size, were probably quicker.

Why the numbers differ. Different methods give different speeds, because each rests on a model with its own assumptions: how heavy the animal was, how strong its muscles were, how its joints moved. Good scientists show their work so others can check it. When you see a speed on a museum sign, ask: was it measured from a trackway, or estimated from a model? A careful estimate is useful, but it is not the same as watching the animal run.

PICTURE STUDY



Leaping Laelaps, Charles R. Knight, 1897 · Painting · American Museum of Natural History, New York
Wikimedia Commons · Public domain

In 1897 most people imagined dinosaurs as slow, dragging giants. Charles R. Knight, working with the scientist Edward Drinker Cope, painted two meat-eaters called *Laelaps* (now named *Dryptosaurus*) leaping and wrestling. It was one of the first paintings to show dinosaurs as quick, athletic animals, an idea most scientists would not fully accept until the 1970s.

Look closely

- Find the dinosaur in the air. Which part of its body is it attacking with?
- Look at the legs. Are they thick and short or long and powerful?
- Look at the tails. What might a tail do for an animal in motion?

Talk about it

1. Do you think a large meat-eater really leaped like this? What evidence would you need to know?
2. Knight painted this almost eighty years before most scientists agreed with him. Is it possible for an artist to be right before the evidence is complete? How?

Safety first. Run only on a flat, clear path away from traffic, wear shoes, and warm up first.

HANDS-ON: BE A TRACKWAY SPEEDOMETER

Measure your own walking, trotting and running strides, find your relative stride, and draw a labeled chart that shows how gait changes with speed.

You will need

- A tape measure, chalk and a helper with a stopwatch (or a phone timer)
- A straight stretch of sidewalk, driveway or grass at least 20 meters long
- Graph paper and your Field Notebook

Steps

1. Measure your hip height (floor to the top of your hip bone) in meters.
2. Mark a start line and a finish line 20 meters apart.
3. Walk the 20 meters at a normal pace while your helper counts your steps and times you. Then trot (jog) it, then run it.
4. For each trial, find your stride: $20 \text{ meters} \div (\text{number of steps} \div 2)$. Then find your relative stride: $\text{stride} \div \text{hip height}$. Find your speed: $20 \div \text{seconds}$, in meters per second; multiply by 3.6 for kilometers per hour.
5. Make a table with columns: gait, steps, stride (m), relative stride, time (s), speed (km/h).
6. **Diagram.** Draw a bar chart with relative stride on the side axis (0 to 4). Draw a dashed line across at 2.0 labeled “walk / trot” and at 2.9 labeled “trot / run.” Add one bar for each of your three trials, and title the chart “My gait chart.” Did your bars land in the right zones?

Check your work

- I measured my hip height and timed three gaits.
- My table has stride, relative stride and speed for each gait.
- My chart has the two dashed lines, three bars, labels and a title.

FIELD NOTEBOOK

1. **Diagram.** Copy your gait chart into your Field Notebook if you made it on scrap paper. Beside it, draw two leg skeletons side by side: an ostrich-like ornithomimid (long tibia and foot) and a stocky ankylosaur (short, thick lower leg). Label the femur, tibia and foot on each, and write “runner” or “walker” under each one.
2. **Notebook entry.** Write a paragraph: “How fast was T. rex?” Explain at least two methods scientists use, give the 2017 estimate, and tell why the movie’s jeep chase is unlikely.

Did you know? Elephants never truly run. Even at their fastest, about 25 kilometers an hour, at least one foot is always on the ground. Many scientists think large dinosaurs moved the same way: a fast, powerful walk rather than a gallop.

Goes deeper in. Arithmetic, units on rates, ratios and measurement (coming soon); Life Science, bones, muscles and movement. On this track, Trail C, Stop C3 (Footprints and trackways) explains how trackways are measured.

For families. Alexander, “Estimates of speeds of dinosaurs,” *Nature* (1976); the walk/trot/run cut-offs of about 2.0 and 2.9 for relative stride follow Thulborn’s later work. La Rioja trackways: Navarro-Lorbés et al., *Scientific Reports* (2021), up to about 45 km/h. T. rex: Hutchinson and Garcia, *Nature* (2002); Sellers et al., *PeerJ* (2017), about 20 km/h. Ornithomimid top speeds are estimates without trackway confirmation. Hip height from footprint length uses ratios of roughly 4 to 6 depending on the dinosaur; the stop uses 4 for simplicity. Knight’s painting is often dated 1896–1897; the course uses 1897, as in the track outline.

PRACTICE

1. **EASY** What does a relative stride below 2.0 tell you? Above 2.9?
2. **EASY** What kind of gait do almost all dinosaur trackways show?
3. **MEDIUM** A theropod footprint is 40 cm long, and the stride is 4 meters. Find the hip height and relative stride. Was it walking, trotting or running?
4. **MEDIUM** A fast theropod trackway gives a speed of 12.4 meters per second. How many kilometers per hour is that? (Multiply by 3.6.)
5. **CHALLENGE** With a calculator, use Alexander’s formula, $\text{speed} = 0.25 \times \sqrt{9.8 \times (\text{stride})^{1.67} \times (\text{hip height})^{-1.17}}$, for a stride of 2.5 m and a hip height of 1.6 m. Give the answer in m/s and km/h, and say which gait it is.

Make it a game • Gait Freeze. A caller shouts “Walk!”, “Trot!” or “Run!” and players move across the yard in that gait. When the caller shouts “Fossilize!”, everyone freezes. The caller checks: does the frozen player have a foot on the ground (walk) or look mid-leap (run)? Take turns calling.

Scripture. “Wherefore seeing we also are compassed about with so great a cloud of witnesses, let us lay aside every weight, and the sin which doth so easily beset us, and let us run with patience the race that is set before us,” (Hebrews 12:1, KJV)

Most dinosaurs did not sprint; they kept walking, steady and strong. The Christian life is called a race run with patience: faithful steps, day after day.

Practice: answers

1. Below 2.0: walking. Above 2.9: running.
2. Walking, usually about 3 to 8 km/h.
3. Hip height = $4 \times 0.4 \text{ m} = 1.6 \text{ m}$. Relative stride = $4 \div 1.6 = 2.5$. It was trotting.
4. $12.4 \times 3.6 \approx 44.6 \text{ km/h}$, about 45 km/h (28 mph).

5. $0.25 \times 3.13 \times 4.62 \times 0.577 \approx 2.1$ m/s, about 7.5 km/h. Relative stride is $2.5 \div 1.6 \approx 1.56$, so it was walking (a brisk walk).

3.6 WERE THEY WARM-BLOODED?

OBJECTIVES

- Explain the difference between an ectotherm, an endotherm and a “mesotherm,” with living examples.
- Describe four kinds of evidence used in the warm-blood debate: bone structure, growth rings, polar fossils and chemistry of the bones.
- Run a cooling experiment and graph how body size affects how fast an animal loses heat.

Warm-up. On a cool morning, a lizard lies still on a rock until the sun warms it. A sparrow is hopping about before sunrise. What is the difference? One gets its warmth from outside; the other makes its own. Which kind was a dinosaur? Scientists have argued about it for more than fifty years.

Video slot. Video coming. Were dinosaurs warm-blooded? Bone histology, growth rings, polar dinosaurs of Alaska, mesotherms. Search approved channels (Royal Tyrrell Museum, Museum of the North (University of Alaska), Smithsonian National Museum of Natural History, Natural History Museum London); preview first.

KEY TERMS

metabolism

All the chemical work a body does to turn food into energy, warmth and growth.

ectotherm

An animal that gets most of its body heat from its surroundings, such as a lizard or crocodile (“cold-blooded”).

endotherm

An animal that makes its own body heat from food and keeps a steady temperature, such as a bird or mammal (“warm-blooded”).

mesotherm

An animal in between, which makes some of its own heat but does not hold a fixed temperature, such as a tuna or a leatherback sea turtle.

bone histology

The study of the tiny structure of bone, seen in thin slices under a microscope.

CORE IDEAS

Slow giants or busy animals? When Richard Owen named the Dinosauria in 1842, he suggested they were more advanced than living reptiles, perhaps with a heart more like a mammal’s. But by the early 1900s most pictures showed dinosaurs as huge, slow, cold-blooded lizards, dragging their tails through swamps. Then came the “Dinosaur

Renaissance.” In 1969 John Ostrom described *Deinonychus*, a quick, sickle-clawed hunter, and in 1975 his former student Robert Bakker argued in *Scientific American* that dinosaurs were warm-blooded, active animals. The debate has gone on ever since.

Clues in the bone. In the 1970s the French scientist Armand de Ricqlès sliced dinosaur bones thin enough to see light through them. Many showed *fibrolamellar* bone, a spongy-looking tissue full of blood-vessel channels. Today this kind of bone grows mainly in fast-growing birds and mammals. **Bone histology** also shows growth rings, like tree rings. Many dinosaurs grew fast, far faster than any living reptile, and fast growth takes a high **metabolism**. Yet the rings also show pauses each year, which are common in reptiles and rarer in birds.

Dinosaurs near the North Pole. Fossils of duck-billed dinosaurs, horned dinosaurs and tyrannosaurs have been found along the Colville River on the North Slope of Alaska, in rocks that formed far to the north. In 2021 scientists reported tiny bones and teeth of baby dinosaurs there, from several kinds, suggesting that dinosaurs nested in the far north instead of only visiting. Even in a milder climate, those northern lands would have had dark winters. Many scientists think animals that lived and nested there must have made a good deal of their own heat.

Chemistry and size. Some studies measure forms of oxygen and carbon in fossil teeth and bones to estimate body temperature; one 2011 study suggested sauropods had body temperatures of about 36 to 38 °C, close to ours. Size matters too. A huge body loses heat slowly, because it has little skin surface for its great volume, so a 30-ton sauropod might have stayed warm even with a slower metabolism. This is sometimes called *gigantothermy*. The cooling experiment in this stop shows why.

The answer so far. In 2014 a team compared growth rates of hundreds of animals and suggested dinosaurs were **mesotherms**, in between. In 2022 another team tested chemical traces of metabolism in fossil bones and found that many dinosaurs, especially the theropods (bird-like meat-eaters) and the sauropods, had high, bird-like metabolisms, while some others, such as *Stegosaurus* and *Triceratops*, may have been lower. The honest answer is that dinosaurs were probably not all the same. God made a world of variety: the tuna and the turtle, the sparrow and the lizard, each fitted for its life.

PICTURE STUDY



Iguanodon and Megalosaurus, from Louis Figuier's The World Before the Deluge, Édouard Riou, 1863 · Wood engraving after Riou's drawing · From Louis Figuier, La Terre avant le déluge (Paris, 1863), published in English as The World Before the Deluge · Wikimedia Commons · Public domain

Édouard Riou, who also drew pictures for Jules Verne's adventure stories, made this engraving for a popular French book about the ancient world. It shows *Iguanodon* and *Megalosaurus* as giant lizards, low and sprawling. This is how many people pictured dinosaurs before skeletons and trackways showed that they stood upright on legs held straight under the body.

Look closely

- Look at the legs. Are they under the body, like a horse's, or out to the sides, like a lizard's?
- Look at the setting: water, rocks, plants, sky. What mood did Riou create?
- Find the horn on Iguanodon's nose. (Later skeletons showed it was a thumb spike.)

Talk about it

1. If dinosaurs looked like this, would you guess they were warm-blooded or cold-blooded? Why?
2. What evidence from Stop C3 (Footprints and trackways) shows that Riou's sprawling legs are probably wrong?

Safety first. Use hot tap water only, never boiling water, and let a grown-up pour it. Keep the containers on a steady table away from younger children.

HANDS-ON: BIG BODY, SMALL BODY: A COOLING EXPERIMENT

Find out whether a big body or a small body loses heat faster, and graph your results.

You will need

- A large jar or pot (about 1 liter) and a small cup (about 100 milliliters), both made of the same material if possible
- Hot tap water (not boiling)
- A kitchen or aquarium thermometer
- A timer, graph paper, a pencil and two colored pencils

Steps

1. Fill both containers with the same hot tap water. Measure and record the starting temperature of each.
2. Every 5 minutes for 40 minutes, measure each temperature and record it in a table with three columns: time (minutes), large jar (°C), small cup (°C).
3. **Diagram.** Draw a line graph. Put time (0 to 40 minutes) along the bottom and temperature up the side. Plot the large jar in one color and the small cup in another. Label each line (“sauropod-size” and “small-dinosaur-size”), and add a title and a key.
4. Which cooled faster? Write one sentence explaining why, using the words surface and volume.
5. Write one sentence telling what this might mean for a huge sauropod and for a small feathered dinosaur.

Check your work

- I recorded at least nine readings for each container.
- My graph has labeled axes, two colored lines, a title and a key.
- I can explain why the large container stayed warm longer.

FIELD NOTEBOOK

1. **Diagram.** Draw two circles side by side to show thin slices of bone under a microscope. In the first, draw many small channels and label it “fibrolamellar bone: fast growth (birds, mammals, many dinosaurs).” In the second, draw few channels and several dark rings, and label it “slow-growing bone with growth rings (many reptiles).”
2. **Notebook entry.** Write a paragraph: “Were dinosaurs warm-blooded?” Give three kinds of evidence and end with the honest answer: what scientists think now, and what is still unknown.

Did you know? The leatherback sea turtle, a reptile, can keep its body several degrees warmer than the cold ocean around it, thanks to its great size, oily insulation and a heat-saving system in its flippers. It swims in waters too cold for most reptiles.

Goes deeper in. Life Science, units on body systems, reptiles, birds and mammals (coming soon); Arithmetic, line graphs; Geography, the Arctic. On this track, Trail C, Stop C7 (Feathers) and Stop C8 (Babies and growth).

For families. Owen's 1842 suggestion of a mammal-like heart is in his *Report on British Fossil Reptiles*, Part II. Ostrom, *Deinonychus* (1969); Bakker, "Dinosaur Renaissance," *Scientific American* (April 1975). Sauropod temperatures: Eagle et al., *Science* (2011). Mesotherms: Grady et al., *Science* (2014). Metabolic signals in bone: Wiemann et al., *Nature* (2022). Alaskan baby dinosaurs: Druckenmiller et al., *Current Biology* (2021). Conventional geology dates these rocks to the Late Cretaceous; the stop avoids dates. This is an active debate, and every result above has been challenged by other scientists.

PRACTICE

1. **EASY** Give one living example each of an ectotherm, an endotherm and a mesotherm.
2. **EASY** What two scientists started the "Dinosaur Renaissance," and what did each do?
3. **MEDIUM** Why does fast-growing fibrolamellar bone suggest a high metabolism?
4. **MEDIUM** A cube 1 cm on each side has a surface of 6 cm² and a volume of 1 cm³. A cube 10 cm on each side has a surface of 600 cm² and a volume of 1,000 cm³. Find surface ÷ volume for each. Which loses heat faster for its size?
5. **CHALLENGE** Baby dinosaur bones found in northern Alaska suggest dinosaurs nested there. Explain why this is evidence about warm-bloodedness, and give one reason to be careful.

Make it a game · Sun or Furnace?. The leader names an animal. Players hold up a hand flat like the sun if it is an ectotherm, make two fists together like a furnace if it is an endotherm, and hold one of each if it is a mesotherm. Include a few dinosaurs and let players argue their answer from the evidence.

Scripture. "O LORD, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches." (Psalm 104:24, KJV)

"Manifold" means many and varied. God did not make every creature run on the same plan; His wisdom shows in their variety.

Practice: answers

1. Ectotherm: a lizard, snake or crocodile. Endotherm: a bird or mammal (a sparrow, a dog, a person). Mesotherm: a tuna or a leatherback sea turtle.
2. John Ostrom described the active hunter *Deinonychus* (1969); Robert Bakker argued that dinosaurs were warm-blooded (1975).
3. Fast growth needs a lot of energy from food, and in living animals this kind of bone is found mainly in warm-blooded birds and mammals.
4. Small cube: $6 \div 1 = 6$. Large cube: $600 \div 1,000 = 0.6$. The small cube has ten times more surface for its size, so it loses heat faster.

5. Animals nesting and raising young through dark, cool northern winters would likely need to make their own heat. Caution: the ancient climate may have been milder than today, and some animals (like the leatherback turtle) manage cold without being fully warm-blooded.

3.7 FEATHERS: WHAT THE FOSSILS SHOW

OBJECTIVES

- Describe what has actually been found: Archaeopteryx (1861), the feathered fossils of Liaoning, China (from 1996), and scaly skin on large dinosaurs.
- Draw and label the parts of a feather and four types of body covering seen in fossils.
- Separate observations from interpretations, including the different ways Christians read feathered fossils.

Warm-up. Hold a feather (from a craft store or a pillow) up to the light. Run your fingers up the vane the wrong way, then smooth it back. It zips back together! Now look at a picture of a dinosaur in an old book and one in a new book. Why do so many new pictures have feathers?

Video slot. Video coming. Feathered dinosaur fossils: Archaeopteryx (London and Berlin specimens), Sinosauropteryx, Microraptor, Yutyrannus, fossil color from melanosomes. Search approved channels (Natural History Museum London, Museum für Naturkunde Berlin, American Museum of Natural History, Field Museum); preview first.

KEY TERMS

vane

The flat, flexible blade of a feather on either side of the central shaft.

rachis

The stiff central shaft of a feather (say “RAY-kis”).

barbs and barbules

The barbs branch off the rachis; tiny hooked barbules on the barbs zip them together into a vane.

filament

A thin, hair-like fiber. Some fossils show coats of simple filaments rather than vaned feathers.

melanosome

A tiny packet of pigment inside a feather or hair. Its shape hints at the color.

CORE IDEAS

A feather in stone. In 1861 quarrymen near Solnhofen in Bavaria, Germany, split a slab of fine limestone and found the print of a single feather. The German scientist Hermann von Meyer named it *Archaeopteryx*, “ancient wing.” Later that same year a nearly complete skeleton with wings and feathers turned up. The British Museum bought it in 1862, and Richard Owen described it in 1863. It had feathered wings like a bird, but also teeth, three

clawed fingers on each wing and a long bony tail. A second famous skeleton, with a beautiful head, was found in the 1870s and is now in Berlin. About a dozen skeletons are known today.

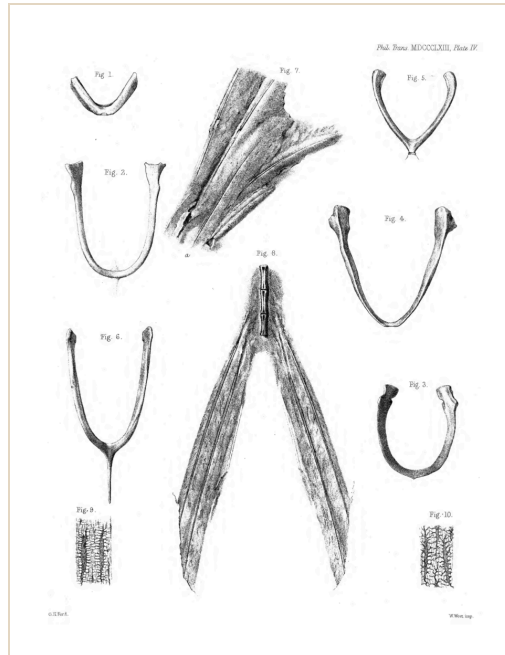
The Liaoning fossils. In 1996 a farmer in Liaoning Province, China, found a small, two-legged animal in fine-grained shale with a fringe of dark, hair-like **filaments** along its back and tail. It was named *Sinosauropteryx*. Since then, Liaoning and nearby places have produced thousands of fossils with feathers or filaments: *Caudipteryx*, with vaned feathers on its arms and tail; *Microraptor*, a crow-sized animal with long flight feathers on both arms and legs, like four wings; and *Yutyrannus* (described in 2012), a tyrannosaur relative about 9 meters long covered in filaments up to about 20 centimeters long.

Colors from the past. In 2010 scientists studied fossil feathers with powerful electron microscopes and found tiny shapes that look like **melanosomes**, the pigment packets that color birds' feathers today. Long, sausage-shaped ones make black and gray; round ones make reddish-brown. From their shapes, scientists suggested that *Sinosauropteryx* had a tail banded in ginger and white, and that a small feathered animal called *Anchiornis* was black and white with a reddish crown. Some scientists ask whether the shapes might be bacteria instead, so testing continues.

Scales too. Not every dinosaur has been found with feathers. Patches of fossil skin from *Tyrannosaurus*, from many duck-billed dinosaurs and from sauropod embryos show scales, often small and bumpy like a Gila monster's. Many large dinosaurs may have been mostly scaly. Some had both: birds today have scales on their legs and feathers elsewhere. Each fossil must be read for itself, not filled in from a guess.

Reading the evidence. Most paleontologists read these fossils as showing that birds descended from small feathered dinosaurs. Young-earth creationists read them differently. Many teach that God created birds on day five and land animals on day six as separate kinds, that *Archaeopteryx* and *Microraptor* were true birds with unusual features, and that some feathered animals may simply be dinosaurs God made with feathers. Some scientists, Christian and not, have argued that the filaments on *Sinosauropteryx* may be fibers of skin rather than feathers. Everyone can agree on the observations, and every claim should be tested. In 1999 a fossil called "Archaeoraptor" was hailed in a popular magazine as a missing link; within a year it was shown to be pieces of two different animals glued together. Careful checking caught the mistake.

PICTURE STUDY



Archaeopteryx, the London specimen, from Richard Owen's description, Lithographic plate for Richard Owen's paper, 1863 · Lithograph · Philosophical Transactions of the Royal Society of London (1863); the fossil is in the Natural History Museum, London
Wikimedia Commons · Public domain

When Richard Owen described the first skeleton of *Archaeopteryx*, photography was still young, so his paper included a careful drawn plate of the slab. The London specimen has no complete head, but the feathers are plain to see.

Look closely

- Find the long feathers of the wing. Do they spread out like a fan?
- Find the tail. Is it a short stump, as in birds today, or a long line of bones with feathers on each side?
- Look for the fingers and claws near the front of each wing.

Talk about it

1. Which features of this animal are bird-like, and which are not like most birds today?
2. Why would a scientist in 1863 want a drawing made so carefully, line by line?

Safety first. In the United States, it is against federal law to keep most feathers of wild native birds, even ones found on the ground. Use craft-store, pillow or farm-bird feathers. Wash your hands after handling feathers.

HANDS-ON: FEATHER LAB AND BODY-COVERING CHART

Study a real feather under a magnifier, then draw a labeled chart of the kinds of body covering found on fossils.

You will need

- Two or three feathers from a craft store, a down pillow, or a farm (chicken, duck or turkey)
- A magnifying glass (a phone camera zoom also works)
- Colored pencils, a ruler and your Field Notebook

Steps

1. Look at a flight or tail feather through the magnifier. Find the rachis, the vane, the barbs and the tiny barbules. Gently separate two barbs, then stroke them back together.
2. Compare a fluffy down feather. Does it have a stiff rachis? Can its barbs zip together?
3. **Diagram 1.** Draw a large feather and label: rachis, vane, barbs, barbules (draw a small zoom-in circle), and the hollow quill at the base.
4. **Diagram 2.** Make a chart with four boxes and draw one covering in each: (1) scales, example: T. rex skin patches; (2) simple filaments, example: Sinosauropteryx; (3) vaned feathers, the same on both sides of the rachis, example: Caudipteryx; (4) flight feathers, narrower on the front side, example: Archaeopteryx or Microraptor.
5. Under each box, write one sentence telling what that covering could do: protect, keep warm, show color, or help with flight.

Check your work

- I found and labeled the rachis, vane, barbs and barbules on a real feather.
- My chart has four boxes, each with a drawing, a fossil example and a use.
- I can explain why a flight feather is narrower on one side.

FIELD NOTEBOOK

1. **Diagram.** Finish both diagrams from the project in your Field Notebook.
2. **Notebook entry.** Write a paragraph with two halves: “What we observe” (at least three facts about feathered fossils) and “How people interpret it” (at least two different readings). End with one sentence about the Archaeoraptor lesson.

Did you know? An asymmetrical vane, narrower on the leading edge, helps a feather work like a little airplane wing. Birds that fly have asymmetrical wing feathers; flightless birds such as the ostrich and emu have symmetrical ones. *Archaeopteryx* and *Microraptor* both have asymmetrical flight feathers.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** “*Archaeopteryx* lived about 150 million years ago in the Late Jurassic and is a link between dinosaurs and birds.” **What we observe:** skeletons in fine Solnhofen limestone with feathered wings, asymmetrical flight feathers, wishbone, teeth, clawed fingers and a long bony tail; in Liaoning, many small animals with filaments or feathers, and some with structures like pigment packets. **How Christians read it:** the date comes from the conventional reading of the rock layers and the methods used to date them, which rest on assumptions about constant rates. Young-earth Christians, the position of this course, read these fine-grained layers as laid down rapidly, many in the Flood year, thousands of years ago, and see *Archaeopteryx* as a created bird with unusual features, not a link. Other Christians accept the long ages, and some accept common descent. Everyone agrees on the observation: these feathered animals are real and beautifully preserved.

Goes deeper in. Life Science, units on birds and classification (coming soon); Gardening & Animals, keeping chickens. On this track, Trail E, Stop E4 (Pterosaurs) shows flying reptiles that had no feathers at all.

For families. Von Meyer named *Archaeopteryx* from the isolated feather in 1861; the London specimen was found in 1861, bought by the British Museum in 1862 and described by Owen in 1863; the Berlin specimen was found in the mid-1870s. *Sinosauropteryx*: Ji and Ji (1996); *Yutyrannus*: Xu et al., *Nature* (2012); melanosomes: Zhang et al. and Li et al. (2010). The collagen-fiber reading of the *Sinosauropteryx* filaments is argued by Lingham-Soliar, Feduccia and others. *Archaeoraptor* appeared in *National Geographic* (November 1999) and was exposed as a composite in 2000. Creationist views on feathered dinosaurs differ (some organizations count all feathered forms as birds); the stop states the common positions without choosing among them beyond the creation of distinct kinds.

PRACTICE

1. **EASY** Name three features of *Archaeopteryx*: two bird-like and one not found in birds today.
2. **EASY** What is a melanosome, and why do scientists look for them in fossils?
3. **MEDIUM** Name a dinosaur known from fossil skin with scales, and one known with filaments or feathers.
4. **MEDIUM** What was “*Archaeoraptor*,” and what does its story teach?
5. **CHALLENGE** Sort into observation (O) or interpretation (I): (a) *Microraptor* has long feathers on its legs; (b) birds descended from dinosaurs; (c) *Archaeopteryx* was a created bird; (d) the London *Archaeopteryx* has a long bony tail.

Make it a game • Feather or Scale?. Make cards with the names of animals, living and fossil (robin, crocodile, *Sinosauropteryx*, T. rex, ostrich, *Microraptor*, *Edmontosaurus*, Gila monster). Players sort them into “feathers,” “scales,” “both” or “we don’t know yet,” and

must name the evidence for each. “We don’t know yet” is a good answer if the fossils have not shown the skin.

Scripture. “He shall cover thee with his feathers, and under his wings shalt thou trust: his truth shall be thy shield and buckler.” (Psalm 91:4, KJV)

A feather is light, warm and strong. Scripture uses a bird sheltering its young under its wings as a picture of God’s care for those who trust Him.

Practice: answers

1. Bird-like: feathered wings, asymmetrical flight feathers, a wishbone. Not like modern birds: teeth, clawed fingers, or a long bony tail (any one).
2. A tiny pigment packet in a feather. Its shape can hint at the animal’s color.
3. Scales: T. rex, a duck-billed dinosaur, or sauropod embryos. Filaments or feathers: Sinosauropteryx, Caudipteryx, Microraptor or Yutyrannus.
4. A fossil announced in 1999 as a missing link that turned out to be parts of two different animals glued together. It teaches that every claim should be tested and checked before it is believed.
5. (a) O; (b) I; (c) I; (d) O.

3.8 BABIES AND GROWTH

OBJECTIVES

- Explain how scientists count growth rings in bones to find a dinosaur's age and growth rate.
- Describe how some dinosaurs changed shape as they grew, with two examples, and why that causes naming debates.
- Draw and label a growth curve for T. rex from a table of numbers.

Warm-up. Find a doorframe where your family has marked your height, or measure yourself now and ask a parent how long you were when you were born. How many times taller are you now? A sauropod grew from an egg about the size of a grapefruit into an animal longer than a basketball court.

Video slot. Video coming. How dinosaurs grew: growth rings in bone, T. rex growth spurt, baby dinosaurs and juveniles, Triceratops horn changes. Search approved channels (Museum of the Rockies, Field Museum, Royal Tyrrell Museum, Smithsonian National Museum of Natural History); preview first.

KEY TERMS

hatchling

A baby animal just out of its egg.

juvenile

A young animal that is no longer a baby but not yet grown.

growth ring

A dark line in a bone, like a tree ring, laid down when growth slowed or paused, usually once a year (scientists call it a line of arrested growth).

growth curve

A graph showing an animal's size or weight at each age.

ontogeny

The way a single animal changes from egg to adult (say "on-TOJ-uh-nee").

CORE IDEAS

Rings in the bone. Cut across a tree trunk and you can count its years. Many dinosaur bones work the same way. When a scientist slices a thin section of a leg bone and looks at it under a microscope, dark lines called **growth rings** often show up, one for each year when growth slowed. Counting them gives an age at death, and measuring the space between them shows how fast the animal grew. The method is not perfect, because the center of an old bone is often hollowed out and early rings are lost, so scientists estimate the missing ones.

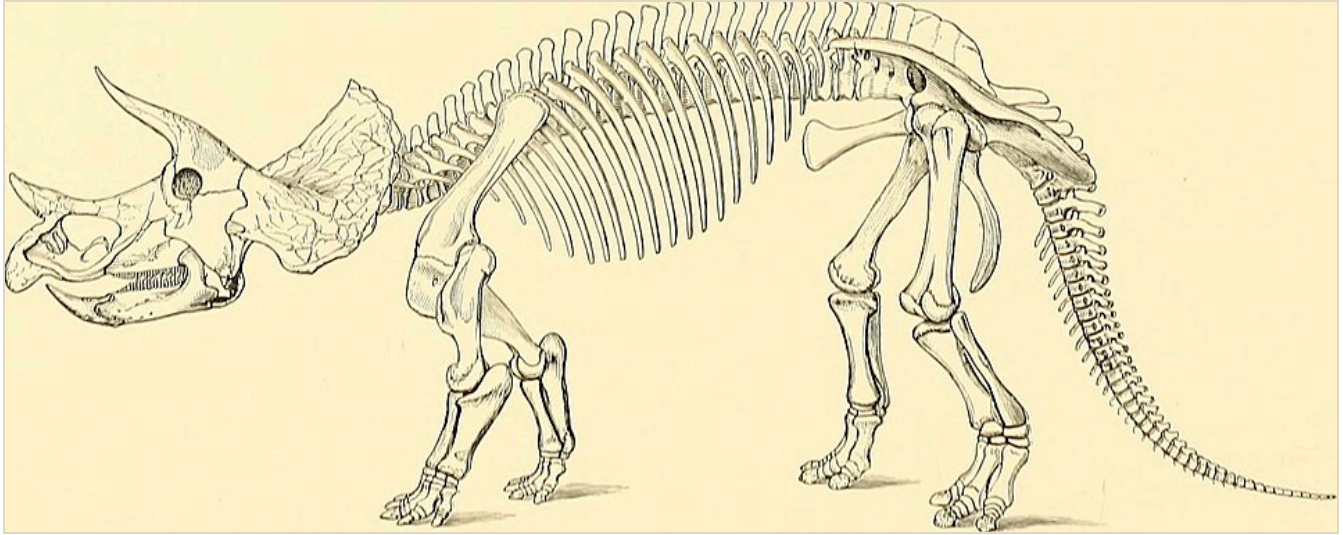
A teenage growth spurt. In 2004 Gregory Erickson and his team counted growth rings in several tyrannosaurs. They found that *Tyrannosaurus rex* grew slowly for its first ten years or so, then put on weight astonishingly fast through its teens, gaining up to about 2 kilograms (nearly 5 pounds) a day, and reached full size at about 18 to 20 years. The famous T. rex named SUE was about 28 years old when it died. That pattern, slow then fast then level, makes an S-shaped **growth curve**, much like a person's.

From tiny to titanic. Dinosaur babies were small. Tiny tyrannosaur embryo bones found in Alberta and Montana and first reported in 2020 suggest a hatchling about 90 centimeters (3 feet) long, nose to tail. A sauropod hatchling may have weighed only a few kilograms, and an adult tens of thousands, a gain of thousands of times its hatching weight, far more than any land animal today. A *Maiasaura* hatchling was about the length of your arm, and one study found that it reached adult size, about 7 meters long, within about eight years.

Who took care of them? Fossils hint that some young dinosaurs were not alone. In 2004 scientists described a slab from Liaoning, China, with 34 young *Psittacosaurus* huddled together beside one older individual. Later study showed the older one was only about four or five years old, perhaps an older brother or sister. Groups of **juveniles** of the ostrich-like *Sinornithomimus* have been found together without adults, as if young ones gathered in their own flocks.

Changing faces. Many dinosaurs looked very different young and old. Young *Triceratops* had short horns that curved backward; as they grew, the horns lengthened and turned to point forward, and the edge of the frill changed shape. Because of this **ontogeny**, scientists sometimes give a young animal its own species name by mistake. Some argue that *Dracorex* and *Stygomoloch* were simply young *Pachycephalosaurus*, and scientists still debate whether the small tyrannosaur called *Nanotyrannus* was a young T. rex or its own kind. Growth is part of God's design: every creature, and every child, is made to change from small to grown.

PICTURE STUDY



Restoration of the skeleton of Triceratops, Plate from O. C. Marsh's *The Dinosaurs of North America*, 1896 · Printed plate (engraving) from a government report · Sixteenth Annual Report of the U.S. Geological Survey (Washington, 1896)

Wikimedia Commons · No restrictions

Othniel Charles Marsh, one of the rivals of the Bone Wars, named *Triceratops* in 1889 and published this restored skeleton in his great survey of North American dinosaurs. It shows a full-grown adult. As you look, try to imagine how the same skull would have looked in a young animal.

Look closely

- Find the two long brow horns and the short nose horn. Which way do the brow horns point?
- Look at the frill. Is its edge smooth or bumpy?
- Compare the size of the skull with the rest of the body. About what fraction of the body length is the head?

Talk about it

1. Young *Triceratops* had short horns curving backward. Why might a growing animal's horns change shape?
2. If you found a small *Triceratops*-like skull with backward horns, what evidence would you need to decide whether it was a baby *Triceratops* or a new species?

HANDS-ON: GRAPH A T. REX GROWTH CURVE

Turn a table of numbers into a growth curve and compare it with your own growth. The numbers below are rounded teaching figures based on growth-ring studies; real estimates vary.

You will need

- Graph paper, a ruler, a pencil and two colored pencils
- Your own height records, if your family has them
- The table: age 2 years, 30 kg; age 6, 250 kg; age 10, 700 kg; age 14, 1,800 kg; age 16, 3,200 kg; age 18, 4,500 kg; age 20, 5,200 kg; age 28, 5,600 kg

Steps

1. Draw a horizontal axis for age, 0 to 30 years (1 square = 2 years), and a vertical axis for weight, 0 to 6,000 kg (1 square = 500 kg). Label both axes with units.
2. Plot the eight points and join them with a smooth curve.
3. Label three parts of the curve: “slow early growth,” “teenage growth spurt” and “adult size.” Add the title “T. rex growth curve (approximate).”
4. Find the steepest part of the curve. Between ages 14 and 18, how many kilograms did T. rex gain? Divide by 4 for kilograms per year, then by 365 for kilograms per day. Write your answer on the graph.
5. If you have your own height records, draw your own growth curve in another color on a second graph. Is its shape similar?

Check your work

- My graph has labeled axes with units, eight plotted points and a smooth curve.
- I labeled the three parts of the curve and gave the graph a title.
- I worked out the growth rate per day for the steepest part.

FIELD NOTEBOOK

1. **Diagram.** Draw a cross-section of a dinosaur leg bone as a large circle with a hollow center. Draw five dark rings spaced widely near the middle and closer together near the outer edge. Label: hollow marrow space, growth ring, wide spacing (fast growth), close spacing (slow growth near adulthood), outer edge (age at death).
2. **Notebook entry.** Write a paragraph: “How did dinosaurs grow up?” Include how scientists find age, T. rex’s growth spurt with numbers, and one example of a dinosaur that changed shape as it grew.

Did you know? Growth rings close together near the outer edge of a bone, sometimes with a thin, dense outer layer, tell scientists the animal had stopped growing. If the rings are still widely spaced at the edge, the animal was still young when it died, however big it looked.

Goes deeper in. Life Science, units on life cycles and growth (coming soon); Arithmetic, graphs and rates. On this track, Trail C, Stop C2 (Eggs and nests) and Trail A, Stop A2 (Triceratops).

For families. T. rex growth: Erickson et al., *Nature* (2004); SUE’s age of about 28 years is from that study. The project table is a rounded teaching set consistent with those results, not data from one specimen. Tyrannosaur embryo bones: Funston et al., *Canadian*

Journal of Earth Sciences (2021), first reported in 2020; the 90 cm hatchling length is their estimate. Maiasaura growth: Woodward et al., *Paleobiology* (2015). Psittacosaurus group: Meng et al., *Nature* (2004), with the older animal's age revised by Hedrick et al. (2014). Triceratops horn changes: Horner and Goodwin (2006); Pachycephalosaurus growth series: Horner and Goodwin (2009), still debated. Nanotyrannus remains debated; a 2025 study argued it was a separate species, and others disagree. Hatchling sizes are estimates.

PRACTICE

1. **EASY** How do scientists find the age of a dinosaur at death?
2. **EASY** About how old was SUE the T. rex when it died?
3. **MEDIUM** Using the project table, how much weight did T. rex gain between ages 14 and 18? About how much per day?
4. **MEDIUM** How did Triceratops horns change as it grew, and why does this matter for naming dinosaurs?
5. **CHALLENGE** A sauropod hatchling weighed about 5 kg, and the adult about 25,000 kg. How many times heavier was the adult? If a 3-kg human baby grew by the same factor, how heavy would the adult be?

Make it a game • Grow Up!. Players start crouched small as hatchlings. The leader calls out ages for a T. rex: “Age 2!”, “Age 10!” (grow a little), “Age 14 to 18, growth spurt!” (stretch up fast), “Age 20!” (stand tall). Anyone who grows too early or too late sits out a round. Then play again for a person's growth.

Scripture. “And Jesus increased in wisdom and stature, and in favour with God and man.” (Luke 2:52, KJV)

Even Jesus grew up, step by step. God made growth part of life for His creatures, and He cares about our growth in wisdom and goodness, not only in size.

Practice: answers

1. They slice a leg bone thin and count the growth rings, estimating any lost from the hollow center.
2. About 28 years old.
3. $4,500 - 1,800 = 2,700$ kg in 4 years, about 675 kg a year. $675 \div 365 \approx 1.8$ kg a day.
4. They started short and curved backward, then grew longer and pointed forward. A young animal can look so different that scientists might name it as a separate species by mistake.
5. $25,000 \div 5 = 5,000$ times heavier. $3 \text{ kg} \times 5,000 = 15,000$ kg, about as heavy as two or three elephants.

3.9 SAUROPOD NECKS

OBJECTIVES

- Compare sauropod necks with a giraffe's in numbers: length, number of vertebrae and weight-saving design.
- Explain three problems a long neck had to solve (weight, blood pressure and breathing) and how sauropods solved them.
- Draw a feeding-envelope diagram and use it to compare how much ground different necks could reach.

Warm-up. Hold a ruler straight out at arm's length by one end. Easy? Now tape a coin or a small eraser to the far end and hold it out again. Feel your wrist work harder? Now imagine a neck 15 meters long with a head on the end. How could any animal hold that up?

Video slot. Video coming. Sauropod necks: air sacs in vertebrae, neck posture, feeding envelope, Mamenchisaurus and Brachiosaurus (Giraffatitan) skeletons. Search approved channels (Museum für Naturkunde Berlin, American Museum of Natural History, Field Museum, Natural History Museum London); preview first.

KEY TERMS

sauropod

A huge, four-legged, plant-eating dinosaur with a long neck, long tail and small head, such as *Diplodocus* or *Brachiosaurus*.

vertebra

One of the bones of the backbone. The plural is *vertebrae* (say "VER-tuh-bray").

pneumatic bone

Bone hollowed out by air sacs connected to the lungs, light but strong, as in birds (from the Greek *pneuma*, "air").

feeding envelope

The whole space an animal can reach with its mouth while standing in one spot.

blood pressure

The force of blood pushing on the walls of the blood vessels as the heart pumps.

CORE IDEAS

The longest necks ever. A giraffe's neck is about 2 meters long and, like yours, has only 7 neck **vertebrae**. A **sauropod** was in a different class. *Diplodocus* had 15 neck vertebrae and a neck about 6 meters long. *Mamenchisaurus*, from China, had 19 neck vertebrae, some over a meter long each, and a 2023 study estimated the neck of the largest kind at about 15 meters, longer than a city bus. That is the longest neck known for any animal. The tall

Giraffatitan skeleton in Berlin (once called *Brachiosaurus brancai*) stands about 13 meters high, as tall as a four-story building.

Light as air. How could a sauropod lift such a neck? The answer is inside the bones. Sauropod neck vertebrae are full of hollows, linked to air sacs connected to the lungs, just as in birds today. These **pneumatic bones** were built like an I-beam or a bridge truss: thin, strong plates of bone arranged along the lines of stress, with air in between. In some sauropods more than half of each neck vertebra was air. Strong ligaments along the top of the neck acted like the cables of a crane, helping hold it up.

Blood and breath. A long neck brings two more problems. If the head were raised high above the heart, the heart would need to push blood uphill a long way. A giraffe's **blood pressure** is already about twice a person's; a sauropod holding its head 8 meters above its heart would need far more. And every breath must travel down a long windpipe and back. Sauropods probably solved the breathing problem with bird-like lungs and air sacs that move air in one direction through the lungs, a design far more efficient than ours. The blood-pressure problem is one reason scientists still argue about how high sauropods held their heads.

Up, down or level? In the early 1900s many scientists pictured sauropods wallowing in lakes to hold up their weight. In 1951 K. A. Kermack showed that water pressure deep in a lake would have squeezed a sauropod's chest so hard it could not breathe, and trackways later showed sauropods walking on dry land. In 1999 two scientists used computer models of the neck joints to argue that some sauropods held their necks almost level. In 2009 another team pointed out that nearly all living animals with necks hold them raised, and argued that sauropods did too. The answer may differ from kind to kind: *Brachiosaurus* was built for reaching high trees, while *Diplodocus* may have swept its head low and wide.

A feeding machine. A long neck let a sauropod stand still and reach a huge **feeding envelope** without walking. Walking a 20-ton body costs a great deal of energy; swinging a light neck costs much less. Sauropods did not chew. They stripped or bit off plants and swallowed them whole, and their giant gut did the rest. Engineers and biologists who study these necks are often amazed at how weight, strength, breathing and blood flow all fit together. It is the kind of design that calls us to praise the Designer.

PICTURE STUDY



Brontosaurus and Diplodocus, Charles R. Knight, 1897 · Painting · American Museum of Natural History, New York
Wikimedia Commons · Public domain

Charles R. Knight painted this scene in 1897 for the American Museum of Natural History, working with the paleontologist Henry Fairfield Osborn. It shows the idea, popular at the time, that sauropods spent much of their lives in water. Compare it with what you have learned about water pressure and trackways.

Look closely

- Find the animal in the water. How much of its body is under the surface?
- Compare the necks of the two animals. How does each one hold its neck?
- Look at the heads. How small are they compared with the bodies?

Talk about it

1. What evidence later made scientists doubt that sauropods lived in deep water?
2. If you repainted this scene today, what would you change, and what would you keep?

HANDS-ON: CHALK A FEEDING ENVELOPE

Draw full-size circles to show how much ground a sauropod could reach without moving its feet, then compare a short neck with a long one.

You will need

- Sidewalk chalk in two colors
- A string about 16 meters long, marked every meter (or a long tape measure)

- A helper and a large paved area or playground, with permission

Steps

1. Mark a small X for the sauropod's shoulders. Your helper holds the end of the string on the X.
2. Walk around the X holding the string at the 6-meter mark, drawing a circle in one color. Label it "Diplodocus neck, about 6 m."
3. Draw a second circle at 15 meters in the other color. Label it "Mamenchisaurus neck, about 15 m." (If you lack room, use a scale of 1 step = 1 meter in a field.)
4. Stand at the edge of each circle and look back at the X. Imagine eating everything inside the circle without taking a step.
5. **Diagram.** In your Field Notebook, draw the two circles to scale (1 cm = 1 m), seen from above, with the X in the middle. Then draw a side view: a sauropod body with three neck positions (low, level and raised) drawn as dashed lines, each labeled, and an arc showing how high and low the head could reach. Add a scale bar and a title.

Check your work

- I drew both circles at the right sizes and labeled them.
- My notebook diagram has a top view and a side view with labels and a scale bar.
- I can explain why reaching food without walking saved energy.

FIELD NOTEBOOK

1. **Diagram.** Draw one sauropod neck vertebra, end-on, as a tall shape with a spine on top. Shade the solid bone and leave the air spaces white. Label: air space (linked to air sacs), thin bony plates, the canal for the spinal cord, and the place where the neck ligament ran.
2. **Notebook entry.** Write a paragraph: "How did a sauropod hold up its neck?" Use at least three numbers from the story and explain one question scientists still argue about.

Did you know? The first part of a *Sauroposeidon* found in Oklahoma in 1994 was a set of four neck vertebrae, the longest over a meter long. At first the workers thought they were fossilized tree trunks.

Goes deeper in. Life Science, units on bones, lungs and the heart (coming soon); Arithmetic, area of a circle. On this track, Trail A, Stop A4 (Brachiosaurus) and Stop A10 (Argentinosaurus).

For families. Mamenchisaurus neck estimate: Moore et al., *Journal of Systematic Palaeontology* (2023), about 15 m. The Berlin Giraffatitan mount is about 13.3 m tall. Kermack (1951) on water pressure; Stevens and Parrish, *Science* (1999), level necks; Taylor, Wedel and Naish, *Acta Palaeontologica Polonica* (2009), raised necks. Air content of vertebrae varies widely by species and bone; "more than half" is conservative.

Sauroposeidon: Wedel, Cifelli and Sanders (2000). Neck posture is still debated, and the stop says so.

PRACTICE

1. **EASY** How many neck vertebrae does a giraffe have? How many did Mamenchisaurus have?
2. **EASY** What made sauropod neck bones light?
3. **MEDIUM** Why do most scientists no longer think sauropods lived in deep water?
4. **MEDIUM** Using $\text{area} = 3.14 \times \text{radius} \times \text{radius}$, find the ground area reached by a 6-meter neck and by a 15-meter neck. About how many times larger is the second?
5. **CHALLENGE** Give one argument that sauropods held their necks raised and one that some held them more level.

Make it a game · Sauropod Reach. Scatter paper “leaves” around a room, some high, some low. Each player plants both feet on a mat (no stepping!) and has one minute to collect as many leaves as possible by reaching and bending. Then try again with one foot allowed to slide. Talk about why a long neck was useful.

Scripture. “Which of you by taking thought can add one cubit unto his stature?” (Matthew 6:27, KJV)

A sauropod did not grow its long neck by worrying about it. Jesus reminds us that God gives each creature what it needs, so we can trust Him instead of being anxious.

Practice: answers

1. A giraffe has 7; Mamenchisaurus had 19.
2. They were pneumatic: hollowed by air spaces linked to air sacs and the lungs, with thin, strong plates of bone.
3. Water pressure would have squeezed the chest so hard the animal could not breathe (Kermack, 1951), and trackways show sauropods walking on land.
4. 6 m: $3.14 \times 36 \approx 113 \text{ m}^2$. 15 m: $3.14 \times 225 \approx 707 \text{ m}^2$. About 6.25 times larger.
5. Raised: nearly all living animals with long necks hold them up, and Brachiosaurus had long front legs suited to reaching high. Level: computer models of some neck joints (Diplodocus, Apatosaurus) suggested a nearly level pose, and lifting the head far above the heart would need extremely high blood pressure.

3.10 DINOSAUR SOUNDS

OBJECTIVES

- Name three kinds of evidence scientists use to guess dinosaur sounds: hollow crests, inner ears and voice organs of living relatives.
- Explain why a longer air tube makes a lower sound, and test it.
- Tell why movie dinosaur roars are artistic inventions, not recordings from evidence.

Warm-up. Hum with your mouth closed. Put your hand on your throat, then on your chest. Feel the buzz? Now make the lowest sound you can, then the highest. Birds sing, crocodiles bellow, and doves coo with their beaks shut. Which of those sounds most like a dinosaur to you?

Video slot. Video coming. Dinosaur sounds: Parasaurolophus crest models, cassowary and emu booming, crocodile bellows, how movie dinosaur sounds were made. Search approved channels (New Mexico Museum of Natural History and Science, Cornell Lab of Ornithology, Smithsonian, Field Museum); preview first.

KEY TERMS

resonance

The way air in a tube or chamber vibrates and makes a sound louder at certain notes.

larynx

The voice box at the top of the windpipe, used for sound by mammals, crocodiles and other reptiles.

syrinx

The voice organ of birds, deep in the chest where the windpipe splits (say “SEER-inks”).

closed-mouth call

A low, booming sound made by puffing up the throat or chest with the mouth shut, as doves, emus and alligators do.

frequency

How fast a sound wave vibrates; low frequency sounds deep, high frequency sounds shrill. It is measured in hertz (Hz).

CORE IDEAS

The silent record. Bones, teeth and footprints can become fossils. Sounds cannot. No one has ever heard a dinosaur, so every dinosaur call is a careful guess. Scientists have three kinds of clues: the shape of the skull and any hollow chambers in it, the inner ear that shows what an animal could hear, and the voices of the dinosaur’s nearest living relatives, birds and crocodiles.

A horn on its head. The duck-billed dinosaur *Parasaurolophus* had a long, hollow crest sweeping back from its head, with air passages running from the nostrils up through the crest and back down to the throat, a path more than 2 meters long in an adult. In 1981 David Weishampel argued the crest worked like a wind instrument, and he built models to show it. In 1995 a well-preserved skull was found in New Mexico, and in 1997 scientists scanned it and used a computer at Sandia National Laboratories to model the air inside. The result was a deep, low, rumbling tone. A longer tube makes a lower note, which is why a tuba sounds deeper than a trumpet. *Corythosaurus* and *Lambeosaurus* had hollow crests too, each a different shape and probably a different voice.

Ears and voice boxes. Scans of dinosaur braincases show the size of the inner ear's hearing tube. Many large dinosaurs seem to have heard low sounds best, like crocodiles and large birds today, and low sounds carry far through forests. Living crocodiles roar and bellow using a **larynx**. Birds sing with a **syrinx**, deep in the chest. A fossil syrinx has been found in an ancient bird called *Vegavis* (reported in 2016), but none yet in a non-bird dinosaur. In 2023 scientists described a fossil larynx from the armored dinosaur *Pinacosaurus*, with bones shaped much like a bird's, suggesting it may have made bird-like calls.

Booms, not roars? In 2016 a team that studied which animals make **closed-mouth calls** suggested that many large dinosaurs may have boomed or cooed with their mouths shut, puffing up the throat like an emu, an ostrich or a pigeon. Cassowaries make booms so low that people feel them as much as hear them. A T. rex may have rumbled more than it roared. The famous roar in a 1993 dinosaur movie was invented by a sound designer who mixed recordings of real animals, including a baby elephant, a tiger and an alligator. It is good art, but it is not evidence.

Made to praise. The world God made was never silent. Birdsong, the lowing of cattle, the boom of the bittern and the bellow of the alligator fill it with sound. Scripture calls on every creature to praise the Lord, and that included the dinosaurs, whatever their voices were. When you hear a guess about dinosaur sounds, ask what part is evidence and what part is imagination.

PICTURE STUDY



The Crystal Palace Iguanodons, Benjamin Waterhouse Hawkins, 1854 · Sculpture (brick, iron and cement), shown in a print or photograph · Crystal Palace Park, London
Wikimedia Commons · Public domain

Benjamin Waterhouse Hawkins built life-size models of ancient animals for the grounds of the Crystal Palace in London, with Richard Owen as his scientific adviser. They opened to the public in 1854 and still stand today. Hawkins had only scraps of bone to work from, so he filled in much from imagination. Every artist who shows a dinosaur, even today, must imagine some things, such as color and sound.

Look closely

- Look at the mouths. Are they open or closed? What would these animals sound like if Hawkins had made them speak?
- Find the horn on the nose. (Stop C4 told where it really belonged.)
- Look at the legs and body. Do they look like a lizard, an elephant or something in between?

Talk about it

1. Hawkins had to imagine much of this animal. Which parts of a dinosaur must even modern artists still imagine?
2. If you were making a museum model of a duck-billed dinosaur that “speaks,” what evidence would you use to choose its sound?

Safety first. Use plastic bottles or tubes rather than glass, and do not blow so hard you feel dizzy; rest between tries.

HANDS-ON: BUILD A CREST HORN

Test whether a longer air tube makes a lower sound, then draw a labeled diagram of the air passage in a *Parasaurolophus* crest.

You will need

- Three or four plastic bottles of the same kind and water, or three cardboard tubes of different lengths (paper towel, wrapping paper, and a short toilet-paper tube)
- A ruler, a pencil and your Field Notebook
- Optional: a garden hose about 2 meters long and a kitchen funnel

Steps

1. Fill the bottles to different levels so the air spaces above the water are different lengths. Measure each air space with the ruler.
2. Blow gently across the top of each bottle to make a tone. Put them in order from lowest note to highest. Record the air-space length beside each note.
3. Hum loudly into each cardboard tube the same way. Which tube makes your voice sound deepest?
4. Optional: push the funnel into one end of the garden hose and buzz your lips into the other end like a trumpet player. The 2-meter hose is about the length of the air path in a *Parasaurolophus* crest. Listen to how low it sounds.
5. **Diagram.** Draw a side view of a *Parasaurolophus* head with its long crest. Inside, draw the air passage as a looped tube: from the nostril up through the crest to the tip, back down, and into the throat. Label: nostril, air passage going up, turn at the tip, air passage coming down, throat, and “total length about 2 m (adult).” Add arrows showing the direction of the air.

Check your work

- I ordered my bottles or tubes from lowest to highest and recorded the lengths.
- I can state the rule: a longer air space makes a lower sound.
- My diagram shows the looped air passage with arrows and at least five labels.

FIELD NOTEBOOK

1. **Diagram.** Finish the crest diagram if you did not do it in the project. Below it, draw a simple “family tree” of voices: a crocodile (larynx, bellow) on one side, a bird (syrinx, song or boom) on the other, and a dinosaur in the middle with a question mark.
2. **Notebook entry.** Write a paragraph: “What did dinosaurs sound like?” Give three kinds of evidence, say what *Parasaurolophus* probably sounded like and why, and explain why a movie roar is not evidence.

Did you know? Elephants and some large birds use very low sounds, some below what people can hear, to call to each other over long distances. Some scientists have suggested

that large dinosaurs may have done the same, but no fossil can prove it yet.

Goes deeper in. Life Science, units on the senses, sound and hearing (coming soon); Art, sound and music in nature. On this track, Trail A, Stop A8 (Parasaurolophus and its crest).

For families. Weishampel, *Paleobiology* (1981), on lambeosaur crests as resonators. The 1995 New Mexico skull of *Parasaurolophus tubicen* was scanned and modeled with Sandia National Laboratories, with results announced in 1997. *Vegavis* syrinx: Clarke et al., *Nature* (2016). *Pinacosaurus* larynx: Yoshida et al., *Communications Biology* (2023). Closed-mouth vocalization: Riede et al., *Evolution* (2016). The 1993 movie roar was created by sound designer Gary Rydstrom from several animal recordings; sources list somewhat different animals. All dinosaur sounds are reconstructions, and the stop says so.

PRACTICE

1. **EASY** Name the voice organ of a crocodile and the voice organ of a bird.
2. **EASY** Why can no one be certain what a dinosaur sounded like?
3. **MEDIUM** Tube A is 0.5 m long and Tube B is 2 m long. Which makes the lower note? Which dinosaur's crest is closer to Tube B?
4. **MEDIUM** What is a closed-mouth call, and which living animals make one?
5. **CHALLENGE** Sort each statement as evidence (E) or imagination (I): (a) Parasaurolophus had a hollow crest with a long air path; (b) T. rex roared like a lion; (c) Pinacosaurus had bird-like larynx bones; (d) dinosaurs called to each other with sounds too low for people to hear.

Make it a game · Dinosaur Call-and-Find. Each player picks a low, closed-mouth call (a hum, a coo or a boom). One player closes their eyes in the middle of the room while the others spread out and take turns calling. The listener points to where each sound came from and guesses who made it. Low sounds are harder to locate; talk about why that might help or hurt a dinosaur.

Scripture. "Let every thing that hath breath praise the LORD. Praise ye the LORD." (Psalm 150:6, KJV)

Every creature with breath, from the songbird to the booming dinosaur, was made to give glory to God. We praise Him with our voices too.

Practice: answers

1. Crocodile: larynx. Bird: syrinx.
2. Sounds do not fossilize, and soft parts of the voice organs rarely do; every dinosaur sound is a reconstruction from clues.

3. Tube B, the longer one, makes the lower note. An adult *Parasaurolophus* crest had an air path of about 2 m.
4. A low boom or coo made with the mouth shut by puffing up the throat or chest. Doves and pigeons, emus, ostriches, cassowaries and alligators.
5. (a) E; (b) I; (c) E; (d) I (an idea not yet supported by fossils).

TRAIL 3 BADGE QUIZZES

The badge quizzes are optional. The student answers in writing, in a sentence or two, and may look back at the Field Notebook but not at the stops. Four right out of five earns each badge. Badges and the certificate are earned by doing the stops, not by scores.

Badge quiz 1 (Stops 1–5)

1. What is a dental battery, and which dinosaurs had one?
2. Give one piece of evidence that some dinosaurs nested in colonies and one that some brooded their eggs.
3. A footprint is 30 cm long. About how tall was the dinosaur at the hip? What is a trace fossil?
4. Why does a bonebed by itself not prove that dinosaurs lived in a herd?
5. A trackway has a stride of 3.6 m and a hip height of 1.2 m. Find the relative stride. Walking, trotting or running?

Badge quiz 2 (Stops 6–10)

6. Give two kinds of evidence scientists use to decide whether dinosaurs were warm-blooded, and the best answer so far.
7. Name one feathered fossil and one dinosaur known from scaly skin. Then give one observation and one interpretation about Archaeopteryx.
8. How do scientists find a dinosaur's age, and what did they learn about T. rex's growth?
9. Name two ways a sauropod's neck was designed to be held up and used efficiently.
10. What evidence suggests Parasaurolophus made a low sound?

TRAIL CERTIFICATE: MY DINOSAUR LIFE FIELD NOTEBOOK AND TRAIL C CERTIFICATE

Gather the Field Notebook pages from this trail into one booklet with a cover: "How Dinosaurs Lived: A Ranger's Field Notebook," your name and the dates you started and finished.

Include at least five of your diagrams and maps: for example, the tooth diagram (C1), the colony map (C2), the trackway diagram (C3), the quarry map (C4), the gait chart (C5), the cooling graph (C6), the feather chart (C7), the growth curve (C8), the feeding envelope (C9) and the crest diagram (C10).

Add a final page titled "Evidence and interpretation": choose one open question from this trail (herds, warm blood, feathers, neck posture or sounds), list the observations in one column and the interpretations in another, and write a closing paragraph giving your own conclusion and the reasons for it.

When the booklet is done, a parent signs the Trail C certificate.

- **Ten stops:** A titled, dated page for each stop with its notebook paragraph.

- **Diagrams and data:** At least five labeled diagrams, maps or graphs with titles, scales or axes, and real measurements or numbers.
- **Reasoning:** The “Evidence and interpretation” page keeps observations apart from interpretations and reaches a reasoned conclusion that is fair to other views.
- **Care:** Writing is in complete sentences; drawings are neat, labeled and done carefully.

Answer key

1. Hundreds of teeth packed in columns and worn into one grinding or slicing surface, with replacement teeth always growing underneath. Duck-billed dinosaurs (hadrosaurs) and horned dinosaurs such as Triceratops.
2. Colonies: the Maiasaura nests at Egg Mountain, Montana, about 7 m apart. Brooding: oviraptorosaur skeletons found sitting on rings of eggs with their arms spread over them.
3. About $4 \times 30 \text{ cm} = 120 \text{ cm}$ (1.2 m). A trace fossil is a sign of what an animal did, such as a footprint, nest or burrow, rather than part of its body.
4. Water or other causes could have carried bodies from different places together after death; scientists check whether the bones were sorted or lined up by a current.
5. $3.6 \div 1.2 = 3.0$, above 2.9, so running.
6. Any two: fast-growing (fibrolamellar) bone, growth rings, dinosaurs nesting in the far north, chemistry of bones and teeth, upright posture, feathers for warmth. Best answer: probably varied; many were warm or in between (mesotherms), and the question is still being studied.
7. Feathered: Archaeopteryx, Sinosauropteryx, Microraptor, Caudipteryx or Yutyrannus. Scaly: T. rex, a duck-billed dinosaur or sauropod embryos. Observation: it has feathered wings, teeth and a long bony tail. Interpretation: it is a link between dinosaurs and birds, or it is a created bird with unusual features.
8. By counting growth rings in thin slices of leg bone. T. rex grew slowly at first, had a teenage growth spurt of up to about 2 kg a day, and reached adult size at about 18 to 20 years.
9. Any two: hollow, air-filled (pneumatic) vertebrae; strong ligaments like crane cables; a small, light head; bird-like lungs and air sacs; reaching a large feeding envelope without walking.
10. Its hollow crest held a looped air passage about 2 m long, and longer air tubes resonate at lower notes; computer models of a scanned skull produced a deep rumble.

DINOSAURS TRAIL D: DINOSAURS AND THE BIBLE

The fourth trail of the Dinosaurs track reads the dinosaurs in the light of Scripture: the land animals made on the sixth day, behemoth in Job 40 and leviathan in Job 41, dinosaurs on Noah's Ark, the great fossil graveyards and the Flood, dragon legends from Babylon to China, the different views of what happened to the dinosaurs, how to read a museum sign, soft tissue and dating, and the design God built into these creatures. Each stop has a story, a picture study, a hands-on project, a map or diagram, a notebook entry, practice questions, a game and a verse of Scripture (KJV).

This is the  **Ranger** level, for ages 10 to 13. The student reads each stop alone in about 25 to 35 minutes and keeps a Field Notebook. The track is creation-friendly: creation and the Flood are taught as history from Genesis 1-11, and dates in "millions of years" are taught as interpretations. Stops D5, D7, D8 and D9 are  stops with the box *What the sign says / What we observe / How Christians read it*. Students learn exactly what museums claim and the assumptions behind those claims, and other Christian views are named fairly, without mocking anyone.

Five stops earn the **Bible and Dinosaurs Ranger badge, part 1**, and ten stops earn part 2 and the **Trail D certificate**. The two badge quizzes at the end are optional; badges are earned by doing the stops.

BEFORE YOU BEGIN

- Read a page of nonfiction alone and write a short paragraph about it.
- Know the order of the six days of creation and the story of Noah's Flood (Genesis 1 and 6-9), or read them first. Trail B, Stop B10 "Mary Schweitzer's soft tissue" is helpful before Stop D9.

MASTERY CHECKLIST

- ☐ I can show from Genesis 1 on which day dinosaurs were made and explain what "after his kind" means.
- ☐ I can list the clues about behemoth and leviathan in Job 40-41 and compare the main readings fairly.
- ☐ I can explain how dinosaurs could fit on the Ark, using kinds, young animals and the Ark's measurements.
- ☐ I can read a museum sign, separate observations from interpretations, and name the three assumptions behind radiometric dating.
- ☐ I can describe the soft-tissue finds and the views of dinosaur extinction, and explain each view in words its own supporters would accept.

OPTIONAL BOOKS AND RESOURCES

- **Answers in Genesis: dinosaurs and the Ark Encounter** (<https://answersingenesis.org/dinosaurs/>): Free articles on dinosaurs in Scripture, kinds and the Ark from a young-earth view; helpful for Stops D1–D4 and D7.
- **Institute for Creation Research** (<https://www.icr.org>): Free articles on soft tissue, radiometric dating and Flood geology for Stops D5, D8 and D9.
- **National Park Service: Dinosaur National Monument** (<https://www.nps.gov/dino>): Photos and history of Earl Douglass and the Wall of Bones for Stop D5.
- **Biodiversity Heritage Library** (<https://www.biodiversitylibrary.org>): Free old books, including Figuiet's *The World Before the Deluge* and Hooke's *Micrographia*, for the picture studies in Stops D7 and D9.

4.1 “EVERY LIVING THING” ON DAY SIX

OBJECTIVES

- Place dinosaurs, sea reptiles and flying reptiles on the days of creation using Genesis 1:20–25.
- Explain what “after his kind” means and why it matters for how animals vary.
- Describe what Genesis 1:29–31 says about the first animals’ food and about the world being “very good.”

Warm-up. Make a quick list of ten land animals you know, from a mouse to an elephant. Now add three dinosaurs. According to Genesis 1, which day were all thirteen made? Keep the list; you will sort it later in this stop.

Video slot. Video coming. Dinosaurs and the days of creation; Genesis 1 and the land animals of day six, for young viewers. Search approved channels (Answers in Genesis, Institute for Creation Research, Creation Ministries International, Genesis Apologetics); preview first.

KEY TERMS

creation week

The six days in which God made the heavens, the earth and all that is in them, and the seventh day on which He rested (Genesis 1–2; Exodus 20:11).

kind

A group of living things God made to reproduce “after his kind.” A biblical kind is often broader than a modern species; for many animals it may be about the level of a family.

beast of the earth

The KJV phrase in Genesis 1:24–25 for wild land animals, made on the sixth day along with cattle and creeping things.

dinosaur

A name (“terrible lizard”) coined by Richard Owen in 1842 for a group of extinct land reptiles with legs held straight under the body.

very good

God’s own verdict on the finished creation (Genesis 1:31), spoken before sin and death entered the world.

CORE IDEAS

Sorting the days. Genesis 1 tells us not only *that* God made the animals but *when*. On the fifth day He filled the waters and the sky: “God created great whales, and every living creature that moveth, which the waters brought forth abundantly, after their kind, and every winged fowl after his kind” (Genesis 1:21). On the sixth day He made the land animals: “the

beast of the earth after his kind, and cattle after his kind, and every thing that creepeth upon the earth" (Genesis 1:25). Dinosaurs were land animals, so the young-earth reading places them on day six. Swimming reptiles such as plesiosaurs and flying reptiles such as pterosaurs, which were not dinosaurs, belong with the creatures of day five.

Neighbors of Adam. Later that same sixth day God made man in His own image (Genesis 1:26-27). That means Adam and the first **Tyrannosaurus** were created only hours apart. In Exodus 20:11 God Himself ties our seven-day week to creation: "For in six days the LORD made heaven and earth, the sea, and all that in them is." This course reads those days as ordinary days. Christians who love the Bible hold other views as well, and you will meet them fairly in Grade 8. Here we read the plain order of Genesis 1 as history.

After his kind. Ten times Genesis 1 says that living things reproduce "after his kind" or "after their kind." A **kind** is not the same as a modern species. Lions, tigers and house cats are separate species, yet they likely come from one original cat kind. Horses, zebras and donkeys can produce offspring together, so many creation biologists place them in one horse kind. In the same way, the hundreds of dinosaur species that paleontologists have named probably belong to far fewer created kinds, with variety inside each. Kinds vary; they do not turn into other kinds.

Green herbs for food. Genesis 1:29-30 adds a surprise. God gave Adam and Eve plants to eat, and to "every beast of the earth, and to every fowl of the air ... I have given every green herb for meat." "Meat" in 1611 English simply meant food. Many young-earth Christians read this to mean that the first animals, even those with sharp teeth, ate plants. Death came into the world through Adam's sin (Romans 5:12), and the whole creation was changed by the curse (Romans 8:20-22). Today some animals with big teeth, like the giant panda, still eat mostly plants, which shows that teeth alone do not prove what an animal must eat.

Very good. When the sixth day ended, "God saw every thing that he had made, and, behold, it was very good" (Genesis 1:31). The dinosaurs were part of that "every thing." Nobody living today has seen a living Triceratops, but we have seen its bones, and they speak of a Maker who delights in variety, strength and beauty. As you walk this trail, you will meet dinosaurs in the Bible's poetry, on the Ark, in the rocks and in old stories, always asking two questions: What do we observe? And what does God's Word tell us about it?

PICTURE STUDY



Triceratops, Charles R. Knight, 1901 · Painting · American Museum of Natural History, New York
Wikimedia Commons · Public domain

Charles R. Knight (1874–1953) was the first great painter of dinosaurs. He worked closely with scientists at the American Museum of Natural History, studied living animals at the zoo, and built small clay models so the light and shadows in his paintings would look real. This painting shows Triceratops, one of the “beasts of the earth” this trail places on day six.

Look closely

- Count the horns on each animal and find the bony frill behind the head.
- Look at the ground and the plants. What kind of place did Knight imagine these animals lived in?
- Compare the size of the animals with anything else in the picture. How does Knight show that they are big?

Talk about it

1. Which parts of this painting come from bones a scientist could measure, and which parts did Knight have to imagine?
2. If you had been on the earth on the afternoon of day six, what might you have noticed first about a Triceratops?

HANDS-ON: THE DAYS OF CREATION CHART

Make a large chart that sorts animals, including dinosaurs and other ancient reptiles, onto the days of creation, using the words of Genesis 1 as your guide.

You will need

- A large sheet of paper or poster board
- A ruler, pencil and colored pencils
- A Bible (KJV)
- Your warm-up list of animals

Steps

1. Divide the paper into seven columns. Label them Day 1 to Day 7. Across the top of each, write a few words from Genesis 1 or 2 telling what God made or did that day.
2. Read Genesis 1:20-25 aloud. Underline in the text every phrase that describes a group of animals: "great whales," "winged fowl," "cattle," "creeping thing," "beast of the earth."
3. Under Day 5, draw and label a plesiosaur, a pterosaur, a fish and a bird. Under Day 6, draw and label Triceratops, T. rex, a sauropod, a horse, a lion and a man and woman (Adam and Eve, clothed in a simple outline).
4. Sort all thirteen animals from your warm-up list onto Day 5 or Day 6.
5. In the Day 6 column, add an arrow and the label "after his kind." Beside it, write one example of a kind with several species in it (for example: cat kind: lion, tiger, house cat).

Check your work

- Every column has a title and a phrase from Genesis.
- Dinosaurs are on Day 6; swimming and flying reptiles are on Day 5.
- I labeled at least one example of a kind that includes several species.

FIELD NOTEBOOK

1. **Diagram.** Draw a "kind tree": one trunk labeled "original cat kind (Day 6)" with branches labeled lion, tiger, leopard and house cat. Beside it, draw a second trunk labeled "a dinosaur kind?" with two or three branches, and write a question mark: scientists are still studying which dinosaur species belong together.
2. **Notebook entry.** In one paragraph, explain on which day dinosaurs were made and how you know from Genesis 1. Use the words "kind," "day six" and "very good," and quote one phrase from Genesis 1:24-25.

Did you know? The word "dinosaur" does not appear in the King James Bible because it was not invented until 1842, more than two centuries after the KJV was printed in 1611. The Bible speaks of animals in plain, everyday groups: cattle, beasts of the earth, creeping things. That is why Bible readers look for dinosaurs under other names, such as behemoth (Stop D2).

Map or diagram. A simple timeline helps: draw a short line divided into seven equal days. Mark Day 5 "sea and sky creatures," Day 6 "land animals, then Adam and Eve," and Day 7 "God rested." The whole creation, dinosaurs included, fits in one week.

Goes deeper in. Life Science, the unit on creation and classification of living things (kinds and species) (coming soon); and Earth Science, the creation unit (coming soon).

For families. This stop teaches the young-earth reading of Genesis 1 as the course's position and only notes that other Christian views exist; the day-age and framework views are presented fairly in Grade 8. "Dinosauria" was coined by Richard Owen in 1842. The idea that a biblical kind often matches the modern family level is a working estimate used by creation biologists (baraminology), not a fixed rule; for some groups the kind may be at the genus or order level. Pterosaurs, plesiosaurs and ichthyosaurs are not dinosaurs in scientific usage, which is why they are placed with the day-five creatures here.

PRACTICE

1. **EASY** On which day of creation were land animals, such as dinosaurs, made? Give the verse.
2. **EASY** On which day were flying and swimming creatures made, and which ancient reptiles would belong there?
3. **MEDIUM** What did "meat" mean in Genesis 1:30 in 1611 English, and what does the verse say animals were given to eat?
4. **MEDIUM** Lions, tigers and house cats are different species. How can they all fit in one created kind?
5. **CHALLENGE** The giant panda has large teeth and claws but eats mostly bamboo. How does this help us think about whether early dinosaurs with sharp teeth could have eaten plants?

Make it a game · Day Five or Day Six?. One player names an animal: "shark," "Stegosaurus," "eagle," "mosquito," "pterosaur," "horse." Everyone else holds up five fingers for Day 5 or five-plus-one for Day 6. Anyone who answers right may challenge the caller with a verse phrase that proves it. Tricky ones to argue about: a bat, a penguin, a crocodile.

Scripture. "And God made the beast of the earth after his kind, and cattle after their kind, and every thing that creepeth upon the earth after his kind: and God saw that it was good." (Genesis 1:25, KJV)

Every land animal, from the smallest creeping thing to the largest dinosaur, was made by God on the sixth day, each after its kind, and He called it good.

Practice: answers

1. The sixth day (Genesis 1:24-25; Genesis 1:31 says "the sixth day").
2. The fifth day (Genesis 1:20-23). Pterosaurs (flying reptiles) and plesiosaurs and ichthyosaurs (swimming reptiles) belong there.
3. "Meat" meant food in general. The verse says God gave "every green herb" (plants) for food to the animals.

4. A kind is broader than a species. God made an original cat kind with built-in variety, and over time it produced different species that are still cats. Kinds vary but do not become other kinds.
5. It shows that an animal's teeth do not by themselves prove what it must eat. A sharp-toothed animal can live on plants, so Genesis 1:30 (plants for food before the Fall) is not contradicted by sharp dinosaur teeth.

4.2 BEHEMOTH (JOB 40)

OBJECTIVES

- Read Job 40:15–24 and list at least six features God gives of behemoth.
- Compare those features with an elephant, a hippopotamus and a sauropod dinosaur, and weigh each view fairly.
- Explain why God showed behemoth to Job and what Job learned.

Warm-up. Go outside and find a tree trunk, or look at a telephone pole. Imagine a tail as thick and long as that, swinging slowly from side to side. What animal alive today has a tail like that? Keep that question in mind as you read Job 40.

Video slot. Video coming. Behemoth in Job 40 and dinosaurs; sauropods such as Brachiosaurus and Apatosaurus. Search approved channels (Answers in Genesis, Institute for Creation Research, Creation Ministries International, Genesis Apologetics); preview first.

KEY TERMS

behemoth

A huge plant-eating land animal God describes in Job 40:15–24. The Hebrew word is a plural form of the word for “beast,” used to mean “the beast of beasts.”

sauropod

A long-necked, long-tailed, plant-eating dinosaur that walked on four legs, such as Brachiosaurus, Apatosaurus or Argentinosaurus.

Hebrew poetry

The style of much of Job and the Psalms, which repeats an idea in a second line with new words (parallelism) and uses vivid pictures.

cedar

A tall, strong evergreen tree. The cedars of Lebanon were famous in Bible times for their great size.

fen

An old English word for marshy, wet ground with reeds (Job 40:21).

CORE IDEAS

God speaks from the whirlwind. The book of Job tells of a righteous man who lost his children, his wealth and his health. For thirty-five chapters Job and his friends argue about why. Then “the LORD answered Job out of the whirlwind” (Job 38:1). God did not explain Job’s suffering. Instead He asked Job more than seventy questions about creation: the stars, the sea, the weather, the lion, the wild goat, the ostrich, the horse. Near the end He pointed to two creatures above all: behemoth and leviathan (Stop D3).

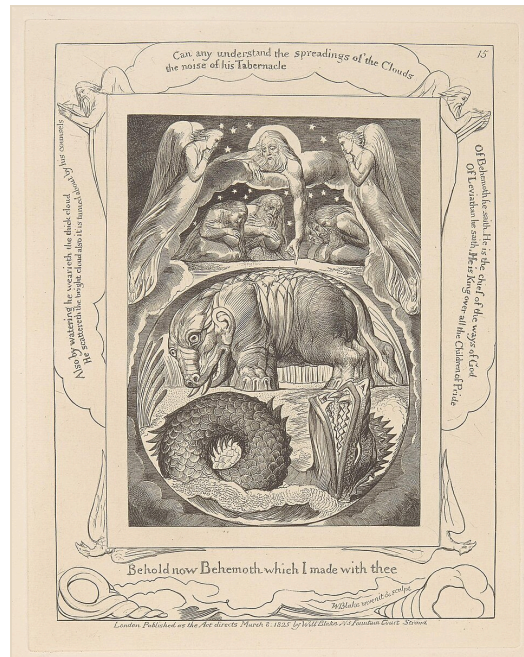
What God says. “Behold now behemoth, which I made with thee; he eateth grass as an ox” (Job 40:15). Notice “made with thee”: behemoth was a fellow creature of the sixth day, made like Job by God’s hand. God then lists its features. Its strength is in its hips and belly (40:16). “He moveth his tail like a cedar” (40:17). “His bones are as strong pieces of brass; his bones are like bars of iron” (40:18). “He is the chief of the ways of God” (40:19), the first or greatest of God’s works. He lies “under the shady trees, in the covert of the reed, and fens” (40:21). When a river floods, he is not afraid: “he trusteth that he can draw up Jordan into his mouth” (40:23).

Three readings. Bible readers have suggested several animals. Some printings of the 1611 King James Bible carried a margin note: “Or, the elephant, as some think.” Many modern study Bibles suggest the **hippopotamus**, which eats grass, lies in reeds and is very strong. But a hippo’s tail is short and thin, about the size of a paintbrush, and an elephant’s tail is a thin rope. Many young-earth Christians therefore think behemoth was a **sauropod**, a long-tailed dinosaur. Apatosaurus had a tail around 12 meters (40 feet) long, with about eighty bones in it. That really is “like a cedar.” Other scholars read behemoth as a poetic figure of great power.

Reading the clues carefully. A good reader tests each view against every clue, not just one. A sauropod fits “chief of the ways of God,” since the largest sauropods were among the biggest land animals ever. It fits a tail like a cedar and bones like iron bars. A hippo fits the reeds and the river. Since Job lived after the Flood, perhaps around the time of Abraham, a sauropod reading means some of these animals were still alive then, which this course thinks is likely. We hold the reading humbly, because God did not label His picture with a modern name.

Why behemoth? God’s point was not a science quiz. He asked Job, in effect: “If you cannot tame the creature I made beside you, how can you question the One who made it?” Only “he that made him can make his sword to approach unto him” (40:19). Job answered, “I know that thou canst do every thing” (Job 42:2) and humbled himself. Looking at a great sauropod skeleton in a museum can teach us the same lesson.

PICTURE STUDY



Behemoth and Leviathan, from Illustrations of the Book of Job, William Blake, 1825 · Line engraving · Illustrations of the Book of Job (plate 15); copies in the British Museum, the Tate and other collections
Wikimedia Commons · CC0

William Blake (1757-1827) was an English poet, painter and engraver. Near the end of his life he made twenty-one engravings of the book of Job. In this one God points down to show Job His two great creatures. Blake drew behemoth looking like a mix of hippo and elephant, because that was the reading most people knew in his day.

Look closely

- Find God, Job and Job's wife and friends. Where is each one placed in the picture?
- Look closely at behemoth. Which features look like a hippo and which like an elephant? How long is its tail?
- Find the words engraved around the border. Blake carved Bible verses into his frames.

Talk about it

1. Blake drew a short tail. If you redrew behemoth to match Job 40:17, what would change?
2. Why do you think Blake placed behemoth and leviathan inside a circle, under God's pointing hand?

HANDS-ON: BEHEMOTH CLUE CHART

Weigh the three readings fairly by testing each animal against every clue in Job 40:15–24.

You will need

- A Bible (KJV)
- Paper, ruler and pencil
- A tape measure and a ball of string (optional, for the tail)

Steps

1. Read Job 40:15–24 aloud. Write each clue on its own row: eats grass, strength in hips and belly, tail like a cedar, bones like brass and iron, chief of the ways of God, lies under shady trees and in reeds, not afraid of a flooding river.
2. Make three columns: elephant, hippopotamus, sauropod. For each clue, mark ✓ (fits), ✗ (does not fit) or ? (not sure).
3. Count the marks in each column. Which animal fits the most clues? Which clue is hardest for each animal?
4. Outdoors, measure out 12 meters (about 40 feet) of string to show an Apatosaurus tail. Lay a paintbrush at one end for a hippo’s tail. Stand beside each one.

Check your work

- My chart tests all three animals against at least six clues.
- I can name the clue that makes the hippo reading hardest.
- I can explain the sauropod reading without mocking the others.

FIELD NOTEBOOK

1. **Diagram.** Draw side-by-side outlines of a hippopotamus and a sauropod, roughly to scale (a hippo is about 4 meters long; an Apatosaurus about 21–23 meters). Label on each: tail, hips (“strength in his loins”), legs and bones (“bars of iron”), mouth (“eateth grass”). Add an arrow to the sauropod’s tail labeled “like a cedar, Job 40:17.”
2. **Notebook entry.** Write a paragraph answering: Which animal do you think behemoth was, and why? Name at least two clues that support your answer and one clue that someone holding a different view might point to.

Did you know? The largest sauropod leg bones are taller than a grown man. Their tails were not dragged on the ground, as early museum mounts showed; trackways rarely show tail marks, so scientists now think sauropods held their tails up, swinging them behind like a counterweight to the long neck.

Goes deeper in. Literature, the unit on Hebrew poetry in Job and the Psalms (coming soon); and Life Science, the unit on large animals and their bodies (coming soon). See also Trail A, Stop A4 “Brachiosaurus.”

For families. Hebrew *behemoth* is the plural of *behemah*, “beast,” used here of a single animal (an “intensive plural”). Sizes are approximate: the hippo tail is about 30–50 cm; Apatosaurus measured about 21–23 m long with a tail of roughly 12 m. The date of Job is uncertain; many conservative scholars place him in the patriarchal era. Some printings of the 1611 KJV give the marginal note “Or, the elephant, as some thinke.” The hippo view is

the most common in modern study Bibles; the sauropod view is held by many young-earth Christians; some scholars read behemoth as a symbolic figure. The verse about the “sinews of his stones” (40:17b) refers to strong thigh muscles; it can be read quickly without comment.

PRACTICE

1. **EASY** What does Job 40:15 say behemoth ate?
2. **EASY** Out of what did God speak to Job?
3. **MEDIUM** Which single clue makes it hard to believe behemoth was a hippopotamus or elephant? Explain.
4. **MEDIUM** An Apatosaurus tail was about 12 meters long. A hippo tail is about 0.4 meters. About how many hippo tails laid end to end equal one Apatosaurus tail?
5. **CHALLENGE** God did not explain Job’s suffering. What was God’s purpose in describing behemoth, and how did Job respond?

Make it a game • Clue Detective. One player secretly picks an animal (living or extinct) and reads out one clue at a time in “Job style”: “His tail is like a rope.” “He drinketh up a river.” Others may guess after each clue. Fewer clues used means more points. Try to write your clues as two-line Hebrew-style poetry.

Scripture. “Behold now behemoth, which I made with thee; he eateth grass as an ox.” (Job 40:15, KJV)

“Which I made with thee”: behemoth was made by the same God who made Job, and on the same day as mankind. The greatest beast is still a creature under its Creator.

Practice: answers

1. Grass, “as an ox.” Behemoth was a plant-eater.
2. Out of the whirlwind (Job 38:1).
3. “He moveth his tail like a cedar” (Job 40:17). Hippos have short, thin tails and elephants have thin, rope-like tails, nothing like a cedar tree.
4. $12 \div 0.4 = 30$ hippo tails.
5. God showed His power and wisdom as the Maker of a creature no man could tame, so Job would trust Him even without an explanation. Job confessed, “I know that thou canst do every thing” (Job 42:2), and humbled himself.

4.3 LEVIATHAN (JOB 41)

OBJECTIVES

- Read Job 41 and list the features of leviathan: scales, teeth, strength, and smoke and fire.
- Compare the crocodile, sea-reptile and symbolic readings of leviathan fairly.
- Find leviathan in three other places in Scripture and explain what God teaches through it.

Warm-up. Try to describe a crocodile to someone who has never seen one, using only poetry and no numbers. Now read God’s description of leviathan in Job 41:15–17. Does it sound like a crocodile, or something more?

Video slot. Video coming. Leviathan in Job 41; crocodiles, marine reptiles such as Kronosaurus, and the bombardier beetle. Search approved channels (Answers in Genesis, Institute for Creation Research, Creation Ministries International, Genesis Apologetics); preview first.

KEY TERMS

leviathan

A fearsome creature of the waters God describes in Job 41 and mentions in Psalms 74 and 104 and Isaiah 27. The Hebrew word may come from a root meaning “twisted” or “coiled.”

marine reptile

A reptile that lived in the sea, such as a plesiosaur, pliosaur or mosasaur. Marine reptiles are not dinosaurs.

habergeon

An old word for a short coat of chain mail armor (Job 41:26).

neesing

An old English word for sneezing (Job 41:18).

bombardier beetle

A living beetle that mixes two chemicals in a chamber in its body and sprays a hot, burning mist at enemies.

CORE IDEAS

“Canst thou draw out leviathan?” Right after behemoth, God turned Job’s eyes to the water: “Canst thou draw out leviathan with an hook? or his tongue with a cord which thou lettest down?” (Job 41:1). The whole chapter, thirty-four verses long, is the longest description of any single animal in the Bible. Job could not catch it with a fishhook, make it a pet “for thy maidens” (41:5), or sell it in pieces to merchants (41:6). Spears and darts could not pierce it, and it laughed at the shaking of a spear (41:29).

The clues. Leviathan had a mouth with “his teeth ... terrible round about” (41:14). “His scales are his pride, shut up together as with a close seal” (41:15), so tight that “no air can come between them” (41:16). His sneezing flashed light, and “his eyes are like the eyelids of the morning” (41:18). Then come the most startling lines: “Out of his mouth go burning lamps, and sparks of fire leap out. Out of his nostrils goeth smoke, as out of a seething pot or caldron” (41:19–20). In the sea, “He maketh the deep to boil like a pot” (41:31). God sums up: “Upon earth there is not his like, who is made without fear” (41:33).

Three readings. Many Bible scholars think leviathan was the **Nile crocodile**, which has armored scales, rows of teeth and great strength, and was hard to kill with ancient weapons. Others note that a crocodile is not a deep-sea animal and does not make “the deep to boil,” and suggest a great **marine reptile** like the pliosaur *Kronosaurus*, whose skull was over two meters long. A third group reads leviathan as a poetic symbol of chaos and evil, because Isaiah 27:1 calls it “the piercing serpent” and “that crooked serpent” that God will punish. These readings can overlap: a real, terrifying animal can also become a picture of evil.

Smoke and fire? Could a real animal breathe out sparks? We do not know of one today, and God’s poetry may describe spray and steaming breath in vivid pictures. But consider the **bombardier beetle**. It stores two chemicals, hydroquinone and hydrogen peroxide, in separate chambers. When threatened, it mixes them with enzymes in a tough reaction chamber and sprays a mist that reaches about 100 °C (212 °F), the boiling point of water, with a popping sound. If the Creator could build that into a beetle, some Christians suggest He could have given leviathan something similar. We hold that idea as a question, not a fact.

Leviathan in the Psalms. Psalm 104:26 shows a peaceful picture: “There go the ships: there is that leviathan, whom thou hast made to play therein.” The creature that terrified men was, to God, a creature that played in His sea. Psalm 74:14 praises God who “brakest the heads of leviathan in pieces.” Every line points the same way. Leviathan was “a king over all the children of pride” (Job 41:34), yet God made it and rules it. In 41:11 God says, “whatsoever is under the whole heaven is mine.”

PICTURE STUDY



The Destruction of Leviathan, Gustave Doré, 1865 · Wood engraving · From La Grande Bible de Tours (an illustrated French Bible, 1866)
Wikimedia Commons · Public domain

Gustave Doré (1832–1883) was a French artist who made 241 engravings for a great illustrated Bible. This one pictures Isaiah 27:1, the day when the LORD “shall punish leviathan the piercing serpent.” Doré shows leviathan as an enormous serpent, not a crocodile, because he was illustrating the prophecy, where leviathan stands for evil.

Look closely

- Follow the coils of the serpent with your finger. How many times does it twist?
- Find the brightest part of the picture and the darkest part. Where does the light come from?
- Look at the waves. How does Doré show that the sea is boiling and stormy?

Talk about it

1. How is Doré’s leviathan different from the one God describes in Job 41? Which verses would you use to draw it differently?
2. Why would a real, frightening sea creature make a good picture of evil that God will one day defeat?

HANDS-ON: LEVIATHAN FIELD REPORT

Write and illustrate a one-page “field report” on leviathan as if you were a scientist sent to collect every clue from Job 41.

You will need

- A Bible (KJV)
- A sheet of paper folded in half
- Pencil and colored pencils
- A picture of a crocodile and of a pliosaur skeleton (library book or museum website)

Steps

1. On the left half, list at least eight clues from Job 41 with verse numbers (for example: scales sealed tight, 41:15-16).
2. Under each clue, write C if it fits a crocodile, M if it fits a marine reptile, and B if it fits both.
3. On the right half, draw your best reconstruction of leviathan. Label at least five parts with the verse that describes them: teeth, scales, eyes, nostrils, the boiling wake behind it.
4. At the bottom, write one sentence: "My best reading is ____ because ____."

Check your work

- My report has at least eight clues with verse numbers.
- My drawing has five labeled parts tied to verses.
- I gave a reason for my reading and stated it humbly.

FIELD NOTEBOOK

1. **Diagram.** Draw a cross-section of a bombardier beetle's defense system: two storage chambers (label "hydroquinone" and "hydrogen peroxide"), a valve, a reaction chamber (label "enzymes"), and the spray nozzle at the tip of the abdomen. Add "about 100 °C" beside the spray.
2. **Notebook entry.** In a paragraph, tell what Psalm 104:26 adds to the picture of leviathan in Job 41. How can the same creature terrify men and yet "play" before God?

Did you know? The Nile crocodile can grow over 5 meters (16 feet) long. Its back is covered with bony plates called osteoderms set in the skin, which made it very hard to spear. Kronosaurus, a pliosaur found in Australia, had teeth up to about 30 cm long including the root.

Goes deeper in. Literature, the unit on Hebrew poetry in Job (coming soon); and Life Science, the units on reptiles and on insects, for the crocodile and the bombardier beetle (coming soon). See also Trail E, Stop E2 "Plesiosaurs."

For families. The crocodile reading is common in modern commentaries; the large marine reptile reading is common among young-earth writers; the symbolic reading draws on Isaiah 27:1, Psalm 74:14 and ancient Near Eastern sea-monster imagery. The stop presents all three without mocking any. The bombardier beetle facts (two chemicals, enzymes, a spray at about 100 °C) are well documented (Eisner and colleagues; Arndt et al., Science, 2015). The idea that leviathan had a similar ability is speculation and is

labeled as such. Kronosaurus skull sizes are estimates; early mounts exaggerated its length. Some printings of the 1611 KJV give the margin note “Or, a whale, or a whirlpoole” at Job 41:1.

PRACTICE

1. **EASY** According to Job 41:15-16, what was special about leviathan’s scales?
2. **EASY** What does Psalm 104:26 say leviathan does in the sea?
3. **MEDIUM** Give one clue that fits the crocodile reading and one clue that some say fits a sea reptile better.
4. **MEDIUM** What is a habergeon, and why does Job 41:26 mention it?
5. **CHALLENGE** Explain how the bombardier beetle helps some Christians think about Job 41:19-21, and why the idea should be held carefully.

Make it a game · Who Can Draw Out Leviathan?. Play a version of tug-of-war with a towel: one player is “leviathan,” kneeling and holding one end. Others take turns trying to “draw him out” by pulling the other end while standing on one foot. Leviathan wins if he is not moved in ten seconds. Then read Job 41:1 and talk about who alone can master leviathan. Play gently and on a soft surface.

Scripture. “Who hath prevented me, that I should repay him? whatsoever is under the whole heaven is mine.” (Job 41:11, KJV)

“Prevented” in 1611 meant “came before” or “gave first.” No one gave God anything first so that He owes them. Everything under heaven, leviathan included, belongs to Him.

Practice: answers

1. They were his pride, shut up together as with a close seal, so close that no air could come between them.
2. It plays there: “whom thou hast made to play therein.”
3. Crocodile: armored, tightly sealed scales; terrible teeth; hard to spear. Sea reptile: “He maketh the deep to boil like a pot” (41:31), since crocodiles do not live in the deep sea.
4. A coat of chain mail armor. The verse says neither sword, spear, dart nor habergeon could hold against leviathan; even an armored warrior was helpless.
5. The beetle mixes two chemicals and sprays a mist at about 100 °C, showing that God can build a creature that “breathes” something hot. That makes fiery breath seem less impossible. But no leviathan fossil shows such organs, and the passage is poetry, so the idea is a possibility, not a proven fact.

4.4 DINOSAURS ON THE ARK?

OBJECTIVES

- Calculate the size of Noah’s Ark from Genesis 6:15 in feet and meters.
- Explain how the idea of created kinds and young animals answers the question “How did dinosaurs fit?”
- Tell what Genesis 6:19–20 and 7:2 say about which animals went on board.

Warm-up. Go outside and pace out 450 feet (about 137 meters), or about one and a half football fields. Turn around and look back. That is the length of Noah’s Ark using an 18-inch cubit. Could you fit a family of elephants in that space? A few hundred?

Video slot. Video coming. Noah’s Ark size and how the animals, including dinosaurs, fit; the Ark Encounter life-size ark in Kentucky. Search approved channels (Answers in Genesis, Ark Encounter, Institute for Creation Research, Creation Ministries International); preview first.

KEY TERMS

cubit

An ancient length measured from the elbow to the tip of the middle finger, about 18 inches (45.7 cm). A longer “royal” cubit was about 20.4 inches.

ark

The great wooden vessel God told Noah to build to save his family and the land animals from the Flood (Genesis 6–8).

clean and unclean

Two groups of animals named in Genesis 7:2. Clean animals went on board by sevens; unclean animals by twos.

juvenile

A young animal that is not yet full-grown.

baraminology

The study, by creation biologists, of which living and fossil species belong to the same created kind (from Hebrew *bara*, “create,” and *min*, “kind”).

CORE IDEAS

God’s blueprint. God gave Noah exact measurements: “The length of the ark shall be three hundred cubits, the breadth of it fifty cubits, and the height of it thirty cubits” (Genesis 6:15). With an 18-inch cubit, that is about 450 feet long, 75 feet wide and 45 feet high (137 × 23 × 14 meters), with three decks inside (6:16). Its proportions, about 6 to 1 for length and width, are close to those of many modern cargo ships, a shape that stays steady in rough

water. The life-size Ark Encounter in Williamstown, Kentucky, opened in July 2016, was built 510 feet long using the longer royal cubit.

Which animals? God told Noah, “of every living thing of all flesh, two of every sort shalt thou bring into the ark” (Genesis 6:19). The next verse explains “every sort”: birds, cattle and “every creeping thing of the earth after his kind” (6:20). Clean animals went by sevens (7:2). Fish and other sea creatures did not need to go, and Genesis 7:22 says it was land animals “in whose nostrils was the breath of life” that died outside the Ark. Since dinosaurs were land animals made on day six, the young-earth reading says that dinosaurs were on the Ark.

Kinds, not species. Noah did not need every species, only representatives of every **kind**. Paleontologists have named well over a thousand dinosaur species, but many are known from only a few bones, and some turn out to be young and old forms of the same animal. Creation researchers estimate there were only about 50 to 90 dinosaur kinds. Counting every kind of land animal and bird, creation researchers at the Ark Encounter estimate fewer than 1,400 kinds, or about 7,000 animals in all.

What about the giants? A full-grown *Argentinosaurus* would never fit through the door. But God did not require Noah to take adults. Dinosaurs hatched from eggs, and the round eggs of giant sauropods found at Auca Mahuevo in Argentina are only about 13–15 cm (5–6 inches) across, about the size of a grapefruit. Young sauropods grew fast, so a teenage sauropod would be strong and healthy but far smaller than its parents, with many years of breeding life ahead of it after the Flood. The Ark Encounter estimates that the average dinosaur, counted by kind, was about the size of a bison.

Space to spare. The Ark’s volume was about 1.5 million cubic feet, roughly the space of 450 standard railroad stock cars. Most animals on board were smaller than a sheep. That leaves room for food, water, and Noah’s family. The Bible does not tell us how Noah fed and cleaned up after everyone for over a year (Genesis 7:11; 8:14), and creation researchers have proposed ideas such as gravity-fed water troughs and sloped floors. What Scripture does tell us is that “Noah did according unto all that the LORD commanded him” (7:5), and “God remembered Noah, and every living thing” (8:1).

PICTURE STUDY



The Entry of the Animals into Noah's Ark, Jan Brueghel the Elder, 1613 · Oil on panel · J. Paul Getty Museum, Los Angeles
Wikimedia Commons · Public domain

Jan Brueghel the Elder (1568–1625) of Antwerp painted animals from life, many from the royal menagerie in Brussels. In this small painting he crowded in dozens of kinds of animals and birds. Look carefully: the Ark itself is far in the background, as if the parade has just begun.

Look closely

- Find at least ten different animals and five different birds. Which are in pairs?
- Find the Ark. What shape did Brueghel give it? How does it compare with the box-like shape in Genesis 6:15?
- Find Noah. What is he doing?

Talk about it

1. Brueghel never painted a dinosaur; the first dinosaur bones were not named until 1824. If you added one, where would you place it, and what age would you make it?
2. Why might Brueghel have placed the Ark far away and the animals in front?

HANDS-ON: THE ARK TO SCALE

Measure and mark out the Ark, then draw a scale floor plan to see how much room the animals had.

You will need

- A tape measure or a long string marked every 10 feet
- Sidewalk chalk or stakes (for outdoors) or graph paper (for indoors)
- Ruler, pencil and colored pencils
- A calculator

Steps

1. Convert the cubits: 300×1.5 feet = ____ feet long; 50×1.5 = ____ feet wide; 30×1.5 = ____ feet high.
2. If you have a field or long sidewalk, mark out the length and width at a corner with chalk, and pace along the side.
3. On graph paper, draw the Ark floor plan at a scale of 1 square = 10 feet (45 squares long, $7\frac{1}{2}$ squares wide). Label it "One deck of three."
4. Inside the deck, draw and label pens to scale: a pair of young sauropods (each about 15 feet long), a pair of bison (10 feet each), a pair of sheep (4 feet each) and a block of small cages for birds and small animals. Label a storage area for food and water.
5. Multiply length $\times$ width $\times$ height to find the volume in cubic feet.

Check your work

- My measurements are $450 \times 75 \times 45$ feet (or $137 \times 23 \times 14$ meters).
- My floor plan is to scale and labeled with at least four kinds of animals and a food store.
- I calculated the volume and can explain why most of the Ark was not needed for big animals.

FIELD NOTEBOOK

1. **Diagram.** Draw a side view of the Ark showing three decks, a door in the side and a window at the top (Genesis 6:16). Label the length, width and height in cubits and in feet. Beside it, draw a school bus (about 40 feet long) to the same scale.
2. **Notebook entry.** In a paragraph, answer the question "How could dinosaurs fit on the Ark?" Use the words "kind," "young" and "cubit," and give at least one number.

Did you know? In 1993 a team of ship engineers at a research institute in Korea, led by Dr. Seon Won Hong, tested scale models of ships with many different proportions in a wave tank and by computer. They reported that the Ark's ratios, 300 by 50 by 30, gave an excellent balance of stability, strength and comfort in rough seas. Modern cargo ships use similar long, broad, low shapes.

Map or diagram. On a map of the Middle East, find the mountains of Ararat in eastern Turkey near the borders of Armenia and Iran. Genesis 8:4 says the Ark rested "upon the mountains of Ararat," a range, not necessarily the single peak called Mount Ararat today.

Goes deeper in. Arithmetic, the units on measurement, scale drawing and volume (coming soon); Earth Science, the Flood unit (coming soon); and Geography, the Middle

East (coming soon).

For families. Cubit lengths vary by source (about 17.5–18 inches for the common cubit; about 20.4 inches for the Egyptian royal cubit). Kind counts are estimates from creation researchers: the Ark Encounter gives about 50–90 dinosaur kinds, fewer than 1,400 kinds of animals overall and about 6,700 animals as its working figure; this stop rounds to “about 7,000.” The stock-car comparison (about 450–520 cars, depending on car size) comes from Whitcomb and Morris, *The Genesis Flood* (1961). The Korean study is Hong et al., “Safety investigation of Noah’s Ark in a seaway,” *CEN Technical Journal* 8(1), 1994 (work done at KRISO in 1992–93); it is published in a creationist journal, and families may want to read it themselves. Christians who hold a local-flood view read these passages differently; this course teaches a global Flood.

PRACTICE

1. **EASY** Using an 18-inch cubit, how long was the Ark in feet?
2. **EASY** How many of each clean animal went on the Ark, and how many of each unclean animal?
3. **MEDIUM** Find the volume of the Ark in cubic feet ($450 \times 75 \times 45$).
4. **MEDIUM** Why did Noah not need to take every one of the more than a thousand named dinosaur species?
5. **CHALLENGE** Give two reasons why taking young adult dinosaurs instead of full-grown ones would have been wise.

Make it a game • Load the Ark. Write 20 animals on cards, including five dinosaurs, each with a “space cost” (mouse 1, sheep 2, bison 5, young sauropod 8, adult sauropod 60). Each player has 40 space points and must load at least eight different kinds. Anyone who tries to load an adult sauropod is “sent back to the field.” The player who loads the most kinds without going over wins.

Scripture. “By faith Noah, being warned of God of things not seen as yet, moved with fear, prepared an ark to the saving of his house; by the which he condemned the world, and became heir of the righteousness which is by faith.” (Hebrews 11:7, KJV)

Noah had never seen a flood like the one God warned of, but he trusted God and built exactly what God commanded. His obedience saved his family and every kind of land animal, dinosaurs among them.

Practice: answers

1. $300 \text{ cubits} \times 1.5 \text{ feet} = 450 \text{ feet}$.
2. Clean animals by sevens; unclean animals by twos (Genesis 7:2).
3. $450 \times 75 = 33,750$; $33,750 \times 45 = 1,518,750$ cubic feet (about 1.5 million).
4. God asked for each kind, not each species. Many species likely belong to the same kind, and some named species are really young and old forms of one animal. Creation researchers

estimate only about 50-90 dinosaur kinds.

5. Any two: they were much smaller and took less space; they ate less food; they were stronger and healthier than old animals; they had many years ahead to have young and refill the earth after the Flood.

4.5 FOSSIL GRAVEYARDS AND THE FLOOD

OBJECTIVES

- Explain why a bone must be buried quickly to become a fossil.
- Describe two real dinosaur bonebeds: the Carnegie Quarry at Dinosaur National Monument and the Cleveland-Lloyd Quarry in Utah.
- Separate what is observed at a bonebed from the two main ways of interpreting it.

Warm-up. Think about a deer that dies in the woods. What happens to its body in a week? In a year? Almost nothing is left: scavengers, insects, weather and bacteria break it down. So how do whole skeletons, by the thousands, end up as fossils in rock?

Video slot. Video coming. Dinosaur National Monument “Wall of Bones,” the Cleveland-Lloyd Dinosaur Quarry, and how fossils form by rapid burial. Search approved channels (National Park Service, Answers in Genesis, Institute for Creation Research, Creation Ministries International); preview first.

KEY TERMS

bonebed

A layer of rock packed with the bones of many animals, often jumbled together.

rapid burial

Being covered by mud, sand or ash quickly, before scavengers and decay can destroy a body. Almost every well-preserved fossil needed it.

sediment

Loose material such as mud, sand and gravel carried and dropped by water or wind. Sediment hardens into sedimentary rock.

formation

A body of rock layers that geologists map and name as one unit, such as the Morrison Formation.

articulated

Describes a skeleton whose bones are still joined in their natural positions, a sign of quick burial.

CORE IDEAS

The rule of rapid burial. Bodies left in the open do not become fossils. Scavengers scatter the bones, and rain, sun and bacteria break them down within a few years. For a bone to fossilize, it must be buried quickly under enough sediment to keep out scavengers and slow decay. Then mineral-rich water can seep into the bone over time. Every geologist agrees on this rule. That is why the most important question at any fossil graveyard is: what buried so many animals so fast?

The Wall of Bones. In August 1909, Earl Douglass, a fossil hunter from the Carnegie Museum in Pittsburgh, found eight tail bones of an Apatosaurus sticking out of a sandstone ridge near Jensen, Utah. Over the next fifteen years his crews dug out tons of bones and shipped them east. In 1915 the site became Dinosaur National Monument. Today visitors can see more than 1,500 bones still in a steeply tilted rock face inside the Quarry Exhibit Hall: Allosaurus, Stegosaurus, Camarasaurus, Diplodocus and others, many broken and jumbled in a layer of sandstone left by fast-moving water.

A predator trap? About 150 kilometers (90 miles) to the west is the Cleveland-Lloyd Dinosaur Quarry, now part of Jurassic National Monument. More than 12,000 bones from at least 74 individual dinosaurs have come out of it, and over 75 percent of the bones belong to meat-eaters, mostly Allosaurus, with at least 46 individuals. That is strange, because in most ecosystems prey animals far outnumber predators. Scientists have argued for decades about what happened here: a drought, a muddy trap, poisoned water or a flood.

One huge formation. Both quarries lie in the **Morrison Formation**, a set of mudstone and sandstone layers that stretches over about 1.5 million square kilometers, from New Mexico north into Canada. It has yielded many of the most famous dinosaurs: Brachiosaurus, Apatosaurus, Stegosaurus, Allosaurus. Bonebeds have also been found in other places, such as Dinosaur Provincial Park in Alberta, where whole herds of horned dinosaurs lie buried together.

Two readings of one graveyard. Mainstream geologists read these bonebeds as many local disasters spread over long ages: rivers in flood, droughts and mud. Creation geologists read them as the work of the global Flood of Genesis 7–8, when “all the fountains of the great deep [were] broken up” (7:11) and vast sheets of sediment buried animals on a continental scale. Creation scientists also study the harder questions, such as dinosaur eggs and footprints within Flood layers, and some propose that animals walked and laid eggs on land that was briefly exposed while the waters rose. The observation is the same for both: many animals, buried quickly, in water-laid rock.

PICTURE STUDY



The Carnegie Quarry at Dinosaur National Monument, Photograph, Carnegie Museum expedition (photographer not recorded), Early 1900s (about 1910–1922) · Black-and-white photograph · Carnegie Museum of Natural History, Pittsburgh; National Park Service, Dinosaur National Monument
Wikimedia Commons · CC BY-SA 2.0

Earl Douglass (1862–1931) and his crews worked the quarry by hand, with picks, chisels and sometimes dynamite to remove the rock above the bones. The bones were wrapped in plaster and burlap, loaded on wagons and hauled to the railroad. Look for a historic photo of the quarry face from those years; the Park Service and the Carnegie Museum have several.

Look closely

- Find the workers. How big are they compared with the rock face and the bones?
- Look at the angle of the rock layer. Is it flat or tilted?
- Find the tools. What did the workers use to free the bones?

Talk about it

1. The layer of bones is tilted steeply today. Was it tilted when the bones were buried, or did something tilt it later? What would you look for to decide?
2. Why would a bonebed in sandstone suggest that water was moving fast when the bones were buried?

HANDS-ON: FLOOD IN A BOTTLE

Watch moving water sort and bury “bones” in layers, and record what you observe.

You will need

- A large clear jar or 2-liter bottle with a lid
- Gravel, coarse sand, fine sand and soil (about a cup each)
- A handful of small plastic animals or broken twigs (the “bones”)
- Water
- A ruler and a colored pencil

Steps

1. Mix the gravel, sands, soil and “bones” in a bowl. Pour them into the jar and fill it about three-quarters with water. Close the lid tightly.
2. Shake hard for 30 seconds, then set the jar on a table and do not touch it.
3. Watch for one minute. Then draw what you see after 1 minute, 10 minutes and 1 hour. Label each layer by grain size and mark where the “bones” ended up.
4. Measure the thickness of each layer with a ruler and write it on your drawing.

Check your work

- My drawings show at least three layers, labeled and measured.
- I marked where the “bones” settled and noticed whether they were jumbled or sorted.
- I can explain that several layers formed in minutes, not years, in my jar.

FIELD NOTEBOOK

1. **Map.** Draw an outline of the western United States. Shade the area of the Morrison Formation (parts of Utah, Colorado, Wyoming, Montana, New Mexico and nearby states). Mark and label: Dinosaur National Monument (Jensen, Utah), Cleveland-Lloyd Quarry (near Price, Utah) and one other Morrison site of your choice, such as Como Bluff, Wyoming. Add a scale bar and a compass rose.
2. **Notebook entry.** Write a paragraph titled “What We Observe at a Bonebed.” Include at least three observations (for example, rapid burial, jumbled bones, sandstone) and then one sentence for each of the two interpretations.

Did you know? Earl Douglass’s first find was a nearly complete Apatosaurus skeleton, now mounted at the Carnegie Museum in Pittsburgh. Douglass loved the canyon country so much that he built a homestead near the quarry and lived there with his family for years.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** “These dinosaurs lived about 150 million years ago, in the Late Jurassic Period. A river buried their bones on a sandbar over many seasons.” **What we observe:** more than 1,500 bones of several kinds of dinosaurs, many broken and disarticulated, in a single tilted layer of sandstone laid down by moving water; at Cleveland-Lloyd, over 12,000 bones from at least 74 animals, most of them Allosaurus. All agree the bodies were buried quickly in water-laid sediment. **How Christians read it:** young-earth creation geologists read the Morrison bonebeds as the work of the Flood about 4,300 years ago, when water and sediment buried animals over whole regions. Christians who

hold an old-earth view accept the mainstream dates and read the beds as local floods over long ages. “Jurassic” is a museum word for this set of rock layers; the date on the sign is an interpretation built on assumptions about rates and ages.

Goes deeper in. Earth Science, the units on sedimentary rock, fossils and the Flood (coming soon); and Geography, the American West (coming soon).

For families. This is a 🕒 stop. Douglass found the Apatosaurus (at first called Brontosaurus) tail vertebrae on August 17, 1909; the Carnegie excavations ran until about 1922–1924; the monument was proclaimed October 4, 1915; the Quarry Exhibit Hall reopened in 2011 (National Park Service). Cleveland-Lloyd figures (over 12,000 bones, at least 74 individuals, at least 46 Allosaurus, over 75% carnivore bones) are from the Bureau of Land Management and published studies; the site became part of Jurassic National Monument in 2019. The Morrison area figure is approximate. Creation geologists (e.g., Clarey, *Carved in Stone*, ICR, 2020) treat the Morrison as Flood deposits and discuss eggs and trackways; the stop mentions this debate without settling it. The distance between the two quarries is approximate.

PRACTICE

1. **EASY** Why must a body be buried quickly to become a fossil?
2. **EASY** Who discovered the Carnegie Quarry, and in what year?
3. **MEDIUM** At Cleveland-Lloyd, at least 46 of at least 74 individual dinosaurs were Allosaurus. About what fraction is that, and why is it surprising?
4. **MEDIUM** Sort these into observation (O) or interpretation (I): (a) The bones are in sandstone. (b) The bones were buried 150 million years ago. (c) Many bones are broken and jumbled. (d) The Flood buried these animals.
5. **CHALLENGE** In your Flood-in-a-bottle jar, several layers formed in minutes. What does this experiment show, and what does it not prove?

Make it a game • Bonebed Dig. Bury 15 craft sticks or plastic animal bones in a tray of sand, some in a jumble and some laid out as a whole “skeleton.” Players take turns digging with a spoon and a paintbrush for one minute each. Each find must be recorded on a quick grid map before it is lifted. Points for each bone mapped correctly; lose a point for any bone broken or lifted unmapped.

Scripture. “And the waters prevailed exceedingly upon the earth; and all the high hills, that were under the whole heaven, were covered.” (Genesis 7:19, KJV)

The Flood covered “all the high hills, that were under the whole heaven.” Such a flood would move and lay down enormous amounts of sediment, the very conditions needed to bury animals quickly by the thousands.

Practice: answers

1. If it is left in the open, scavengers, weather and bacteria destroy it. Quick burial protects the bones so minerals can preserve them.
2. Earl Douglass, in 1909.
3. $46 \div 74 \approx 0.62$, about $3/5$ (62%). It is surprising because predators are usually far fewer than plant-eaters in a living community.
4. (a) O; (b) I; (c) O; (d) I.
5. It shows that moving water can lay down several distinct layers very quickly, so layers do not always need long ages. It does not prove by itself how any particular real rock layer formed; that requires studying the real rocks.

4.6 DRAGON LEGENDS WORLDWIDE

OBJECTIVES

- Name dragon or great-serpent stories from at least four parts of the world and tell where and when each was written down.
- Explain two ways people account for dragon legends: memories of real animals, or people finding fossils.
- Tell how the KJV uses the word “dragon” and test a legend against what can be checked.

Warm-up. Draw a dragon in one minute without thinking about it. Now look at your drawing. Does it have a long neck? A long tail? Scales? Horns or a frill? Where do you think people first got the idea for those features?

Video slot. Video coming. Dragon legends around the world and dinosaurs; the Ishtar Gate dragons of Babylon; Saint George and the dragon. Search approved channels (Answers in Genesis, Institute for Creation Research, Creation Ministries International, the British Museum, the National Gallery); preview first.

KEY TERMS

legend

An old story handed down from earlier times, often with a core of real people, places or events and some added details that cannot be checked.

chronicle

A written record of events, usually set down year by year.

mušḫuššu

The dragon of Babylon (say “moosh-HOOSH-oo”), shown on the Ishtar Gate with scales, a long neck and tail, and the front legs of a lion and back legs of an eagle.

tannin

A Hebrew word translated in the KJV as “dragon,” “serpent,” “sea monster” or “whale,” depending on the verse.

griffin

A legendary beast with the body of a lion and the head and wings of an eagle, told of by ancient Greek writers.

CORE IDEAS

Dragons everywhere. Nearly every people on earth has told stories of great reptiles. In Babylon, King Nebuchadnezzar II (the same king in the book of Daniel) built the blue-glazed Ishtar Gate around 575 BC and covered it with images of the **mušḫuššu**, a scaly dragon with a long neck and tail. The Greek historian Herodotus, writing about 430 BC, reported winged

serpents in Arabia and said he had seen piles of their bones in Egypt. In England the poem *Beowulf*, copied in a manuscript around AD 1000, ends with a fire-breathing dragon guarding treasure. In China the dragon became the emblem of the emperors.

Saint George. The most famous dragon story in Europe was written down by Jacobus de Voragine, an Italian archbishop, in *The Golden Legend* about 1260. He told of a dragon near a town called Silene in Libya, and of George, a Christian soldier, who rescued a princess and led the town to faith in Christ. George himself was a real Christian martyr who died around AD 303. The dragon part of his story was added centuries later. Medieval Christians often used it as a picture of good overcoming evil.

Dragons in the KJV. The word “dragon” appears over thirty times in the King James Bible. Often it translates the Hebrew *tannin* or *tan*. Some verses describe real animals of the wild: “I am a brother to dragons, and a companion to owls” (Job 30:29). Others describe great sea creatures (Psalm 148:7). In Revelation 12:9 the dragon is plainly named as “that old serpent, called the Devil, and Satan.” The translators of 1611 chose “dragon” for creatures that were huge, reptile-like and frightening.

Where did the stories come from? One answer, held by many young-earth Christians, is that dragon legends are distant memories of real dinosaurs and other great reptiles that lived alongside people after the Flood. Many legends describe a long tail, scales, horns or plates, and a habit of living near water, features we also find in dinosaur skeletons. A second answer is that ancient people found fossil bones and imagined the animals. The writer Adrienne Mayor has argued that Greek griffin stories came from nomads who saw Protoceratops skeletons in the deserts of Central Asia. Fossils were certainly found long ago: for centuries Chinese healers ground up “dragon bones,” many of them fossils, as medicine. Both explanations may be true in different places.

Testing a legend. A careful student neither swallows every legend nor scoffs at all of them. Ask: When was this written down? By whom? How far was the writer from the events? Which details could be checked? Herodotus visited Egypt himself, but *Beowulf* is poetry and Saint George’s dragon was added a thousand years after his death. The details that keep turning up across many cultures, far apart in time and place, are the ones worth thinking hardest about.

PICTURE STUDY



Saint George and the Dragon, Paolo Uccello, About 1470 · Oil on canvas · National Gallery, London
Wikimedia Commons · Public domain

Paolo Uccello (about 1397–1475) was a painter of Florence, Italy, who loved perspective, the art of making flat pictures look deep. Here he painted the story from *The Golden Legend*. In that story, after George wounds the dragon, the princess ties her belt around its neck and leads it into the town like a tame animal.

Look closely

- Find the dragon's wings. What pattern did Uccello paint on them? What does the dragon have instead of front legs?
- Find the storm in the sky. Which way is it swirling, and where does it point?
- Look at the grass. How did Uccello make the ground look as if it goes back into the distance?

Talk about it

1. Which features of Uccello's dragon are like a real reptile, and which come from imagination?
2. Why do you think the princess looks so calm?

HANDS-ON: WORLD DRAGON MAP

Gather dragon and great-reptile stories from around the world and compare their features on a map and chart.

You will need

- A printed or hand-drawn world map
- Colored pencils and small sticky notes
- A library book of world legends, or reliable museum websites

Steps

1. Mark and label on the map: Babylon (Iraq), Egypt and Arabia (Herodotus), England (Beowulf), Libya (Saint George), China (imperial dragon) and the Gobi Desert (griffins and Protoceratops).
2. Add at least two more dragon or great-serpent stories you find from other places, for example Wales, Japan or the Americas.
3. Make a chart with a row for each story and columns for: long neck, long tail, scales, horns or frill, wings, near water, breathes fire, when written down.
4. Circle the features that appear in the most stories.

Check your work

- My map shows at least eight places, each labeled.
- My chart compares at least six features.
- I can name the features most common across cultures.

FIELD NOTEBOOK

1. **Diagram.** Copy the Ishtar Gate mušḫuššu from a photograph (the Pergamon Museum in Berlin has the rebuilt gate). Label its scales, horned head, forked tongue, long neck and tail, lion forelegs and eagle hind legs. Beside it, sketch a dinosaur outline and draw arrows between any matching features.
2. **Notebook entry.** Write a paragraph testing one legend from this stop. Tell when and by whom it was written down, which details can be checked, and what you think may lie behind it.

Did you know? “Dragon bones” from Chinese medicine shops led to real discoveries. In 1899 a scholar in Beijing noticed writing scratched on some of them. They turned out to be oracle bones, ox bones and turtle shells carved with the oldest known Chinese writing, more than three thousand years old. The red dragon on the flag of Wales has been a Welsh emblem for well over a thousand years.

Map or diagram. Draw a timeline from 600 BC to AD 1500 and place: the Ishtar Gate (about 575 BC), Herodotus (about 430 BC), Saint George’s death (about AD 303), the Beowulf manuscript (about AD 1000), *The Golden Legend* (about 1260) and Uccello’s painting (about 1470).

Goes deeper in. History, the units on Babylon and on medieval Europe (coming soon); Literature, *Beowulf* and the Saint George legend (coming soon); and Art, the Italian Renaissance (coming soon).

For families. The Ishtar Gate dates to the reign of Nebuchadnezzar II (604–562 BC), usually given as about 575 BC; a reconstruction is in the Pergamon Museum, Berlin. Herodotus describes winged serpents in *Histories* 2.75 and 3.107–109. The Beowulf manuscript (Cotton Vitellius A.xv) is dated about 975–1025. Adrienne Mayor’s griffin hypothesis is in *The First Fossil Hunters* (2000); it is a scholarly proposal, not settled. KJV counts of “dragon” vary by form (singular and plural, about 35). The oracle-bone discovery is usually credited to the scholar Wang Yirong (1899); the Shang-dynasty inscriptions date to about 1250–1050 BC. The Welsh red dragon appears in the *Historia Brittonum* (about 830) and became the official flag in 1959. The young-earth reading that some legends preserve memories of living dinosaurs is presented as this course’s view, beside the fossil-discovery explanation.

PRACTICE

1. **EASY** Which king built the Ishtar Gate, and what dragon is shown on it?
2. **EASY** Who wrote down the story of Saint George and the dragon in The Golden Legend, and about when?
3. **MEDIUM** Give two explanations for why dragon legends are found around the world.
4. **MEDIUM** Saint George died about AD 303 and The Golden Legend was written about 1260. About how many years apart are they, and why does that matter?
5. **CHALLENGE** In Revelation 12:9 the dragon is called “that old serpent, called the Devil, and Satan.” In Job 30:29 Job is “a brother to dragons.” What does this show about how to read the word “dragon” in the KJV?

Make it a game • Legend or Ledger?. The leader reads short statements: “Herodotus visited Egypt.” “George’s dragon had a leash.” “The Ishtar Gate is in a museum in Berlin.” “Beowulf’s dragon breathed fire.” Players hold up a book (a ledger: can be checked) or a crown (a legend: cannot be checked) and must explain how they would check the “ledger” ones.

Scripture. “Praise the LORD from the earth, ye dragons, and all deeps:” (Psalm 148:7, KJV)

The psalmist calls even the dragons and the creatures of the deep to praise God. Whatever the great reptiles were, they were His creatures, made for His glory.

Practice: answers

1. Nebuchadnezzar II of Babylon, about 575 BC; the mušḫuššu.
2. Jacobus de Voragine, an Italian archbishop, about 1260.
3. (1) They may be memories of real dinosaurs or great reptiles that lived with people after the Flood. (2) People may have found fossil bones and imagined the animals, as Adrienne Mayor suggests for griffins and Protoceratops.
4. $1260 - 303 = 957$, nearly a thousand years. A detail written down so long after a person lived is much harder to trust than an eyewitness report.

5. The word is used in more than one way. In Job it names a real animal of desolate places; in Revelation it is a title for Satan. Each verse must be read in its context.

4.7 WHAT HAPPENED TO THE DINOSAURS? EACH VIEW

OBJECTIVES

- Explain the asteroid-impact and volcano explanations for dinosaur extinction, with the evidence each side points to.
- Explain the young-earth view: most dinosaurs died in the Flood, and the kinds on the Ark died out afterward.
- Compare the views fairly in a chart, separating observations from interpretations.

Warm-up. Name three animals that have died out in the last 500 years. (Hints: a flightless bird of Mauritius, a pigeon that once filled American skies, a huge cow of European forests.) What caused each to disappear? Keep your answers; they are clues for this stop.

Video slot. Video coming. Why did the dinosaurs die out? The Chicxulub crater and the iridium layer; a creation view of dinosaur extinction after the Flood. Search approved channels (Answers in Genesis, Institute for Creation Research, Creation Ministries International, the Smithsonian, the American Museum of Natural History); preview first.

KEY TERMS

extinct

Describes a kind of living thing that has died out completely, with no living members left.

iridium

A rare, heavy metal, scarce in the earth's crust but more common in meteorites. A thin clay layer rich in iridium is found at many places around the world.

Chicxulub crater

A buried impact crater about 180 kilometers (110 miles) wide under the Yucatán Peninsula of Mexico (say "CHEEK-shoo-loob").

Deccan Traps

Enormous layers of volcanic basalt rock in western India, in places more than 2 kilometers thick.

the curse

God's judgment on the creation after Adam's sin (Genesis 3:17–19), which brought death, decay and hardship into the world (Romans 8:20–22).

CORE IDEAS

The museum answer: an asteroid. In 1980 the physicist Luis Alvarez and his son, the geologist Walter Alvarez, reported that a thin clay layer near Gubbio, Italy, held far more **iridium** than normal rock. They proposed that a giant asteroid had struck the earth, throwing up dust that blocked sunlight, killed plants and starved the dinosaurs. In 1991

geologists identified the **Chicxulub crater**, about 180 kilometers wide, buried under Mexico's Yucatán Peninsula. Today most museum signs give this as the main cause, sometimes together with the giant volcanic eruptions that formed the **Deccan Traps** in India.

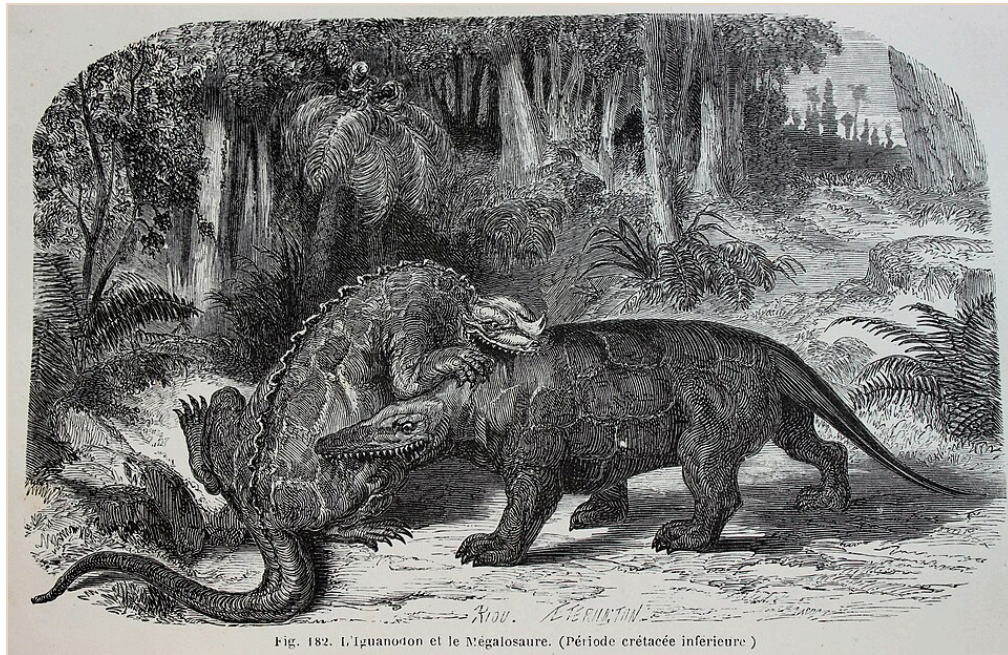
The observations. Everyone can check the same things: the iridium-rich clay layer, found at more than a hundred places; tiny grains of “shocked” quartz that form under enormous impact pressure; the buried crater; and the huge basalt flows in India. Above a certain level in the rock, no more dinosaur fossils are found. These are observations. The claim that all this happened “66 million years ago,” and that dinosaurs had been living for over 150 million years before that, is an interpretation built on dating methods (Stop D8).

The young-earth answer, part one: the Flood. Creation geologists read most dinosaur fossils as animals buried in the global Flood about 4,300 years ago. Many think there may have been impacts and huge volcanic eruptions during the Flood year itself, which would fit the iridium layer, the crater and the Deccan Traps. In this reading, the “extinction level” in the rocks marks a stage of the Flood, not the end of the dinosaurs.

Part two: after the Ark. The dinosaur kinds that rode the Ark came out into a changed world (Stop D4). The young-earth view suggests several causes for their later dying out: a cooler, drier climate and the Ice Age that followed the Flood; loss of the plants they ate; competition with other animals; and hunting by people, who may remember these battles in dragon legends (Stop D6). We have watched this kind of extinction in recent history. The dodo of Mauritius was gone by about 1681; the aurochs, a giant wild cow, died out in Poland in 1627; the last passenger pigeon, Martha, died at the Cincinnati Zoo in 1914.

Why it matters. The first view sees death and extinction as part of the world for hundreds of millions of years before any human existed. The young-earth view sees death as an intruder that came after Adam's sin. Paul writes that “the whole creation groaneth and travaileth in pain together until now” (Romans 8:22). Christians who hold an old-earth view accept the asteroid timeline and read Genesis differently; you will meet their reasons in Grade 8. Weigh the evidence and the assumptions honestly, and be ready to explain both.

PICTURE STUDY



Iguanodon and Megalosaurus, from The World Before the Deluge, Édouard Riou, 1863 · Wood engraving (book illustration) · From Louis Figuier, La Terre avant le déluge (Paris, 1863), published in English as The World Before the Deluge
Wikimedia Commons · CC BY 2.0

Édouard Riou (1833–1900) was a French illustrator best known for drawing the pictures in Jules Verne’s adventure novels. For Louis Figuier’s popular book on the ancient world he drew “ideal scenes” of ancient life. Notice the book’s title: even in 1863 people connected the fossil world with the Deluge, the Flood.

Look closely

- Look at how the dinosaurs stand. Do their legs sprawl out like a lizard’s or stand straight under the body?
- Find Iguanodon’s nose. In 1863 scientists thought its thumb spike was a horn on the snout. Is there one?
- Look at the plants and the sky. What kind of world did Riou imagine?

Talk about it

1. This picture has many mistakes that scientists later corrected. Which parts were based on bones, and which were guesses?
2. Why is it important to know when a picture or sign was made before you trust it?

HANDS-ON: EXTINCTION VIEWS CHART

Build a fair, side-by-side comparison of the main views of dinosaur extinction.

You will need

- A large sheet of paper and a ruler
- Two colored pencils: one for observations, one for interpretations
- This stop and Stops D4 and D5

Steps

1. Make three columns: "Asteroid and volcanoes (mainstream)," "Flood and after the Ark (young-earth)," "What both agree on."
2. Fill the rows: When did dinosaurs die out? What killed them? What evidence is pointed to? What does the view say about death before Adam?
3. In the "What both agree on" column, write only observations: the iridium layer, shocked quartz, the Chicxulub crater, the Deccan Traps, no dinosaur fossils above a certain layer, dinosaurs are gone today.
4. Go back and color every observation one color and every interpretation the other.

Check your work

- My chart has three columns and at least four rows.
- Each view is described in words its own supporters would accept.
- Observations and interpretations are marked in two colors.

FIELD NOTEBOOK

1. **Map.** On a world map, mark and label: Gubbio, Italy (iridium layer, 1980); the Chicxulub crater, Yucatán, Mexico (1991); the Deccan Traps, India; Mauritius (dodo); Poland (last aurochs, 1627); and Cincinnati, Ohio (last passenger pigeon, 1914). Use one symbol for evidence sites and another for recent extinctions, and add a key.
2. **Notebook entry.** Write a paragraph explaining what happened to the dinosaurs according to the young-earth view. Then write one sentence explaining fairly what the asteroid view says.

Did you know? Walter Alvarez first went to Gubbio to study rock layers for a different reason. He asked his father, a Nobel Prize-winning physicist, how to measure how long the thin clay layer had taken to form, and the iridium they found surprised them both. Crocodiles, turtles, birds and many other animals are found both below and above the clay layer.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** "An asteroid struck the earth 66 million years ago at the end of the Cretaceous Period, ending the Age of Dinosaurs." **What we observe:** a thin iridium-rich clay layer at many sites; shocked quartz; a buried crater about 180 km wide in Mexico; vast volcanic basalts in India; no dinosaur fossils above a certain rock level; no living dinosaurs today. **How Christians read it:** young-earth Christians read the impact and eruptions as events of the Flood year, about 4,300 years ago, and think the dinosaur kinds saved on the Ark died out afterward from a changed climate, food loss and hunting, as many animals have in recorded history. Christians who hold an old-earth view accept the mainstream date

and the asteroid explanation. “Cretaceous” is a museum word for a set of rock layers; the “66 million years” is an interpretation based on radiometric dating and its assumptions.

Goes deeper in. Earth Science, the units on meteorites, volcanoes and the Flood (coming soon); Life Science, the unit on extinction and conservation (coming soon); and History, for the dodo and the passenger pigeon.

For families. This is a ⏳ stop. Alvarez, Alvarez, Asaro and Michel, *Science* 208 (1980); Chicxulub identified as the impact site by Hildebrand and colleagues (1991). Crater diameter estimates range about 150–200 km. The dodo’s last accepted sighting is usually given as 1662, with extinction by about 1681; the last aurochs died in the Jaktorów Forest, Poland, in 1627; Martha died September 1, 1914. The date of the Flood (about 4,300 years ago) follows the Masoretic chronology commonly used by young-earth writers. Creation geologists differ on where the Flood/post-Flood boundary lies in the rock record; the stop gives the general view. Old-earth Christian views are named fairly but not argued here. Riou’s plate titles differ between the French and English editions of Figuiet’s book; search for the plate showing Iguanodon and Megalosaurus together.

PRACTICE

1. **EASY** What rare metal did the Alvarez team find in a clay layer, and where?
2. **EASY** Where is the Chicxulub crater, and about how wide is it?
3. **MEDIUM** Name three causes that the young-earth view suggests for the dinosaurs dying out after the Flood.
4. **MEDIUM** The aurochs died out in 1627 and the passenger pigeon in 1914. How many years apart are those two extinctions? What does this show?
5. **CHALLENGE** Why does the question of dinosaur extinction connect to the Bible’s teaching about death and the curse?

Make it a game • Clue Court. Write the clues from this stop on cards (iridium layer, shocked quartz, crater, Deccan Traps, dragon legends, dodo, Ice Age, no dinosaurs above a layer). Two “lawyers” take turns drawing a card and explaining how it fits their assigned view. The “judge” awards a point for each fair, clear argument and takes one away for any mocking. Switch sides and play again.

Scripture. “For we know that the whole creation groaneth and travaileth in pain together until now.” (Romans 8:22, KJV)

Death and extinction are part of a creation that groans under the curse. Paul goes on to say that creation waits for redemption: God will one day make all things new.

Practice: answers

1. Iridium, in a clay layer near Gubbio, Italy (1980).
2. Buried under the Yucatán Peninsula of Mexico; about 180 kilometers (110 miles) wide.

3. Any three: a cooler, drier climate and the Ice Age; loss of the plants they ate; competition with other animals; hunting by people.
4. $1914 - 1627 = 287$ years. Extinction is still happening in recorded history; animals can die out without a worldwide catastrophe.
5. If dinosaurs died out 66 million years before people, death and extinction existed long before Adam. The young-earth view holds that death entered after Adam's sin (Romans 5:12; 8:20-22), so dinosaur death came after the Fall, mostly in the Flood and afterward.

4.8 READING A MUSEUM SIGN

OBJECTIVES

- Mark every sentence of a museum sign as an observation, an interpretation or a mixture of both.
- Explain how a date like “68 million years” is assigned to a fossil, and name the three assumptions behind radiometric dating.
- Rewrite a museum sign so that it is accurate and fair without leaving out what the museum claims.

Warm-up. Read this sentence: “Sue walked to the store, bought milk and came home.” Now suppose you only found a milk carton on the kitchen table. Which parts of the sentence could you prove from the carton? Which parts are an explanation? Museum signs mix the two in just the same way.

Video slot. Video coming. How dinosaur fossils are dated; radiometric dating of volcanic ash layers and its assumptions; reading a museum sign. Search approved channels (Answers in Genesis, Institute for Creation Research, Creation Ministries International, the Smithsonian National Museum of Natural History); preview first.

KEY TERMS

radiometric dating

A method that estimates the age of a rock from how much of an unstable (radioactive) element has changed into another element, using the measured rate of that change.

half-life

The time it takes for half of a sample of a radioactive element to decay. Half-lives are measured in laboratories today.

assumption

Something taken as true without being directly observed, used as a starting point for a calculation or argument.

volcanic ash bed

A layer of rock made of ash from an eruption. Ash beds above or below fossils are what are usually dated, not the bones themselves.

hedge word

A word that shows uncertainty, such as “may,” “probably,” “scientists think” or “about.” Good signs use them honestly.

CORE IDEAS

Three kinds of sentences. A museum sign beside a skeleton usually mixes three kinds of sentences. Some are **observations**: “This skull is 1.5 meters long.” “This skeleton was found

in Montana in 1990.” Some are **interpretations**: “T. rex was the top predator of its world.” “Birds are living dinosaurs.” And some mix both together: “This 67-million-year-old skeleton is about 90 percent complete.” Learning to separate them is not disrespectful to the museum. It is simply careful reading, the same skill a judge or a historian uses.

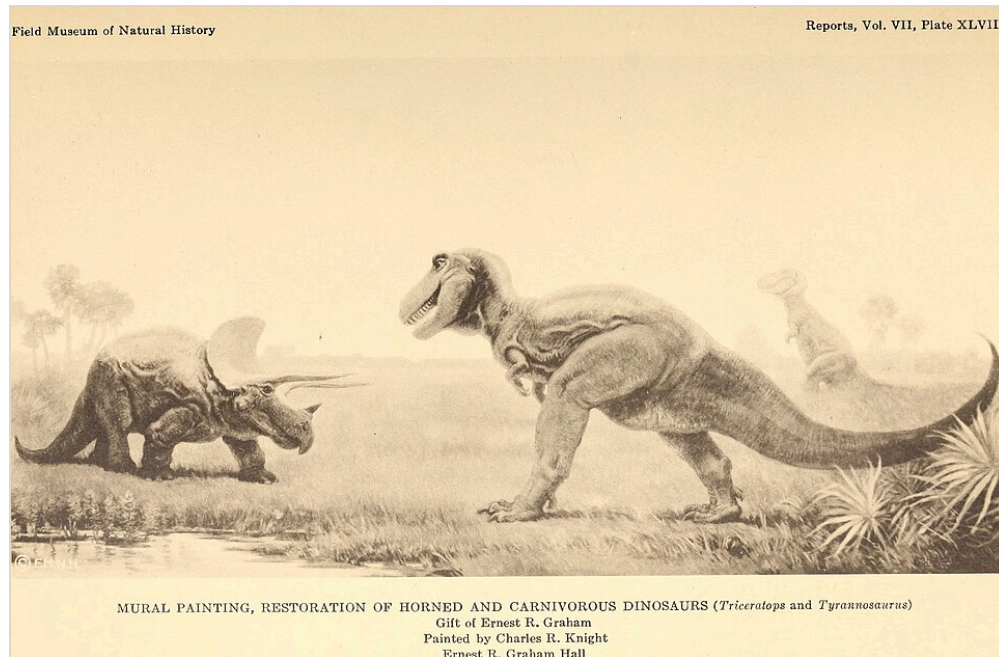
Where the date comes from. Most dinosaur bones are not dated directly. Instead, geologists date layers of volcanic ash above or below the fossils, using methods such as potassium-argon or uranium-lead dating. A radioactive “parent” element slowly decays into a “daughter” element. Scientists measure how much of each is in a crystal, then use the decay rate measured in the laboratory to calculate how long the decay would have taken. The number on the sign is the result of a calculation.

Three assumptions. Every such calculation rests on three assumptions no one can directly observe for the past. (1) **Starting amounts**: how much daughter element was in the rock when it formed. (2) **Constant rates**: that decay has always run at today’s measured speed. (3) **A closed system**: that no parent or daughter atoms leaked in or out since the rock formed. Geologists use cross-checks to test these assumptions. But when they fail, the date changes. In a study published in 1996, the creation geologist Steven Austin had lava from the lava dome of Mount St. Helens dated by the potassium-argon method. The rock had cooled in 1986 and was collected in 1992, only six years later, yet the lab reported about 350,000 years, likely because argon was already in the rock when it formed. Mainstream geologists answer that the method is not meant for such young rock, which is just the point: the method depends on its assumptions.

Words to watch. Good signs use hedge words honestly: “about,” “probably,” “scientists think.” Some signs drop them and state an interpretation as fact. Watch also for words such as “evolved,” “ancestor,” “ruled the earth” and “Age of Dinosaurs.” These are not observations; they come from a framework, a whole way of seeing the past. So do period names: **Triassic, Jurassic and Cretaceous** are museum words for sets of rock layers. Use them so you can read any sign, but notice the dates attached to them.

Reading with respect. Museums do wonderful work. They dig, clean, measure and display real fossils for everyone to see, and the people who prepare them are often very skilled. A Christian student can stand in front of a skeleton with gratitude, learn the vocabulary, and still say, “That date is an interpretation. Here are its assumptions, and here is how many Christians read the same bones.” That is neither mocking nor swallowing. It is reading wisely.

PICTURE STUDY



Tyrannosaurus and Triceratops, a mural for the Field Museum, Charles R. Knight, About 1927–1930 · Oil on canvas (mural) · Field Museum of Natural History, Chicago
Wikimedia Commons · Public domain

Between 1926 and 1930 Charles R. Knight painted 28 large murals of ancient life for the Field Museum in Chicago. Millions of visitors came to “see” dinosaurs through his eyes, and his pictures shaped books and films for decades. A mural like this is itself a kind of museum sign: part observation, part interpretation.

Look closely

- Look at how T. rex is standing. Is its tail on the ground or held up? (Scientists today think it held its tail up.)
- Find the Triceratops’s horns and frill. How is it defending itself?
- Look at the colors of the animals. Could Knight have known these from the bones?

Talk about it

1. Name two things in this mural that came from fossils, and two that Knight had to imagine.
2. Knight painted T. rex upright, but scientists now think it held its body level. What does that teach us about museum displays?

HANDS-ON: THE MUSEUM SIGN REWRITE

Mark up a real museum sign, then rewrite it so that every sentence is accurate and fair.

You will need

- A museum sign: from a visit (take a photo, with permission), a museum website, or the sample below
- Three highlighters or colored pencils
- Paper and a pen

Steps

1. If you do not have a real sign, use this one: "Tyrannosaurus rex lived 68 to 66 million years ago, at the end of the Cretaceous Period. This skeleton is 12.3 meters long and was found in South Dakota. T. rex had the strongest bite of any land animal. It evolved from small, feathered ancestors. Birds are living dinosaurs."
2. Highlight each observation in green, each interpretation in yellow, and any sentence that mixes both in orange.
3. Under the sign, list every assumption hidden in the yellow and orange sentences.
4. Rewrite the sign. Keep every observation. Rewrite each interpretation honestly, for example: "Many scientists date this layer to 68 to 66 million years ago using radiometric dating; young-earth scientists read the same rocks as Flood deposits about 4,300 years old."
5. Read your sign to a family member. Is it accurate? Is it fair to both views? Is it still interesting?

Check your work

- Every sentence of the original is highlighted in one of three colors.
- My rewrite keeps every observation and states the museum's claim accurately.
- My rewrite labels interpretations and assumptions clearly, without mocking anyone.

FIELD NOTEBOOK

1. **Diagram.** Draw a column of rock layers: a dinosaur skeleton in a middle layer, an ash bed above it labeled "dated layer A" and an ash bed below labeled "dated layer B." Draw arrows from each ash bed to a small box labeled "lab: parent and daughter atoms measured." Beside the box, write the three assumptions: starting amount, constant rate, closed system.
2. **Notebook entry.** Write a paragraph explaining to a younger child how a museum gets the date on a dinosaur sign, and why a Christian can read it carefully without mocking it or simply accepting it.

Did you know? Many museums have rebuilt their old dinosaur mounts as new evidence came in. Older displays showed T. rex standing upright like a kangaroo with its tail on the floor; newer mounts hold it level, like a seesaw balanced on the hips. The bones did not change; the interpretation did.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** "Tyrannosaurus rex lived 68 to 66 million years ago, in the Late Cretaceous Period." **What we observe:** a skeleton, its measurements, the rock layer it was found in,

and ratios of parent and daughter atoms in crystals from nearby ash beds measured in a laboratory. **How Christians read it:** young-earth Christians accept the measurements but question the assumptions of starting amount, constant rate and closed system, and read the bones as buried in the Flood about 4,300 years ago. Christians who hold an old-earth view generally accept the radiometric dates. Both can read the sign accurately and know exactly what it claims.

Goes deeper in. Earth Science, the units on radiometric dating and rock layers (coming soon); and Literature, on careful reading and argument (coming soon). See also Stop D9 “Soft tissue and dating.”

For families. This is a ⌚ stop. The Mount St. Helens study is Steven A. Austin, “Excess Argon within Mineral Concentrates from the New Dacite Lava Dome at Mount St Helens Volcano,” *CEN Technical Journal* 10(3), 1996 (whole-rock age about 0.35 ± 0.05 million years, mineral ages up to about 2.8 million years). Mainstream geologists respond that potassium-argon is not designed for very young rocks because of excess argon; the stop gives both sides. Knight painted 28 murals for the Field Museum’s Hall of Fossils, 1926–1930; the exact date of this panel is uncertain. The sample sign is invented for practice; the T. rex length is roughly that of SUE (about 12.3 m). Many families combine this stop with a real museum visit.

PRACTICE

1. **EASY** Is “This skull is 1.5 meters long” an observation or an interpretation?
2. **EASY** Name the three assumptions behind radiometric dating.
3. **MEDIUM** Is a dinosaur bone usually dated directly? If not, what is dated?
4. **MEDIUM** A radioactive element has a half-life of 1,000 years. If a rock started with 800 atoms of it, how many would be left after 3,000 years, assuming the rate stays constant and the system is closed?
5. **CHALLENGE** In the Mount St. Helens study, lava that cooled in 1986 gave a date of about 350,000 years. Which assumption most likely failed, and what does this teach about dates on museum signs?

Make it a game • Green, Yellow, Orange. One player reads sentences from any nature book or museum website. Others hold up green (observation), yellow (interpretation) or orange (both mixed). Each correct color earns a point; a bonus point goes to anyone who can rewrite an orange sentence into one green and one yellow sentence on the spot.

Scripture. “He that is first in his own cause seemeth just; but his neighbour cometh and searcheth him.” (Proverbs 18:17, KJV)

The first explanation we hear always sounds right until someone asks questions. A wise reader listens to the sign, then searches it: What was observed? What was assumed?

1. An observation: it can be measured.
2. Known starting amounts; constant decay rate; a closed system (nothing added or lost).
3. No. Usually volcanic ash layers above or below the fossil are dated, and the fossil is given an age between them.
4. $3,000 \div 1,000 = 3$ half-lives. $800 \rightarrow 400 \rightarrow 200 \rightarrow 100$ atoms.
5. The starting-amount assumption: argon was already in the rock when it cooled. It teaches that a date is only as good as its assumptions, so dates are interpretations to be examined, not observations.

4.9 SOFT TISSUE AND DATING

OBJECTIVES

- Describe at least four reports of soft tissue or original proteins in dinosaur fossils since 2005, with dates.
- Explain why these finds raise questions about the ages on museum signs, and the iron-preservation explanation offered in reply.
- Calculate how much carbon-14 would remain after several half-lives, and explain why that matters for dinosaur bones.

Warm-up. Put a slice of raw chicken or a leaf on a plate and leave it on the counter (or simply imagine it). How long until it rots? A day? A week? Now ask: could a blood vessel stay soft and stretchy for 68 years? 6,800 years? 68 million years? Write down your guess for the longest time you think it could last.

Video slot. Video coming. Soft tissue and proteins in dinosaur bones; Mary Schweitzer's research; creation scientists on soft tissue and carbon-14. Search approved channels (Answers in Genesis, Institute for Creation Research, Creation Ministries International, the Smithsonian, North Carolina State University); preview first.

KEY TERMS

collagen

The most common protein in bone and skin. It forms tough fibers. Pieces of collagen have been reported in several dinosaur fossils.

protein sequence

The order of the building blocks (amino acids) in a protein chain, which can be read in a laboratory using a machine called a mass spectrometer.

carbon-14

A radioactive form of carbon made in the upper atmosphere and taken in by living things. It has a half-life of about 5,730 years.

contamination

Material that gets into a sample from outside, such as bacteria, groundwater or handling, and can confuse a test.

hypothesis

A proposed explanation that can be tested by more observation and experiment.

CORE IDEAS

Not just one surprise. When Mary Schweitzer's team reported stretchy vessels inside a T. rex thighbone in 2005 (Trail B, Stop B10), many scientists hoped it was a one-time oddity. It was not. In 2007 a team led by John Asara reported short protein sequences of **collagen**

from the same T. rex. In 2009 Schweitzer's team reported proteins and vessel-like structures in a duck-billed dinosaur, Brachylophosaurus. In 2013 Mark Armitage and Kevin Anderson reported soft sheets of tissue and bone cells with fine branching extensions from a Triceratops horn found in Montana. In 2015 researchers in London reported structures like red blood cells and collagen fibers in ordinary museum fossils. Since then the list has kept growing.

Why it is a puzzle. In the laboratory, proteins break down. Chemists can measure how fast collagen falls apart under different temperatures, and those rates suggest that even in cold conditions original collagen should not survive anything close to millions of years. DNA breaks down faster still. So the finds raise a real question: are the bones as old as the signs say?

The iron hypothesis. Schweitzer proposed an answer in 2014. When an animal dies, iron from its blood can form highly reactive molecules that link proteins together, like a natural tanning, the same idea as using chemicals to preserve leather. To test it, her team soaked ostrich blood vessels in water: they fell apart in less than a week. Vessels soaked in concentrated red blood cells stayed intact for two years on a laboratory bench. Supporters of long ages say iron could protect tissue much longer, perhaps for millions of years. Creation scientists answer that two years in a lab is a long way from 68 million years, and that the iron idea does not explain every find.

The carbon-14 question. Carbon-14 has a half-life of about 5,730 years. After ten half-lives, about 57,000 years, only about one-thousandth of the starting amount is left, too little to measure reliably. So a bone millions of years old should have no measurable carbon-14 of its own. Some creation researchers have reported measurable carbon-14 in dinosaur bones and in coal and diamonds. Mainstream scientists reply that the carbon comes from contamination, from bacteria or groundwater, or from the machines themselves. This debate is still going on, and honest students should know both sides.

Thinking like a scientist. What we observe: soft, flexible material and protein fragments inside dinosaur bones, from several species and several labs. What is debated: how old they are. Good science welcomes such surprises. As God asked Job, "Where wast thou when I laid the foundations of the earth?" (Job 38:4). None of us watched these animals die. We test, we measure, we weigh the assumptions, and we hold our conclusions under the authority of the One who was there.

PICTURE STUDY



*Cork cells, Observation XVIII, from Micrographia, Robert Hooke, 1665 · Engraving (book illustration) · From Micrographia (London, 1665); copies in the Royal Society, the Wellcome Collection and many libraries
Wikimedia Commons · Public domain*

Robert Hooke (1635–1703) was an English scientist who built one of the best early microscopes. Looking at a thin slice of cork, he saw tiny boxes and called them “cells,” the first use of that word for living structures. Every soft-tissue study in this stop is part of the same long tradition: looking closely and drawing exactly what is there.

Look closely

- Look at the shape of the compartments. Are they all the same size?
- Compare the two slices. How are they cut differently?
- Find the sprig of cork plant. Why do you think Hooke included it?

Talk about it

1. Hooke drew only what he saw and wrote separately about what he thought it meant. How does that help later readers?
2. What would Hooke have thought if he had seen a stretchy blood vessel from a dinosaur bone under his microscope?

HANDS-ON: THE HALF-LIFE SHAKEDOWN

Model radioactive decay with coins and see why carbon-14 runs out quickly.

You will need

- 100 coins (or two-colored counters or wrapped candies with a mark on one side) in a box with a lid
- Graph paper and a pencil

Steps

1. Count 100 coins into the box. Each coin is a carbon-14 atom.
2. Close the lid and shake. Open it and remove every coin that landed tails up; those atoms have “decayed.” Count the coins left and record them. One shake = one half-life (about 5,730 years for carbon-14).
3. Repeat until no coins are left, recording the count each time.
4. Make a graph: half-lives (and years) along the bottom, coins left up the side. Draw a smooth curve through your points.
5. On your graph, mark where 68 million years would be (it would be far off the page: about 11,900 half-lives).

Check your work

- I recorded the number of coins after every shake.
- My graph is labeled with half-lives and years.
- I can explain why a bone millions of years old should have no carbon-14 of its own.

FIELD NOTEBOOK

1. **Diagram.** Draw a cross-section of a dinosaur thighbone. Label: the hard outer bone, the spongy inner bone, a tiny channel with a branching blood vessel inside, and a bone cell (osteocyte) with fine branches. Add a box labeled “What was observed” and another labeled “What is debated: the age.”
2. **Notebook entry.** Write a paragraph comparing the iron hypothesis with the young-earth reading of soft tissue. State the strongest point of each fairly, and say which you find more convincing and why.

Did you know? In 2020 a team studying a baby duck-billed dinosaur, *Hypacrosaurus*, reported cartilage cells with what looked like cell nuclei, and chemical stains that react with DNA. The authors were careful to say they had not found a DNA sequence; the claim is still debated.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** “This Triceratops lived about 66 million years ago. Its bones have turned to stone.” **What we observe:** several teams have found flexible tissue, vessel-like structures, cell-like structures and fragments of proteins such as collagen in fossils of T. rex, Brachylophosaurus, Triceratops and other animals; lab studies measure how quickly such proteins break down. **How Christians read it:** young-earth Christians see soft tissue as strong evidence that the bones are thousands, not millions, of years old, buried in the Flood. Christians who hold an old-earth view, Mary Schweitzer among them, think

special conditions such as iron from blood preserved the tissue for millions of years. Both agree on the observations; the age is the interpretation.

Goes deeper in. Life Science, the units on cells and proteins (coming soon); Earth Science, the unit on dating methods (coming soon); and Arithmetic, on halving and exponential decay (coming soon).

For families. This is a ⏳ stop. Sources: Schweitzer et al., *Science* 307 (2005); Asara et al., *Science* 316 (2007); Schweitzer et al., *Science* 324 (2009, Brachylophosaurus MOR 2598); Armitage and Anderson, *Acta Histochemica* 115 (2013, Triceratops horn); Schweitzer et al., *Proc. R. Soc. B* 281 (2014, iron and ostrich vessels); Bertazzo et al., *Nature Communications* 6 (2015); Bailleul et al., *National Science Review* (2020, Hypacrosaurus). The 2007 collagen sequences were questioned by some scientists and later supported by further work; the stop presents them as reported. Carbon-14 results in dinosaur bones come mostly from creationist researchers and are disputed as contamination by mainstream scientists; the stop states both. Ten half-lives leave 1/1,024 of the original.

PRACTICE

1. **EASY** What is collagen, and why does finding it in a dinosaur bone matter?
2. **EASY** About how long is the half-life of carbon-14?
3. **MEDIUM** Starting with 1,000 carbon-14 atoms, about how many are left after 4 half-lives? How many years is that?
4. **MEDIUM** Describe Schweitzer's ostrich experiment and what it showed.
5. **CHALLENGE** Give one argument a supporter of long ages makes about the iron hypothesis, and one reply a creation scientist gives.

Make it a game • Half-Life Race. Each player starts with 32 counters. Each round, everyone flips all their counters and removes the tails. After each round, the leader calls out how many years have passed (5,730, 11,460 ...). The last player with any counters left wins the round. Then ask: how many rounds would it take to reach 68 million years?

Scripture. "Where wast thou when I laid the foundations of the earth? declare, if thou hast understanding." (Job 38:4, KJV)

God reminded Job that no man watched the world begin. Scientists measure carefully today, but every date for the past depends on assumptions. God alone was there, and His Word is our surest guide.

Practice: answers

1. The main protein in bone and skin. Proteins break down over time, so finding original collagen raises questions about how old the bone really is.
2. About 5,730 years.

3. $1,000 \rightarrow 500 \rightarrow 250 \rightarrow 125 \rightarrow$ about 62 atoms. $4 \times 5,730 = 22,920$ years.
4. Ostrich blood vessels soaked in water fell apart in less than a week; vessels soaked in concentrated red blood cells (rich in iron) stayed intact for two years. It showed iron from blood can help preserve tissue.
5. Long-ages supporter: iron cross-links proteins and could protect tissue far longer than normal decay rates suggest, possibly millions of years. Creation scientist: two years in a lab is enormously shorter than 68 million years, measured decay rates still set limits, and iron does not explain every find.

4.10 FEARFULLY MADE: DESIGN IN DINOSAURS

OBJECTIVES

- Describe four design features in dinosaurs: air-filled bones in sauropods, the duck-billed dinosaurs' tooth batteries, breathing pores in eggshells and the T. rex's skull.
- Explain how engineers learn from such designs and what an argument from design says.
- Connect Psalm 139:14 and Romans 1:20 to what we see in God's creatures.

Warm-up. Hold a solid wooden pencil in one hand and a drinking straw of the same length in the other. Which is lighter? Now try bending each one gently. A hollow tube can be surprisingly strong for its weight. Keep that in mind as you meet the biggest animals that ever walked.

Video slot. Video coming. Design in dinosaurs: sauropod air-filled bones, hadrosaur dental batteries, dinosaur eggshell pores; biomimetics. Search approved channels (Answers in Genesis, Institute for Creation Research, Creation Ministries International, the American Museum of Natural History, the Natural History Museum London); preview first.

KEY TERMS

design

A plan in which the parts are arranged to fit together for a purpose. The argument from design reasons from such plans in nature to a wise Designer.

pneumatic bone

A bone with air spaces inside, connected to air sacs of the breathing system, as in birds and many dinosaurs (from Greek *pneuma*, "air").

dental battery

A set of hundreds of teeth packed in columns in the jaw, with new teeth growing up to replace worn ones, as in duck-billed and horned dinosaurs.

biomimetics

Copying designs found in living things to solve human engineering problems.

fearfully

In Psalm 139:14, with awe and reverence; a thing so wonderful that it fills the one who sees it with holy wonder.

CORE IDEAS

Light-weight giants. A sauropod such as *Brachiosaurus* held its neck high, and the neck alone could be about 9 meters (30 feet) long. If the neck bones had been solid, the weight would have been enormous. But many sauropod vertebrae were **pneumatic**: hollowed out

with chambers, thin walls and crossed struts, like the frame of a bridge. Air sacs from the lungs reached into them, as they do in birds today. This made the neck light but strong, and many scientists think the air sacs also helped these huge animals breathe efficiently and shed heat.

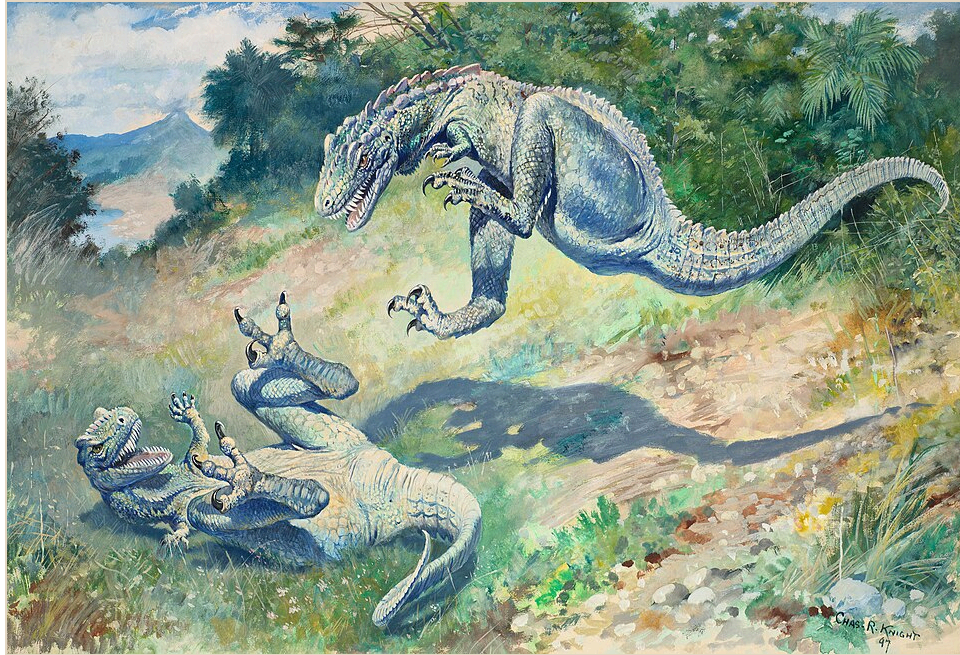
A grinding machine. Duck-billed dinosaurs such as Edmontosaurus ate tough plants. Their jaws held **dental batteries**: hundreds of teeth packed side by side in columns, with replacement teeth already growing beneath the ones in use. As the top teeth wore down, the next ones moved up, so the grinding surface never wore out. In 2012 a team led by Gregory Erickson reported that hadrosaur teeth were made of six different tissues, more than the four found in the teeth of horses or cows. Hard and soft tissues wore at different rates, keeping the surface rough like a file.

An egg that breathes. A baby dinosaur sealed inside a hard egg needs oxygen. Dinosaur eggshells, like bird eggshells, are pierced by thousands of tiny **pores** that let oxygen in and carbon dioxide and water vapor out. Shells from nests buried in soil often have more or wider pores than shells from open nests, because buried eggs need help to breathe. The shell must be strong enough to protect the chick, yet weak enough for it to break out when the time comes.

The T. rex skull. A Tyrannosaurus skull about 1.5 meters long was full of openings that saved weight. Yet it was strong enough for one of the most powerful bites of any land animal: computer models published in 2012 estimated about 35,000 to 57,000 newtons, many times the force of a lion. Its eyes faced forward enough to judge distance, and its brain areas for smell were very large. Every part fits the others: bones, muscles, teeth and senses work as one.

Fearfully and wonderfully made. Engineers study such designs. Hollow, strutted bones inspire light structures for buildings and aircraft; self-sharpening teeth inspire cutting tools. When we copy a design, we honor the designer, and Paul writes that God's "eternal power and Godhead" are "clearly seen, being understood by the things that are made" (Romans 1:20). David wrote Psalm 139:14 about the human body, but the same Maker built the dinosaurs. The bones in a museum are not only a record of death but a witness to the wisdom of God.

PICTURE STUDY



Leaping Laelaps, Charles R. Knight, 1897 · Watercolor (gouache) on paper · American Museum of Natural History, New York
Wikimedia Commons · Public domain

Charles R. Knight painted this under the guidance of the scientist Edward Drinker Cope, who had named the animal *Laelaps* (it is now called *Dryptosaurus*). Most artists of the 1890s showed dinosaurs as slow, heavy reptiles. Knight boldly painted them as quick and agile, and many scientists today think he was closer to right.

Look closely

- Look at the leaping dinosaur's legs, tail and claws. How do they work together in the leap?
- Find the dinosaur on its back. How is it defending itself?
- Look at how Knight shows motion: which lines in the picture make your eye move?

Talk about it

1. Which design features of these animals' bodies does Knight show off in this picture?
2. Knight studied living animals such as birds and big cats before painting dinosaurs. Why would that help him paint creatures no one had seen alive?

HANDS-ON: THE HOLLOW-BONE BRIDGE

Test whether hollow, strutted "bones" can be both light and strong, like a sauropod's neck vertebrae.

You will need

- Paper (several sheets of the same kind) and tape
- Two stacks of books of equal height, about 15 cm apart
- Small objects of known weight (coins, washers or small bags of rice)
- A kitchen scale (optional) and a ruler

Steps

1. Make three “bones” from one sheet of paper each: (A) a flat strip folded once, (B) a rolled tube taped closed, (C) a tube with a folded paper “strut” in a zigzag inside it.
2. Lay each bone across the gap between the book stacks.
3. Add coins one at a time to the middle until the bone bends to touch the table or collapses. Record the number for each.
4. Weigh each bone if you have a scale. Divide the coins held by the weight to find the strongest for its weight.
5. Draw a labeled sketch of your best design next to a drawing of a sauropod vertebra with air chambers.

Check your work

- I tested three designs and recorded the results.
- I can say which design was strongest for its weight and why.
- My drawing compares my paper bone with a real pneumatic vertebra.

FIELD NOTEBOOK

1. **Diagram.** Draw a cutaway of a duck-billed dinosaur’s lower jaw. Show at least three columns of stacked teeth, with the worn teeth on top and new teeth growing beneath. Label: grinding surface, worn tooth, replacement tooth, jawbone. Add arrows showing which way the new teeth move.
2. **Notebook entry.** Write a paragraph choosing one design from this stop and explaining how its parts work together for a purpose. End by copying Psalm 139:14 and writing one sentence about what it means to you.

Did you know? Many birds also have hollow, air-filled bones joined to air sacs, and their lungs take in fresh air on both breathing in and breathing out. Because many dinosaur skeletons show similar air spaces, scientists think some dinosaurs may have breathed in a similar way. Chicken eggshells have about 7,000 to 17,000 tiny pores.

Goes deeper in. Life Science, the units on the skeleton, teeth and breathing (coming soon); Art, for drawing from life the way Charles R. Knight did (coming soon); and Small Business & Economics, on how engineers and inventors use biomimetics (coming soon).

For families. Sauropod pneumaticity is well documented (e.g., Wedel, 2003 and later work). The hadrosaur study is Erickson et al., *Science* 338 (2012). The T. rex bite estimate is Bates and Falkingham, *Biology Letters* (2012). Eggshell pore density linked to nest type comes from studies of modern birds and dinosaur eggs; the stop states it generally. Neck

lengths and bite forces are estimates. Mainstream scientists explain these features by evolution; this stop presents them as evidence of design, the course's position, while teaching the observations accurately. Leaping Laelaps (1897) was painted for Cope; it is at the AMNH.

PRACTICE

1. **EASY** What is a pneumatic bone?
2. **EASY** Why did duck-billed dinosaurs never wear out their grinding teeth?
3. **MEDIUM** Why do eggshells need pores, and why might eggs buried in soil need more of them?
4. **MEDIUM** Hadrosaur teeth had six tissues; horse teeth have four. How many more tissues is that, and why did the mix of tissues help?
5. **CHALLENGE** Using Romans 1:20, explain how studying a dinosaur skeleton can teach something about God.

Make it a game • Design Detective. Take turns choosing an object from the house (an umbrella, a zipper, a bicycle). Others must name its parts and what each one is for. Then match it with an animal design that works the same way (umbrella ⇒ bat wing; zipper ⇒ bird feather barbs; bicycle frame ⇒ hollow, strutted bones). A point for each good match.

Scripture. "I will praise thee; for I am fearfully and wonderfully made: marvellous are thy works; and that my soul knoweth right well." (Psalm 139:14, KJV)

David praised God for the design of his own body. The same Maker designed the dinosaurs. When we study His works carefully, we learn to say with David, "marvellous are thy works."

Practice: answers

1. A bone with air spaces inside, connected to the air sacs of the breathing system.
2. They had dental batteries: hundreds of teeth in columns, with new teeth constantly moving up to replace worn ones.
3. The growing chick needs oxygen in and carbon dioxide and water vapor out. Buried eggs get less fresh air, so more or wider pores help them breathe.
4. Two more. Hard and soft tissues wore at different rates, keeping the grinding surface rough like a file.
5. Romans 1:20 says God's eternal power and Godhead are clearly seen through the things He has made. A skeleton whose parts fit together for a purpose (light hollow bones, self-replacing teeth, breathing eggs) shows the wisdom and power of its Designer.

TRAIL 4 BADGE QUIZZES

The badge quizzes are optional. The student answers in writing, in a sentence or two each. Four right out of five earns each badge. Badges and the certificate are earned by doing the stops, not by scores; use the quizzes to find stops worth reviewing.

Badge quiz 1 (Stops 1-5)

1. On which day were dinosaurs made, and on which day were plesiosaurs and pterosaurs made? Give a verse for one of them.
2. Which clue in Job 40 makes many Christians think behemoth was a sauropod rather than a hippo?
3. Name two features of leviathan from Job 41 and one way it is read.
4. Give the Ark's measurements in cubits and in feet (18-inch cubit), and one reason dinosaurs could fit.
5. What do all geologists agree on about a bonebed such as the Wall of Bones, and how do young-earth geologists read it?

Badge quiz 2 (Stops 6-10)

6. Name two dragon legends from different parts of the world and one explanation for why such legends are so widespread.
7. What evidence is given for the asteroid explanation, and what does the young-earth view say happened to the dinosaurs?
8. Name the three assumptions behind radiometric dating.
9. What has been found in dinosaur bones since 2005, and what explanation did Mary Schweitzer offer for how it lasted?
10. Describe one design feature in dinosaurs and connect it to Romans 1:20 or Psalm 139:14.

TRAIL CERTIFICATE: MY DINOSAURS AND THE BIBLE FIELD NOTEBOOK AND TRAIL D CERTIFICATE

Gather the Field Notebook pages from this trail into one booklet with a cover: "Dinosaurs and the Bible: Field Notebook," your name and the dates you started and finished.

Include your Days of Creation chart (D1), your behemoth clue chart (D2), your Ark floor plan (D4), your Morrison Formation map (D5) and your rewritten museum sign (D8).

Add a final page: a one-paragraph answer to the question "How should a Christian read a museum sign about dinosaurs?" using the words observation, interpretation and assumption.

When the booklet is done, a parent signs the Trail D certificate.

- **Ten stops:** At least one notebook entry and one map or diagram for each stop, each with a title and a date.

- **Scripture:** Bible verses are quoted accurately with references and used in their context.
- **Observation and interpretation:** The museum sign rewrite and the ⌚ stops clearly separate what is observed from what is interpreted, and name the assumptions.
- **Fairness and care:** Other views are described accurately and without mocking; drawings and maps are neat and labeled.

Answer key

1. Dinosaurs (land animals) on day six (Genesis 1:24-25); plesiosaurs and pterosaurs (sea and flying creatures) on day five (Genesis 1:20-21).
2. "He moveth his tail like a cedar" (Job 40:17); hippos and elephants have small, thin tails.
3. Any two: tightly sealed scales, terrible teeth, smoke and fire from its mouth and nostrils, spears cannot pierce it, it makes the deep boil. Readings: a crocodile, a great marine reptile, or a symbol of evil (Isaiah 27:1).
4. $300 \times 50 \times 30$ cubits = $450 \times 75 \times 45$ feet. Noah needed only each kind (about 50-90 dinosaur kinds), and young animals were much smaller.
5. The animals were buried quickly in water-laid sediment. Young-earth geologists read it as the work of the global Flood.
6. Any two: the mušḫuššu of Babylon's Ishtar Gate, Herodotus's winged serpents, Beowulf's dragon, Saint George, the Chinese dragon. Explanations: memories of real dinosaurs living with people after the Flood, or people finding fossils.
7. The iridium layer, shocked quartz and the Chicxulub crater (and the Deccan Traps). Young-earth view: most died in the Flood, and the kinds on the Ark died out afterward from a changed climate, loss of food, competition and hunting.
8. Known starting amounts, a constant decay rate, and a closed system.
9. Flexible tissue, vessel-like and cell-like structures, and protein fragments such as collagen. She proposed that iron from blood cross-linked and preserved the proteins.
10. Any one: light, air-filled sauropod vertebrae; self-replacing dental batteries; breathing pores in eggshells; the strong, light T. rex skull. These show God's wisdom and power "clearly seen ... by the things that are made" (Romans 1:20); "marvellous are thy works" (Psalm 139:14).

DINOSAURS TRAIL E: SEA AND SKY REPTILES, AND THE ICE AGE

The fifth trail of the Dinosaurs track leaves the dinosaurs themselves and visits their neighbors in the fossil record: the ichthyosaurs, plesiosaurs and mosasaurs of the sea; the pterosaurs of the sky, with the giant Quetzalcoatlus; and then the great animals of the Ice Age: woolly mammoths, saber-toothed cats and giant ground sloths, ending at the La Brea Tar Pits of Los Angeles. The last stop asks the student to build a small museum display of their own. Along the way students meet the people who found these animals, from Mary Anning and Georges Cuvier to Thomas Jefferson, Douglas Lawson and an eleven-year-old fossil hunter in 2020.

This is the  **Ranger** level, for ages 10 to 13. The student reads each stop alone and works through it in 25 to 35 minutes: a story with facts, dates and numbers, five key terms, a picture study, a hands-on project, a labeled diagram and a paragraph for the Field Notebook, five practice questions with answers, a game and a verse of Scripture (KJV). The track is creation-friendly: God made the great sea creatures and the flying creatures on the fifth day and the land animals on the sixth (Genesis 1:20–25). Museum words such as **Triassic**, **Cretaceous** and **Ice Age** are taught so students can read any sign, and dates are labeled as interpretations. Stops E1, E6, E9 and E10 include the  box: *What the sign says / What we observe / How Christians read it.*

Five stops earn the **Sea and Sky Ranger badge**, and ten stops earn the **Ice Age Ranger badge** and the **Trail E certificate**. The two badge quizzes at the end of the trail are optional; badges are earned by doing the stops.

BEFORE YOU BEGIN

- Read a page of about 500 words on your own and write a paragraph about it.
- Know the difference between an observation and an interpretation (Trail B, Stop B10, or Trail D, Stop D8), and find Europe, North and South America and Siberia on a world map.

MASTERY CHECKLIST

- ☐ I can tell an ichthyosaur, a plesiosaur, a mosasaur and a pterosaur apart, and explain why none of them was a dinosaur.
- ☐ I can describe how a pterosaur's wing was built and compare Quetzalcoatlus's wingspan with a bald eagle and the Wright Flyer.
- ☐ I can name three features of woolly mammoths, saber-toothed cats and giant ground sloths and the evidence (bones, frozen bodies, dung, footprints) that tells us about them.
- ☐ I can explain how the La Brea asphalt trapped animals and why meat-eaters outnumber plant-eaters there.

- ☐ I can write an honest museum label that keeps what we observe apart from how it is interpreted, including dates.

OPTIONAL BOOKS AND RESOURCES

- **La Brea Tar Pits and Museum** (<https://tarpits.org>): Free pages, photos and live views of Project 23 and the excavations; used with Stops E7 and E9.
- **Natural History Museum, London: Discover** (<https://www.nhm.ac.uk/discover.html>): Free articles on ichthyosaurs, plesiosaurs, pterosaurs and mammoths, including the 2024 Ichthyotitan find.
- **Big Bend National Park (National Park Service)** (<https://www.nps.gov/bibe>): Fossil pages about Quetzalcoatlus and the park where it was found (Stop E5).
- **Biodiversity Heritage Library** (<https://www.biodiversitylibrary.org>): Free scans of old books by Cuvier, Faujas de Saint-Fond, Figuier and Thomas Hawkins, with the pictures used on this trail.

5.1 ICHTHYOSAURS: THE FISH LIZARDS

OBJECTIVES

- Describe the body plan of an ichthyosaur and explain how its eyes, tail and flippers fit life in the open sea.
- Tell what fossils of mothers with babies show about how ichthyosaurs were born, and the story of the giant Ichthyotitan found in 2020.
- Draw and label an ichthyosaur diagram and compare its shape with a dolphin and a shark.

Warm-up. Cup your hands around your eyes like goggles and look at a dinner plate. Some ichthyosaur eyes were about as wide as that plate, around 10 inches (25 cm) across: the biggest eyes known in any animal with a backbone. Why might an animal need eyes that big?

Video slot. Video coming. Ichthyosaur fossils: Holzmaden mothers with babies, giant eyes, and the 2024 Ichthyotitan jawbone from Somerset. Search approved channels (Natural History Museum London, University of Manchester, Smithsonian, Answers in Genesis once vetted); preview first.

KEY TERMS

ichthyosaur

A sea reptile with a dolphin-like body, a long toothy snout, four flippers and a fish-like tail; the name means “fish lizard” (say “ICK-thee-o-sore”). It was not a dinosaur.

marine reptile

A reptile that lives in the sea, such as a sea turtle today or an ichthyosaur, plesiosaur or mosasaur in the fossil record.

sclerotic ring

A ring of small bony plates inside the eye that supports the eyeball. Ichthyosaur fossils often preserve it.

live birth

Giving birth to babies instead of laying eggs. Ichthyosaurs could not crawl onto land, so their babies were born in the water.

convergence

When very different animals share a similar shape because they live in a similar way, such as the streamlined bodies of ichthyosaurs, dolphins and sharks.

CORE IDEAS

A puzzle on the beach. In 1811 and 1812, Joseph and Mary Anning dug a strange skeleton out of the cliffs at Lyme Regis in England (Trail B, Stop B1). It had a long snout full of teeth,

vertebrae like a fish's and paddles instead of feet. In 1819 Charles König of the British Museum named it **Ichthyosaurus**, "fish lizard." Since then, scientists have described more than a hundred kinds of ichthyosaurs from every continent, including Antarctica.

Built for speed. An ichthyosaur looks so much like a dolphin that it can fool you. It had a smooth, streamlined body, a fin on its back, front flippers for steering and a tall tail fin shaped like a half-moon. Unlike a dolphin's tail, which beats up and down, an ichthyosaur's tail fin stood upright and swept side to side, like a shark's. A reptile, a mammal and a fish with the same basic shape is called **convergence**: the same wise design for moving fast through water. Inside each flipper, the finger bones were packed together like cobblestones, sometimes with extra fingers and extra rows of bones.

Eyes for the deep. Ichthyosaurs had huge eyes held in shape by a **sclerotic ring** of bony plates. The eye of *Temnodontosaurus*, which grew to about 30 feet (9 m) long, measured about 10 inches (25 cm) across. *Ophthalmosaurus*, whose name means "eye lizard," had eyes about 9 inches (23 cm) wide in a body only about 13 feet (4 m) long. Big eyes gather more light, so many scientists think these animals hunted squid-like animals in deep or dim water.

Babies in the water. At Holzmaden in southern Germany, quarry workers have split open slate and found ichthyosaur mothers with tiny skeletons inside them, and some with a baby partly born. Most babies came out tail first, as dolphin calves do, so that they would not drown before they were fully born. A 2018 study of a *Stenopterygius* from Holzmaden found traces of smooth skin, a layer of fat like blubber, and dark pigment on the back, lighter below. These finds tell us ichthyosaurs gave **live birth** and were warm-bodied swimmers.

An eleven-year-old's giant. In May 2020, Ruby Reynolds, age eleven, was hunting fossils with her father, Justin, at Blue Anchor in Somerset, England, when she spotted a chunk of bone. Together they found more pieces of a jawbone more than 6.5 feet (2 m) long. In April 2024, scientists named it **Ichthyotitan severnensis**, "giant fish lizard of the Severn." They estimate the animal was about 82 feet (25 m) long, close to the size of a blue whale, and still growing.

Who made the sea creatures? Genesis 1:21 says God created the great creatures of the sea on the fifth day, before the land animals. Ichthyosaurs are found only as fossils today; no one has seen a living one. But their bodies show careful design: eyes for darkness, tails for speed and mothers that bore living young. Psalm 104 calls the sea a place "wherein are things creeping innumerable, both small and great beasts."

PICTURE STUDY



Ichthyosaurus and Plesiosaurus, from The World Before the Deluge, Édouard Riou, 1863 · Wood engraving (book illustration) · From Louis Figuier, La Terre avant le déluge (Paris, 1863), published in English as The World Before the Deluge
Wikimedia Commons · Public domain

Édouard Riou was a French illustrator who also drew pictures for Jules Verne's adventure novels. For Louis Figuier's popular science book of 1863, he drew scenes of the ancient world. This is one of the most famous: an ichthyosaur and a plesiosaur locked in battle at the surface of the sea.

Look closely

- Find the ichthyosaur. Is its tail drawn the way we now know it was, with a tall half-moon fin, or as a plain pointed tail?
- Look at the waves and sky. How did Riou make the scene feel dramatic?
- Find the ichthyosaur's eye. Did Riou draw it large or small?

Talk about it

1. The tail fin of an ichthyosaur was first seen in skin outlines found at Holzmaden in the 1890s, after this picture was made. Why would an artist in 1863 get the tail wrong?
2. Which parts of this picture come from bones (observation) and which from the artist's imagination (interpretation)?

HANDS-ON: THREE SWIMMERS, ONE SHAPE

Make a labeled comparison diagram of an ichthyosaur, a dolphin and a shark to see convergence for yourself.

You will need

- A large sheet of paper and a ruler
- Pencil and colored pencils
- Pictures of a dolphin, a shark and an ichthyosaur skeleton (library book or museum website)

Steps

1. Draw a line across the paper in three rows. In each row draw one animal from the side, all about the same length.
2. Label on each: snout, eye, back fin, front flipper or fin, tail fin, and nostril or blowhole.
3. Add an arrow on each tail to show which way it beats: up and down (dolphin) or side to side (shark and ichthyosaur).
4. Under each animal write what kind of creature it is (mammal, fish, reptile) and how it breathes (air through a blowhole, water through gills, air through nostrils near the eyes).
5. Circle in red the features all three share.

Check your work

- All three animals are drawn from the side and labeled with at least five parts.
- My tail arrows are correct.
- I can explain the word convergence in my own words.

FIELD NOTEBOOK

1. **Diagram.** Draw an ichthyosaur skeleton from the side. Label: snout and teeth, sclerotic ring in the eye, nostril, backbone, front flipper with packed finger bones, back flipper, and the bend in the backbone where it turns down into the lower lobe of the tail. Draw the outline of the flesh fin around the bones in dotted lines.
2. **Notebook entry.** Write a paragraph of five or six sentences: "How an Ichthyosaur Was Made for the Sea." Give at least three features with the job each did, and include one number (eye size, body length or the Ichthyotitan jaw).

Did you know? Early collectors were puzzled that the backbone of many ichthyosaur skeletons had a sharp kink near the tail. Some thought it was damage. Then fossils with skin outlines showed that the backbone bent down into the lower half of the tail fin, while the upper half had no bones at all, only tough flesh.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** "Ichthyotitan lived in the Late Triassic, about 202 million years ago." **What we observe:** a huge jawbone in a layer of rock on the Somerset coast; ichthyosaur skeletons in many layers around the world, some with babies inside, buried whole and fast enough to keep skin outlines. **How Christians read it:** many young-earth Christians read layers full of sea reptiles as laid down during the Flood about 4,300 years ago, which

would explain quick burial and fine preservation. Most geologists date the layers by radiometric methods that assume constant decay rates, known starting amounts and closed systems. “Triassic” is a museum word for a group of rock layers; learn it so you can read any sign, and remember that the date is an interpretation.

Map or diagram. On a map of Europe, mark Lyme Regis and Blue Anchor (both in southwest England) and Holzmaden (near Stuttgart, Germany). On a world map, add Berlin-Ichthyosaur State Park in Nevada, USA, where giant *Shonisaurus* skeletons lie in a rock quarry.

Goes deeper in. Life Science, the reptiles and sea animals units; Earth Science, the fossils and rock layers units (coming soon). Stop E2 meets the plesiosaurs, and Trail B, Stop B1 tells Mary Anning’s story.

For families. Facts follow the Natural History Museum, London, and the University of Manchester (Lomax et al., *PLOS ONE*, April 2024) for Ichthyotitan; its length is an estimate from a partial jaw. The skin and blubber study is Lindgren et al., *Nature* (2018). Eye sizes follow Motani, Rothschild and Wahl, *Nature* (1999). The aside gives the young-earth reading as the course’s position alongside the mainstream date, as the track’s ⌚ policy asks.

PRACTICE

1. **EASY** What does “ichthyosaur” mean, and was it a dinosaur?
2. **EASY** Which way did an ichthyosaur’s tail fin beat, and which modern animal’s tail beats the same way?
3. **MEDIUM** Name two kinds of evidence that ichthyosaurs gave live birth.
4. **MEDIUM** *Ophthalmosaurus* was about 13 feet (4 m) long, and its eye was about 9 inches (23 cm) across. About how many eye-widths long was its body? (1 foot = 12 inches.)
5. **CHALLENGE** Ichthyotitan is known only from pieces of jawbone, yet scientists estimate it was about 82 feet (25 m) long. How could they make that estimate, and why should we call it an estimate rather than a measurement?

Make it a game · Eyes in the Deep. Darken a room and hide five paper “squid” around it. One player is the ichthyosaur with “big eyes” (a dim flashlight) and the other has “small eyes” (no light). Each has one minute to find squid. Switch roles, then talk about why big eyes help in dark water.

Scripture. “So is this great and wide sea, wherein are things creeping innumerable, both small and great beasts. There go the ships: there is that leviathan, whom thou hast made to play therein.” (Psalm 104:25–26, KJV)

The psalmist praises God for the great creatures of the sea. Ichthyosaurs, large and small, were part of that “great and wide sea” God made and filled.

Practice: answers

1. "Fish lizard." No; it was a marine reptile, not a dinosaur.
2. Side to side, like a shark's (a dolphin's beats up and down).
3. Fossil mothers with small skeletons inside their bodies, and at least one mother with a baby partly born, tail first (Holzmaden, Germany). Also, their flippers could not carry them onto land to lay eggs.
4. $13 \times 12 = 156$ inches; $156 \div 9 \approx 17$. Its body was about 17 eye-widths long.
5. They compared the size of the jawbone with the same bone in smaller ichthyosaurs whose whole skeletons are known, and scaled up. It is an estimate because no complete skeleton has been found; body proportions could have been different.

5.2 PLESIOSAURS: FOUR FLIPPERS AND A LONG NECK

OBJECTIVES

- Tell the difference between long-necked plesiosaurs and short-necked, big-headed pliosaurs, with one example of each.
- Explain how four flippers worked for “underwater flight,” and what the 2011 *Polycotylus* fossil shows about plesiosaur babies.
- Tell the story of Cope’s *Elasmosaurus* mistake and what it teaches about correcting errors.

Warm-up. Hold your arms out like wings and slowly “fly” them up and down, twisting your hands a little on each stroke. Sea turtles and penguins move their flippers this way to fly through water. Now imagine doing it with four flippers instead of two.

Video slot. Video coming. Plesiosaurs and pliosaurs: *Elasmosaurus*, the *Polycotylus* mother and baby, how four flippers swim. Search approved channels (Natural History Museum of Los Angeles County, Natural History Museum London, Smithsonian, Answers in Genesis once vetted); preview first.

KEY TERMS

plesiosaur

A sea reptile with a broad, flat body, four long flippers and a short tail; many had very long necks and small heads. The name means “near to a lizard.” It was not a dinosaur.

pliosaur

A kind of plesiosaur with a short neck and a huge head with strong jaws, such as *Liopleurodon* and *Kronosaurus* (say “PLY-o-sore”).

vertebra (plural vertebrae)

One of the small bones that link together to make the backbone and neck.

gastrolith

A “stomach stone”: a stone an animal swallowed, found among its ribs. Plesiosaurs may have used them to grind food or help control floating.

hoax

A trick made to fool people into believing something false.

CORE IDEAS

“A snake threaded through a turtle.” In December 1823, Mary Anning uncovered the first nearly complete skeleton of a creature with a small head, a neck longer than its body, a broad trunk and four great paddles. In 1824 William Conybeare named it ***Plesiosaurus***, “near to a lizard.” The neck was so strange that the famous French anatomist Georges

Cuvier at first suspected a fake, until he studied the drawings and agreed it was real. A later writer said a plesiosaur looked like “a snake threaded through the shell of a turtle.”

Two body plans. Scientists sort the plesiosaurs into two broad shapes. Long-necked kinds, like *Elasmosaurus* of Kansas, had tiny heads and necks of up to 70 or more **vertebrae**; the neck alone of *Elasmosaurus* was about 23 feet (7 m) long in an animal about 34 feet (10 m) long. Short-necked **pliosaurs**, like *Liopleurodon* of England and *Kronosaurus* of Australia, had skulls up to about 7 to 8 feet (2 m or more) long and teeth as big as bananas. The long-necks likely snapped up fish and squid; the pliosaurs were top hunters.

Flying underwater. No living animal swims with four big flippers, so how did plesiosaurs move? Their flippers were long, stiff and shaped like wings. Most scientists think they “flew” through the water, as sea turtles and penguins do, with a twist on each stroke. Studies with swimming robots suggest the back flippers gained extra push from the swirl of water left by the front ones. Many skeletons have smooth stones, **gastroliths**, among their ribs.

A mother and her baby. In 2011, scientists at the Natural History Museum of Los Angeles County described a fossil of the plesiosaur *Polycotylus*, dug up in Kansas in 1987. Inside the mother, about 15 feet (4.7 m) long, lay one large unborn baby, already about a third of her length. Plesiosaurs, like ichthyosaurs, gave live birth, and they seem to have had one big baby at a time, as whales do.

The head on the tail. In 1868 the American scientist Edward Drinker Cope described *Elasmosaurus* and drew it with the head on the end of its tail! He thought the long series of vertebrae was the tail. His rival Othniel Marsh and the anatomist Joseph Leidy pointed out the mistake, and Leidy showed in 1870 that the head belonged on the neck. Cope tried to buy up the copies of his paper. The error fed the bitter Bone Wars (Trail B, Stop B6). The lesson: everyone makes mistakes, and an honest scientist corrects them quickly.

The Loch Ness story. For a century, people have said a plesiosaur might live in Loch Ness, Scotland. The famous 1934 “Surgeon’s Photograph” of a long neck rising from the water was admitted in 1994 to be a **hoax**, made with a toy submarine and a model head. A careful student tests a claim before believing it.

PICTURE STUDY



The Sea Dragons as They Lived, John Martin, 1840 · Mezzotint (frontispiece) · From Thomas Hawkins, *The Book of the Great Sea-Dragons* (London, 1840)
Wikimedia Commons · Public domain

John Martin was an English painter famous for huge, dramatic Bible scenes such as the Flood and the fall of Babylon. In 1840 the fossil collector Thomas Hawkins asked him to picture the “great sea-dragons” for the front of his book. Martin made them look like monsters from an ancient story.

Look closely

- Find a long-necked plesiosaur. How many flippers can you see on it?
- Where does the light come from? What does Martin keep in shadow?
- Look at the rocks and the sky. Does this feel like a calm sea or a frightening one?

Talk about it

1. Compare Martin’s plesiosaurs with what you now know. What would you change to make them more accurate?
2. Why do you think artists of the 1800s showed sea reptiles always fighting?

HANDS-ON: PAPER PLESIOSAUR TO SCALE

Build a flat paper model of *Elasmosaurus* at 1/10 scale to feel how long that neck really was.

You will need

- A roll of paper or taped-together sheets (at least 3.5 m long)
- A tape measure and a marker

- Scissors and tape

Steps

1. At 1/10 scale, Elasmosaurus (about 10.3 m) becomes 103 cm. Mark a line 103 cm long on the floor paper.
2. Mark the neck: 70 cm. Mark the head: about 4 cm. The trunk and tail take the rest.
3. Draw a broad oval trunk about 20 cm wide and four wing-shaped flippers, each about 20 cm long.
4. Cut it out. Then lay a 1/10-scale outline of yourself beside it (your height $\div$ 10).
5. Challenge: count how many of your own neck lengths fit into Elasmosaurus's real neck (7 m).

Check your work

- My model is 103 cm long with a 70 cm neck.
- It has four flippers and a short tail.
- I can explain what scale 1/10 means.

FIELD NOTEBOOK

1. **Diagram.** Draw two plesiosaurs side by side from above: a long-necked elasmosaur and a short-necked pliosaur. Label on each: head, neck, front flippers, back flippers, trunk, tail. Add the lengths (Elasmosaurus about 10 m, neck 7 m; a pliosaur skull up to about 2 m). Draw arrows showing the up-and-down “flying” stroke of a flipper.
2. **Notebook entry.** Write a paragraph: “The Head on the Wrong End.” Tell what Cope did, who corrected him, and what you think he should have done when he learned of his mistake.

Did you know? Plesiosaurs could probably not lift their long necks high out of the water like a swan, as old pictures show. Studies of how the neck bones fit together suggest the neck was fairly stiff and was held out in front, reaching down or sideways to catch fish.

Map or diagram. On a world map, mark where the plesiosaurs in this stop were found: Lyme Regis, England (Plesiosaurus); western Kansas, USA (Elasmosaurus and Polycotylus); Queensland, Australia (Kronosaurus). Then mark Loch Ness in Scotland and write “1934 hoax” beside it.

Goes deeper in. Life Science, the reptiles and sea animals units (coming soon). Trail B, Stops B1 and B6 tell of Mary Anning and the Bone Wars.

For families. Elasmosaurus measurements follow Sachs, Kear and Everhart (2013). The Polycotylus find is O’Keefe and Chiappe, *Science* (August 2011). The Loch Ness photograph was revealed as a hoax in 1994 when one of the men involved told how it was made. Some creation writers have suggested plesiosaurs could survive today; the stop simply teaches students to test claims and does not take up the question further.

PRACTICE

1. **EASY** What is the difference between a long-necked plesiosaur and a pliosaur?
2. **EASY** Who found the first nearly complete plesiosaur, and when?
3. **MEDIUM** What did the *Polycotylus* fossil described in 2011 show?
4. **MEDIUM** *Elasmosaurus* was about 10.3 m long and its neck about 7 m. About what fraction of its length was neck?
5. **CHALLENGE** Cope's mistake and the Loch Ness photograph were both errors. How were they different, and what habit protects against both?

Make it a game · Head or Tail? One player lays out a row of 15 to 20 blocks or spoons as a “backbone” and secretly decides which end is the head. The others ask yes-or-no questions (“Are the bones at this end getting smaller?”) to discover which end is the neck. Talk about what clues Leidy used: the shape of each vertebra and where the hip and shoulder bones sat.

Scripture. “And God created great whales, and every living creature that moveth, which the waters brought forth abundantly, after their kind, and every winged fowl after his kind: and God saw that it was good.” (Genesis 1:21, KJV)

The Hebrew word translated “great whales” means great sea creatures. On the fifth day God filled the waters, and the plesiosaurs, strange as they look, were part of what He called good.

Practice: answers

1. A long-necked plesiosaur had a small head on a very long neck; a pliosaur had a short neck and a huge head with powerful jaws.
2. Mary Anning, in December 1823, at Lyme Regis, England.
3. A mother with one large unborn baby inside, so plesiosaurs gave live birth, probably to one big baby at a time.
4. $7 \div 10.3 \approx 0.68$, so about two-thirds of its whole length.
5. Cope made an honest mistake about the bones; the photograph was a deliberate hoax. Both were caught by testing: checking the evidence again and letting others examine it. Proving all things (1 Thessalonians 5:21) protects against both.

5.3 MOSASAURS: THE GREAT LIZARD OF THE MEUSE

OBJECTIVES

- Tell the history of the Maastricht skull, from the chalk quarry to Paris, and why it changed how people thought about extinct animals.
- Describe three features of a mosasaur’s head and body that made it a top sea hunter.
- Draw and label a mosasaur skull diagram that shows its double-hinged jaw and the extra teeth on the roof of its mouth.

Warm-up. Try to swallow a big bite of apple without chewing (only pretend, please!). Snakes and mosasaurs had jaws that could flex and teeth that pointed backward to “walk” large prey down the throat without chewing at all.

Video slot. Video coming. Mosasaurs: the Maastricht skull, Tylosaurus from the Kansas chalk, mosasaur jaws and tail fins. Search approved channels (Natural History Museum Maastricht, Sternberg Museum of Natural History, Smithsonian, Answers in Genesis once vetted); preview first.

KEY TERMS

mosasaur

A large sea reptile with a long body, a long skull full of teeth, four paddle-like flippers and a tail with a fin. The name means “lizard of the Meuse,” a river in the Netherlands (say “MOE-za-sore”). It was not a dinosaur.

chalk

A soft, white rock made mostly of the tiny shells of sea creatures. Many mosasaurs are found in chalk in the Netherlands and Kansas.

pterygoid teeth

Extra rows of teeth on the roof of the mouth that helped a mosasaur grip and swallow prey, as in many snakes (say “TER-ih-goyd”).

extinction

When every member of a kind of living thing has died, so that the kind no longer lives anywhere on earth.

fluke

A wide, flat fin at the end of a tail that pushes an animal through water.

CORE IDEAS

A monster in the quarry. Under a hill near Maastricht, in the Netherlands, men cut blocks of soft chalk from tunnels for building. In 1764 workers there found pieces of a huge jaw. Around 1770–1774 another skull was found, more than 3 feet (1 m) long, with sharp curved teeth. A local doctor, Johann Hoffmann, collected it, but the landowner, a church official

named Godding, went to court and won the skull for himself. People argued about what it was: a crocodile? a whale? a giant fish?

Captured by an army. In 1794 a French army besieged Maastricht. A famous story says the French offered the soldiers 600 bottles of wine for the skull, unbroken. Whether or not that is true, the skull was taken to the National Museum of Natural History in Paris in 1795, where it still is. In 1808 Georges Cuvier showed that it was a giant sea lizard, related to the monitor lizards. In 1822 William Conybeare named it **Mosasaurus**, “lizard of the Meuse,” after the nearby river.

Why it mattered. Before 1800, many scholars doubted that any kind of animal God made could ever die out completely. The Maastricht skull, with mammoth bones and others, helped Cuvier show that **extinction** was real: no lizard that big swims in any sea today. Christians came to see that this fits a world marred by the Fall and the Flood, where death and loss are real (Romans 8:20-22).

A hunter’s head. A mosasaur’s lower jaw had a hinge in the middle of each side, so the jaw could flex outward. Besides the teeth along its jaws, it had two more rows of backward-pointing **pterygoid teeth** on the roof of its mouth. Like a snake, it could “walk” prey down its throat. Fossils show what mosasaurs ate: fish, squid-like animals, sea turtles, birds, sharks, plesiosaurs and even smaller mosasaurs. A *Tylosaurus* from Kansas was found with the bones of a diving bird in its stomach.

Sizes and shapes. Many mosasaurs were 10 to 20 feet (3 to 6 m) long, but *Mosasaurus hoffmannii* reached about 40 feet (12 m), perhaps more, and *Tylosaurus* from the Kansas chalk about 40 feet as well. In 2013 a mosasaur skeleton from Jordan was found with the outline of a shark-like tail **fluke**. Other fossils show mosasaurs gave live birth, and tiny newborn mosasaurs have been found in rocks laid down in the open sea.

The chalk of Kansas. In the late 1800s, collectors such as Charles H. Sternberg and his sons dug hundreds of mosasaurs from the chalk of western Kansas, far from any ocean today. Mosasaurs, plesiosaurs and sea birds lie together there. A sea once covered the middle of North America. Many creation geologists read these chalk layers as laid down while the waters of the Flood covered the land.

PICTURE STUDY



The Great Fossil Animal of the Maastricht Quarries (the discovery of the Mosasaurus skull), G. R. Levillaire (engraver), for Barthélemy Faujas de Saint-Fond, 1799 · Engraving (book plate) · From Faujas de Saint-Fond, *Histoire naturelle de la montagne de Saint-Pierre de Maestricht* (Paris, 1798-1799)
Wikimedia Commons · Public domain

Faujas de Saint-Fond was a French geologist who wrote a large book about the hill of Saint Peter at Maastricht and its fossils. For this plate, the engraver Levillaire pictured the famous skull being discovered inside the quarry tunnels, with gentlemen and workmen gathered around it.

Look closely

- Find the skull in the rock. How do the men show us how big it is?
- Find the light source in the tunnel. Why would the quarry need lamps or torches?
- Look at the clothes. What do they tell you about when the picture was made?

Talk about it

1. The artist was not there when the skull was found. What parts of the scene might be imagined?
2. Why would a picture like this help people believe the skull was real and important?

HANDS-ON: SNAKE-JAW SWALLOWING MODEL

Build a cardboard model of a mosasaur's jaw to see how the middle hinge and backward teeth help it swallow.

You will need

- Two strips of stiff cardboard, about 30 cm by 5 cm each

- Two brass paper fasteners
- Toothpicks or cut drinking straws
- Glue or tape, a pencil and a ruler

Steps

1. Cut each cardboard strip in half across the middle. Rejoin the halves with a paper fastener so each “jaw” bends in the middle.
2. Glue toothpick “teeth” along one edge of each jaw, all leaning back toward the throat end.
3. Join the two jaws at the front with tape, so they form a V that can spread apart.
4. Push a rolled-up sock (the prey) into the V. Move one side forward and back, then the other. Watch the backward teeth pull the sock in but not let it slide out.
5. Label the front tip, the middle hinge and the throat end.

Check your work

- Each jaw bends at the middle hinge.
- All the teeth point back toward the throat.
- I can explain why backward teeth help a hunter that swallows prey whole.

FIELD NOTEBOOK

1. **Diagram.** Draw a mosasaur skull from the side. Label: snout, nostril opening, eye socket, jaw teeth, the hinge in the middle of the lower jaw, the pterygoid teeth on the roof of the mouth (shown with dotted lines), and the joint at the back of the jaw. Add a scale bar: “Maastricht skull, about 1 m long.”
2. **Notebook entry.** Write a paragraph: “The Skull that Proved Extinction.” Tell where and when it was found, how it reached Paris, who named it and why it mattered.

Did you know? Mosasaurs are close cousins of today’s monitor lizards and snakes. The Komodo dragon of Indonesia, the largest living lizard, is a monitor lizard, so it is a good living picture of a mosasaur’s head.

Map or diagram. On a map of Europe, follow the Meuse River from France through Belgium to Maastricht in the Netherlands. Draw an arrow from Maastricht to Paris and label it “Skull taken, 1795.” On a map of the United States, shade western Kansas and label it “Niobrara Chalk: mosasaurs, plesiosaurs, Pteranodon.”

Goes deeper in. Earth Science, the rocks and fossils units (chalk and limestone); History, the French Revolutionary Wars (coming soon). Stop E4 meets Pteranodon, also from the Kansas chalk.

For families. Dates follow the Natural History Museum Maastricht and Mulder’s histories: first finds 1764; the Hoffmann skull about 1770–1774 (Faujas’s account, which historians think he embellished); taken by the French in 1794 and sent to Paris in 1795;

Cuvier's study 1808; Conybeare's name 1822. The 600 bottles of wine is told as a story because only Faujas reports it. The tail fluke is Lindgren et al., *Nature Communications* (2013). The museum name "Maastrichtian" for the top Cretaceous layers comes from this hill; no dates are used in this stop.

PRACTICE

1. **EASY** What does "Mosasaurus" mean?
2. **EASY** Name two features of a mosasaur's mouth that helped it swallow big prey.
3. **MEDIUM** Put in order: Conybeare names Mosasaurus; the French army takes the skull; Cuvier shows it is a giant lizard; the skull is found.
4. **MEDIUM** Why did the Maastricht skull help convince scientists that extinction is real?
5. **CHALLENGE** Mosasaur fossils are found in the middle of Kansas, more than 600 miles from the nearest ocean. Give the observation and two possible interpretations.

Make it a game · Mosasaur Menu. Make cards for prey found inside or bitten by mosasaurs (fish, squid-like ammonite, sea turtle, diving bird, shark, plesiosaur, smaller mosasaur) and three that were not on the menu (pinecone, mammoth, grasshopper). Shuffle. Players take turns drawing a card and saying "On the menu!" or "Not on the menu!" with a reason.

Scripture. "The LORD on high is mightier than the noise of many waters, yea, than the mighty waves of the sea." (Psalm 93:4, KJV)

The mosasaur was one of the mightiest hunters of the sea, yet the Lord who made the sea and all its creatures is mightier still.

Practice: answers

1. "Lizard of the Meuse," after the river near Maastricht where it was found.
2. A hinge in the middle of each side of the lower jaw, and extra rows of backward-pointing teeth (pterygoid teeth) on the roof of its mouth.
3. Skull found (about 1770-1774); French take it (1794-1795); Cuvier's study (1808); Conybeare names it (1822).
4. It was a sea lizard far larger than any lizard alive anywhere today, so its kind must have died out completely.
5. Observation: sea reptile bones, sea birds and shells lie in chalk in Kansas. Interpretations: mainstream geologists say a shallow inland sea covered the middle of North America over long ages; many creation geologists say the chalk was laid down when Flood waters covered the continent. Both agree the sea once covered Kansas.

5.4 PTEROSAURS: WING-FINGER REPTILES

OBJECTIVES

- Explain how a pterosaur's wing was built and how it differs from the wing of a bird and of a bat.
- Tell how Collini, Hermann and Cuvier figured out the first pterosaur fossil between 1784 and 1809.
- Compare three pterosaurs (Pterodactylus, Rhamphorhynchus and Pteranodon) by size, tail and teeth.

Warm-up. Hold up your hand and look at your ring finger. A pterosaur's whole wing hung from one hugely long finger: its fourth, the same one as your ring finger. If your ring finger were as long as a pterosaur's compared with its body, it would reach past your feet!

Video slot. Video coming. Pterosaurs: wing structure, Pterodactylus from Solnhofen, Pteranodon from Kansas, pterosaur trackways. Search approved channels (Natural History Museum London, American Museum of Natural History, Smithsonian, Answers in Genesis once vetted); preview first.

KEY TERMS

pterosaur

A flying reptile with wings of skin stretched from a very long fourth finger to the legs; the name means “winged lizard” (say “TER-o-sore”). Pterosaurs were not dinosaurs and not birds.

wing membrane

The thin, strong sheet of skin and muscle that formed a pterosaur's wing, stiffened by tiny fibers.

pteroid

A small rod-shaped bone found only in pterosaurs, at the wrist, that held up the front part of the wing.

pycnofibers

Fine hair-like fibers that covered the bodies of many pterosaurs, like fuzz (say “PIK-no-fibers”).

trackway

A line of footprints left by one animal as it walked.

CORE IDEAS

A puzzle in a palace. In the 1700s, quarry workers at Solnhofen in Bavaria split thin slabs of fine limestone for printing stones. In one slab lay a small skeleton with a long beak, sharp

teeth and enormously long fingers. It went to the natural history collection of the Elector Charles Theodore at Mannheim. In 1784 its keeper, the Italian Cosimo Alessandro Collini, described it. He was puzzled: it was not a bird or a bat, so he guessed it was some sea creature that swam with its long arms.

Three men solve it. In 1800 Jean Hermann, a professor in Strasbourg, wrote to Georges Cuvier with a sketch showing the long fourth finger holding up a wing of skin, a flying animal. Cuvier studied Collini's drawings and agreed. In 1801 and more fully in 1809 he named it the "Ptero-Dactyle," Greek for "wing finger." Today it is **Pterodactylus**. Each man built on the others' careful work.

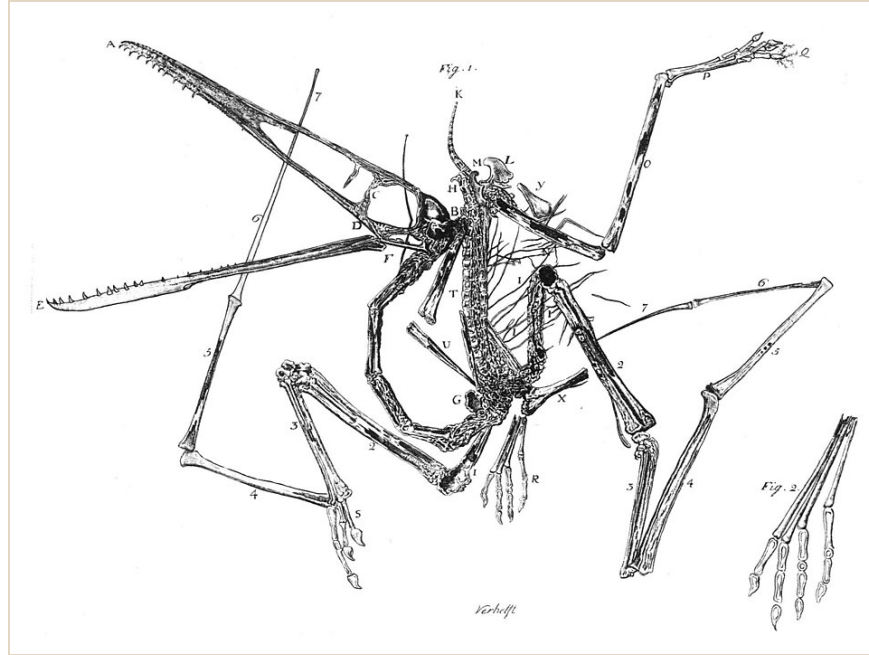
How the wing was built. A bird's wing is made of feathers on a fused hand. A bat's wing is skin stretched between five long fingers. A pterosaur's wing was different from both: the **wing membrane** hung from a single, huge fourth finger and ran back to the leg. A special bone, the **pteroideum**, held up a small front flap of wing near the wrist. Fossils from Solnhofen and Brazil show the membrane was stiffened with thin fibers and had muscle and blood vessels inside. Pterosaur bones were hollow with thin walls and air sacs, very light and very strong. Many had a fuzzy coat of **pycnofibers**.

Many shapes. More than 200 kinds of pterosaurs have been named. *Pterodactylus* was about the size of a crow, with a short tail and many small teeth. *Rhamphorhynchus*, also from Solnhofen, had a long, stiff tail ending in a diamond-shaped vane and forward-pointing teeth for catching fish. *Pterodactylus* of Argentina had about 1,000 bristle-like teeth to strain tiny food from water, like a flamingo. **Pteranodon**, found by O. C. Marsh's team in the Kansas chalk in 1870 and named in 1876, had no teeth at all (its name means "toothless wing"), a tall bony crest and wings about 18 to 23 feet (5.5 to 7 m) across.

Walking on all fours. How did pterosaurs move on the ground? **Trackways** found in France, the United States and elsewhere answer the question: small hand prints with three fingers beside long, narrow footprints. Pterosaurs walked on all four limbs, folding the great wing-finger up out of the way. Many scientists think they took off by vaulting up with their strong arms.

Made to fly. Genesis 1:20 says God made creatures to "fly above the earth in the open firmament of heaven." Birds, bats, insects and pterosaurs each fly in a different way, with a different wing. Engineers still study pterosaur wings to learn how a thin skin can hold up a large animal.

PICTURE STUDY



The first pterosaur fossil (Pterodactylus), plate from Collini's description, Cosimo Alessandro Collini (engraved plate), 1784 · Engraving · From Collini's paper in the Acta Academiae Theodoro-Palatinae (Mannheim, 1784)

Wikimedia Commons · Public domain

This is the very first published picture of a pterosaur. Collini had the skeleton engraved exactly as it lay in the stone, without guessing what the living animal looked like. That made it useful: Hermann and Cuvier, who never saw the fossil, could work from this picture.

Look closely

- Find the skull and the beak. Can you see teeth?
- Trace the longest bones with your finger. Where do they join the body?
- Look at the neck. Is it bent or straight?

Talk about it

1. Why is an exact drawing of a fossil “as found” more useful to scientists than a guess at the living animal?
2. Collini guessed the animal lived in the sea. What clue in the bones might have led Cuvier to say it flew?

HANDS-ON: THREE WINGS COMPARED

Build three simple wing models from paper and pipe cleaners to see how birds, bats and pterosaurs solved flight in different ways.

You will need

- Six pipe cleaners
- Tissue paper or thin plastic bags
- Clear tape and scissors
- A sheet of cardstock for labels

Steps

1. Bat wing: bend a pipe cleaner into an arm with five long fingers spread out. Tape tissue paper between all the fingers.
2. Pterosaur wing: bend a pipe cleaner into an arm with three short clawed fingers and one very long fourth finger. Tape tissue from the tip of the long finger back to a “leg” pipe cleaner.
3. Bird wing: make a short arm and hand, and tape paper “feathers” along the back edge.
4. Label each. Wave each wing gently. Which bends most? Which would tear most easily?

Check your work

- My pterosaur wing hangs from one long fourth finger and attaches to the leg.
- All three wings are labeled.
- I can explain one difference between each pair of wings.

FIELD NOTEBOOK

1. **Diagram.** Draw a pterosaur from above with its wings spread. Label: skull, neck, upper arm, forearm, wrist, pteroid bone, three small clawed fingers, the long fourth (wing) finger, wing membrane, leg, and the small membrane between the legs. Beside it, draw a bat and a bird wing in small boxes for comparison.
2. **Notebook entry.** Write a paragraph: “How the Wing Finger Was Discovered.” Tell what Collini, Hermann and Cuvier each did, with their years, and what this shows about working together.

Did you know? People often call any flying reptile a “pterodactyl,” but Pterodactylus is only one kind. Mary Anning found the first British pterosaur in 1828 at Lyme Regis; it was later named Dimorphodon. Pterosaur eggs found in China and Argentina show that babies hatched able to fly, or nearly so, very soon.

Map or diagram. On a world map, mark Solnhofen, Germany (Pterodactylus, Rhamphorhynchus); western Kansas, USA (Pteranodon); and San Luis Province, Argentina (Pterodaustro). Draw a line from Solnhofen to Mannheim and on to Paris to show where the first fossil and its pictures travelled.

Goes deeper in. Life Science, flight in birds, bats and insects (coming soon); Arithmetic, scale drawing. Stop E5 meets Quetzalcoatlus, the largest pterosaur.

For families. Dates follow the Biodiversity Heritage Library’s history of Pterodactylus: Collini 1784; Hermann’s letter 1800; Cuvier 1801 and 1809. The original fossil is now in

the Bavarian State Collection in Munich. Pteranodon wingspans vary between individuals; the stop gives the common range. Pterosaurs are a separate group from dinosaurs; museums usually show them together, which confuses students.

PRACTICE

1. **EASY** What does “Pterodactyl” mean, and which finger held up the wing?
2. **EASY** Were pterosaurs dinosaurs? Were they birds?
3. **MEDIUM** How do we know pterosaurs walked on all four limbs?
4. **MEDIUM** Pterodactylus was first described in 1784 and named by Cuvier in 1809. How many years passed between them? Who wrote to Cuvier in between?
5. **CHALLENGE** Make a comparison table for Pterodactylus, Rhamphorhynchus and Pteranodon with three columns: size, tail and teeth.

Make it a game · Bird, Bat or Pterosaur?. The leader reads a clue: “My wing hangs from one finger,” “I have feathers,” “I have five fingers in my wing,” “I walk on all fours with my wings folded,” “I hang upside down to sleep.” Players flap like a bird, fold their arms like a bat or hold up a ring finger for a pterosaur. Wrong guesses become the next clue-giver.

Scripture. “And God said, Let the waters bring forth abundantly the moving creature that hath life, and fowl that may fly above the earth in the open firmament of heaven.” (Genesis 1:20, KJV)

God made creatures to fill the sky as well as the sea. Birds, bats, insects and pterosaurs each fly with a different wing, and each wing works.

Practice: answers

1. “Wing finger.” The fourth finger (the same as our ring finger).
2. Neither. They were flying reptiles in their own group.
3. Fossil trackways show small three-fingered handprints beside long, narrow footprints.
4. 25 years. Jean Hermann wrote to Cuvier in 1800 with a sketch of the wing.
5. Pterodactylus: about crow-sized; short tail; many small teeth. Rhamphorhynchus: small to medium; long stiff tail with a diamond vane; forward-pointing fish-catching teeth. Pteranodon: wingspan about 5.5–7 m; short tail; no teeth (“toothless wing”) and a tall crest.

5.5 QUETZALCOATLUS: THE GIANT OF THE TEXAS SKY

OBJECTIVES

- Tell the story of Douglas Lawson’s 1971 find in Big Bend and how Quetzalcoatlus got its name.
- Use numbers to compare Quetzalcoatlus with a bald eagle, a giraffe and the Wright Flyer.
- Explain two ideas about how a giant pterosaur took off and how it found food, and which evidence supports each.

Warm-up. Take a tape measure outside and mark 33 feet (10 m) on the ground with two sticks. That is the wingspan of Quetzalcoatlus, nearly as long as a school bus and close to the width of the Wright brothers’ first airplane.

Video slot. Video coming. Quetzalcoatlus: size, discovery in Big Bend National Park, how giant pterosaurs launched into flight. Search approved channels (University of Texas Jackson School of Geosciences, National Park Service, Smithsonian, Answers in Genesis once vetted); preview first.

KEY TERMS

Quetzalcoatlus

One of the largest flying animals ever found, a pterosaur from Texas with a wingspan of about 33–36 feet (10–11 m) (say “KET-sal-co-AT-lus”).

azhdarchid

The family of giant pterosaurs with long, stiff necks, long beaks and no teeth, to which Quetzalcoatlus belongs (say “az-DAR-kid”).

wingspan

The distance from one wingtip to the other when the wings are spread.

type specimen

The particular fossil a species name is based on; scientists compare new finds with it.

quadrupedal launch

A takeoff that uses all four limbs, vaulting into the air with a push of the strong arms.

CORE IDEAS

A wing in the desert. In 1971, Douglas Lawson, a 22-year-old geology student at the University of Texas, was searching the dry hills of Big Bend National Park in southwest Texas for the bones of the giant dinosaur *Alamosaurus*. Instead he found pieces of an enormous wing: hollow bones far too thin-walled for a dinosaur. When he reported it in the journal *Science* in 1975, the animal was the largest flying creature anyone had ever found.

A name from Mexico. Lawson named it **Quetzalcoatlus northropi**. The first name comes from Quetzalcoatl, the “feathered serpent” worshiped as a sky god by the Aztecs of Mexico. The second honors Jack Northrop, an American aircraft designer who built “flying wing” airplanes without tails. The wing bones are the **type specimen**. Another, smaller kind with many bones, *Quetzalcoatlus lawsoni*, named in 2021 after Lawson himself, comes from the same park.

How big? From the long wing bones, scientists estimate a **wingspan** of about 33 to 36 feet (10 to 11 m), about five times that of a bald eagle. The Wright Flyer of 1903 had a wingspan of 40 feet 4 inches (12.3 m). Weight is harder to guess, because the bones were hollow: most recent estimates are about 400 to 550 pounds (about 200 to 250 kg). Standing on all fours, with its long neck raised, a big Quetzalcoatlus could look a giraffe in the eye.

A stalker on the ground. Quetzalcoatlus was an **azhdarchid**, with a long, stiff neck, a long toothless beak, and long legs. Many scientists think it walked on all fours across open ground, snapping up small animals as storks and ground hornbills do. A large study in 2021 compared it to a heron wading in shallow water. Both pictures fit a hunter that spent much of its time on foot.

Getting off the ground. How could so large an animal take off? Birds jump with their legs. But pterosaur arm bones were much stronger than their leg bones, so many scientists think pterosaurs used a **quadrupedal launch**: crouching on all fours, then vaulting up with the arms, like a pole-vaulter, opening the wings at the top. The 2021 study argued instead for a big leap with the legs. Scientists are still testing both ideas with computer models and bone strength.

Engineers take notice. In 1985 the inventor Paul MacCready built a half-size flying model of Quetzalcoatlus, with an 18-foot (5.5 m) wingspan, for a film about flight. It flew under remote control, flapping its wings, though it later crashed at an air show. People who design aircraft still look to the creatures God made for ideas.

PICTURE STUDY



*First Flight (the Wright Flyer, Kitty Hawk, December 17, 1903), John T. Daniels (photograph, set up by Orville Wright), 1903 · Glass-plate photograph · Library of Congress, Washington, D.C.
Wikimedia Commons · Public domain*

No one has ever seen a living Quetzalcoatlus, so this stop studies something about the same size that we do have a photograph of. Orville Wright set up his camera and asked John Daniels, a lifesaving station worker, to squeeze the bulb if the airplane lifted. Orville is flying; Wilbur runs beside the wingtip. The flight lasted 12 seconds and went 120 feet.

Look closely

- Find the long wooden rail the airplane took off from. Why did it need help getting started?
- Look at how wide the wings are compared with Wilbur. Quetzalcoatlus was almost as wide.
- Find the pilot. Where is he lying, and why might that help?

Talk about it

1. The Wright Flyer weighed about 600 pounds with its engine. Quetzalcoatlus may have weighed less with nearly the same wingspan. What do you think made that possible?
2. Why is a real photograph a stronger kind of evidence than a painting of a pterosaur?

Safety first. Draw the chalk chart only on a driveway or path away from traffic, with a grown-up's permission.

HANDS-ON: CHALK WINGSPAN COMPARISON

Draw a life-size wingspan chart on a driveway or sidewalk to compare flying creatures and machines.

You will need

- Sidewalk chalk in four colors
- A tape measure at least 25 feet long (or a string marked every foot)
- A notebook to record measurements

Steps

1. Draw a straight baseline about 45 feet (14 m) long.
2. From one end, mark and label these wingspans in different colors: bald eagle, 7 feet (2.1 m); Pteranodon, 20 feet (6 m); Quetzalcoatlus, 35 feet (10.5 m); Wright Flyer, 40 feet 4 inches (12.3 m).
3. Lie down at the start with your arms out. Have someone mark your arm span. Write your name beside it.
4. Find how many of your arm spans fit into the Quetzalcoatlus line. Write it in your notebook.
5. Draw a simple Quetzalcoatlus outline over its line: tiny body, long neck and head, wings to each end.

Check your work

- All four wingspans and my own arm span are marked and labeled.
- I worked out how many arm spans equal one Quetzalcoatlus wingspan.
- My outline shows the long neck and beak.

FIELD NOTEBOOK

1. **Diagram.** Draw a Quetzalcoatlus standing on all fours, side view, next to a giraffe and a person drawn to the same scale (person 5.5 feet, giraffe about 16 feet at the head). Label: beak, crest, long stiff neck, folded wing finger, hand, hind leg and foot. Add a second small drawing in four steps showing the “vault” takeoff: crouch, push with arms, legs leave the ground, wings open.
2. **Notebook entry.** Write a paragraph: “The Biggest Flyer.” Give its wingspan and weight estimates, compare it with the Wright Flyer, and explain the two ideas about how it took off.

Did you know? Even the biggest Quetzalcoatlus bones are surprisingly thin. Some pterosaur bones have walls only about as thick as a credit card, held strong inside by tiny struts. Another giant azhdarchid, Hatzegopteryx from Romania, may have been as big, with a heavier skull.

Map or diagram. On a map of Texas, find Big Bend National Park on the Rio Grande, where the river bends along the border with Mexico. Mark Austin, home of the University of Texas, where the bones are kept. Draw a line between them and measure the distance with the map scale (roughly 350 miles in a straight line).

Goes deeper in. Geography, the United States and Texas (coming soon); History, the Wright brothers and early flight (coming soon); Arithmetic, scale and measurement.

For families. Facts follow the University of Texas Jackson School of Geosciences and the 2021 Society of Vertebrate Paleontology Memoir on Quetzalcoatlus (Padian, Cunningham, Langston, Conway and others), which named *Q. lawsoni* and proposed a leg-powered launch. The quadrupedal launch idea is from Habib (2008) and Witton. Weight estimates vary widely in the literature; the stop gives a common recent range. The name honors an Aztec god; the stop states this as history, and the Scripture sets the creature beside its true Maker. The MacCready model (QN) flew for the 1986 IMAX film *On the Wing*.

PRACTICE

1. **EASY** Who found Quetzalcoatlus, where and when?
2. **EASY** Who are the two names in Quetzalcoatlus northropi taken from?
3. **MEDIUM** A bald eagle's wingspan is about 7 feet. Quetzalcoatlus's was about 35 feet. How many times wider?
4. **MEDIUM** Why do many scientists think pterosaurs launched with their arms instead of jumping with their legs like birds?
5. **CHALLENGE** Weight estimates for Quetzalcoatlus have ranged from about 150 pounds to over 1,000 pounds. Why is weight so hard to estimate from fossils, and what would help?

Make it a game • Vault and Fly. Players crouch on hands and feet like a pterosaur. On "Launch!" each pushes off with the arms and springs up, spreading arms wide, then "glides" to a line 10 steps away. Next round, launch with legs only. Talk about which felt stronger and why the bones matter. Play on grass and keep space between players.

Scripture. "Doth the eagle mount up at thy command, and make her nest on high?" (Job 39:27, KJV)

God asked Job whether he commanded the eagle to fly. People once named this giant flyer after a false god of the sky, but it was the one true God who made it and taught it to fly.

Practice: answers

1. Douglas Lawson, a University of Texas student, in Big Bend National Park, Texas, in 1971.
2. Quetzalcoatl, the Aztec feathered-serpent sky god, and Jack Northrop, a designer of "flying wing" aircraft.
3. $35 \div 7 = 5$, so about five times wider (four to five times, depending on the estimate).

4. Pterosaur arm bones were much stronger than their leg bones, so the arms could give a more powerful push.
5. The bones were hollow and full of air sacs, and the amount of muscle and flesh cannot be measured from bones alone; only a few bones of the biggest kind are known. More complete skeletons, comparisons with living flyers and computer models of bone strength would help.

5.6 WOOLLY MAMMOTHS

OBJECTIVES

- Describe five features God gave the woolly mammoth for life in a cold, dry grassland.
- Tell the story of Lyuba, the baby mammoth found in 2007, and what scientists learned from her.
- Explain the difference between a mammoth and a mastodon by their teeth, and read an Ice Age museum sign carefully.

Warm-up. Put one hand in a bowl of ice water for ten seconds. Then put on a thick mitten and try again. A woolly mammoth wore a “mitten” all over: thick fat, a woolly undercoat and long outer hair up to about 3 feet (90 cm) long.

Video slot. Video coming. Woolly mammoths: Lyuba the baby mammoth, mammoth teeth and tusks, the Mammoth Site of Hot Springs. Search approved channels (Field Museum, Smithsonian, The Mammoth Site of Hot Springs, Answers in Genesis or Institute for Creation Research once vetted); preview first.

KEY TERMS

woolly mammoth

An extinct elephant with long shaggy hair, small ears and long curved tusks that lived in the cold north of Europe, Asia and North America (*Mammuthus primigenius*).

mastodon

A different extinct elephant-like animal with cone-shaped bumps on its teeth for chewing twigs and leaves.

permafrost

Ground that stays frozen all year. Mammoth bodies have been kept in Siberian permafrost like a freezer.

steppe

A wide, dry, treeless grassland. Mammoths lived on a cold steppe full of grasses and wildflowers.

Ice Age

A time when great ice sheets covered much of the northern lands. It is a museum word you will see on signs; Christians read it as a time after the Flood.

CORE IDEAS

A baby in the riverbank. In May 2007, Yuri Khudi, a reindeer herder of the Nenets people, was walking with his three sons along a frozen river on the Yamal Peninsula in Arctic Russia when he saw a small, gray body lying on the sandbank. It was a baby mammoth, whole, with

her trunk, eyes and skin. He traveled to a nearby town to report the find, and he was allowed to name her. He called her **Lyuba**, after his wife.

What Lyuba taught. Lyuba was about a month old, about 33 inches (85 cm) tall and 110 pounds (50 kg). Scans showed milk from her mother still in her stomach, along with a little of her mother's dung, which elephant calves eat to gain helpful stomach bacteria. Her trunk and mouth were packed with fine mud. Scientists think she sank in soft mud by a riverbank and smothered, then was quickly buried and frozen in **permafrost**.

Built for the cold. A grown woolly mammoth stood about 9 to 11 feet (2.7 to 3.4 m) at the shoulder, about the size of an African elephant, and weighed around 6 tons. It had small ears and a short tail, so less heat escaped; a layer of fat up to 4 inches (10 cm) thick; a woolly undercoat under long guard hair; and a fatty hump on its shoulders for hard times. Its curving tusks could grow over 13 feet (4 m) long and were likely used to sweep snow away from grass and to spar with rivals.

Teeth tell the diet. A mammoth chewed with huge flat molars, each made of thin ridges of enamel like a washboard, good for grinding tough grass on the **steppe**. A **mastodon** had teeth with rows of cone-shaped bumps for crunching twigs and leaves in forests. Like elephants, mammoths had six sets of molars in a lifetime; when the last wore out, the animal could no longer eat.

People and mammoths. People knew mammoths well. Mammoths are painted and carved on the walls of caves in France, such as Rouffignac, called "the Cave of a Hundred Mammoths." In Ukraine, people built huts from mammoth bones. Today, mammoth ivory still washes out of Siberian riverbanks. The last known mammoths lived on Wrangel Island in the Arctic Ocean, long after they had vanished elsewhere.

Reading the Ice Age. In Job 38:29-30 God asks, "Out of whose womb came the ice?" Many creation scientists think the Flood set up one great **Ice Age**: warm oceans gave off moisture, and volcanic dust cooled the summers, so snow piled up for centuries. Mammoths spread over the cold grasslands in that time. When the climate changed again, they died out.

PICTURE STUDY



Woolly Mammoths and Woolly Rhinoceros (Field Museum mural), Charles R. Knight, 1926–1930 · Oil on canvas (mural) · Field Museum of Natural History, Chicago
Wikimedia Commons · Public domain

Charles R. Knight painted 28 large murals of ancient animals for the Field Museum in Chicago between 1926 and 1930. He studied living elephants at the zoo, mammoth skeletons, frozen mammoth hair and skin from Siberia and the cave paintings of France before he painted. His mammoths shaped how people pictured them for the next hundred years.

Look closely

- Count the mammoths. How does Knight show that some are far away?
- Look at the shape of the back. Can you find the high shoulder hump?
- Find the tusks. Do they curve in, out or up?

Talk about it

1. Knight could not see a living mammoth. Name three kinds of evidence he could use.
2. What feeling does the cold landscape give you? How does Knight make it feel cold?

Safety first. Take your hands out of the ice water as soon as they ache. Wash hands after handling shortening.

HANDS-ON: BLUBBER MITTEN TEST

Test how a layer of fat keeps a warm-blooded animal warm in icy water, as it did for mammoths.

You will need

- A large bowl of ice water
- Solid vegetable shortening (about 1 cup)

- Four zip-top sandwich bags and duct tape
- A timer

Steps

1. Fill one bag with shortening. Turn a second bag inside out and put it inside the first, so the shortening is between the two layers. Tape the tops together. This is the “blubber mitten.”
2. Put one hand in an empty bag (no fat) and the other in the blubber mitten.
3. Put both hands in the ice water at once. Time how long each hand can comfortably stay in.
4. Record the times. Take hands out at once if they hurt.
5. Write a sentence explaining the result.

Check your work

- I tested both hands at the same time.
- I recorded the times in my notebook.
- I can explain how fat helped a mammoth stay warm.

FIELD NOTEBOOK

1. **Diagram.** Draw a woolly mammoth from the side and label at least eight parts: small ears, trunk with two “fingers” at the tip, tusks, shoulder hump, long guard hair, woolly undercoat, fat layer (show a cut-away patch), short tail, and wide feet. Below, draw a mammoth molar and a mastodon molar from above and label “ridges for grass” and “cones for twigs.”
2. **Notebook entry.** Write a paragraph: “What Lyuba Taught Us.” Tell who found her, where and when, three things scientists learned and how she was preserved.

Did you know? In 1799 an Evenk hunter named Ossip Shumachov found a mammoth melting out of the ice near the mouth of the Lena River in Siberia. By the time the scientist Mikhail Adams reached it in 1806, wolves and dogs had eaten much of the flesh, but he saved the skeleton, some skin and hair. The “Adams mammoth” was one of the first mammoth skeletons ever mounted, in St. Petersburg.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** “Lyuba died about 42,000 years ago, during the last Ice Age. The Ice Age began about 2.6 million years ago, with many advances of the ice.” **What we observe:** a baby mammoth with milk in her stomach, buried quickly in fine mud and frozen in permafrost; many other mammoths, some with food in their mouths, in frozen ground across Siberia and Alaska. **How Christians read it:** many young-earth scientists think there was one Ice Age, lasting several centuries after the Flood, about 4,000 years ago. Radiocarbon dates assume the amount of carbon-14 in the air has stayed nearly constant;

a major event like the Flood could change that. “Ice Age” is a useful museum word for the time of the ice sheets; the length and date are interpretations.

Map or diagram. On a world map, shade the far north of Europe, Asia and North America where woolly mammoths lived. Mark: the Yamal Peninsula (Lyuba, 2007), the Lena River delta (Adams mammoth, 1799), Wrangel Island (last mammoths), and Rouffignac Cave in France (paintings).

Goes deeper in. Earth Science, the Ice Age and glaciers units; Life Science, mammals and how animals keep warm (coming soon). Stop E9 visits La Brea, where Columbian mammoths are found.

For families. Lyuba facts follow National Geographic (May 2009) and the Field Museum, which displayed her in 2010. Mammoth sizes and the six sets of molars follow the Royal BC Museum and Natural History Museum, London. The post-Flood Ice Age model is Michael Oard’s (Institute for Creation Research and Answers in Genesis), who estimates about 500–700 years. Mainstream dates are stated as what museum signs say, per the track’s ⌚ policy.

PRACTICE

1. **EASY** Name four features that kept a woolly mammoth warm.
2. **EASY** Who found Lyuba, where and when?
3. **MEDIUM** How can you tell a mammoth tooth from a mastodon tooth, and what does each tell about diet?
4. **MEDIUM** Lyuba weighed about 50 kg. A grown mammoth weighed about 6,000 kg. About how many Lyubas equal one grown mammoth?
5. **CHALLENGE** Read this sign: “This mammoth died 40,000 years ago when it fell through thin ice.” Split it into an observation and interpretations.

Make it a game • Mammoth or Mastodon? Make 12 cards with clues: “ridged molars,” “cone-shaped teeth,” “grassland,” “forest,” “Lyuba,” “shaggy coat and small ears,” “twigs and leaves,” and so on. Players sort the cards into a Mammoth pile, a Mastodon pile or a Both pile. Score a point for each correct card.

Scripture. “Out of whose womb came the ice? and the hoary frost of heaven, who hath gendered it? The waters are hid as with a stone, and the face of the deep is frozen.” (Job 38:29–30, KJV)

God reminded Job that He rules the ice and the frost. The great ice sheets, and the mammoths that lived beside them, were never outside His care.

Practice: answers

1. Any four: small ears, a short tail, a thick fat layer, a woolly undercoat, long guard hair, a fatty hump.
2. Yuri Khudi, a Nenets reindeer herder, with his sons, on the Yamal Peninsula in Arctic Russia, in May 2007.
3. A mammoth molar has flat ridges like a washboard, for grinding grass; a mastodon molar has cone-shaped bumps, for crunching twigs and leaves.
4. $6,000 \div 50 = 120$ Lyubas.
5. Observation: a mammoth body was found in frozen mud or ice. Interpretations: the date (40,000 years), and the cause of death (falling through ice), unless there is direct evidence such as mud in the trunk and lungs.

5.7 SABER-TOOTHED CATS

OBJECTIVES

- Describe Smilodon's teeth, jaws and body and explain how its hunting method differed from a lion's.
- Tell how Smilodon was first found in the caves of Brazil and why it became California's state fossil.
- Weigh the evidence for and against the idea that Smilodon lived in groups.

Warm-up. Open your mouth as wide as you can without strain. Most people open to an angle of about 40 to 50 degrees. A saber-toothed cat could open its jaws to about 110 degrees, wider than a square corner, so its long teeth could clear its lower jaw.

Video slot. Video coming. Smilodon saber-toothed cat: skulls at La Brea, jaw gape and bite, healed injuries. Search approved channels (La Brea Tar Pits and Museum, Natural History Museum of Los Angeles County, Smithsonian, Answers in Genesis once vetted); preview first.

KEY TERMS

Smilodon

The best-known saber-toothed cat, with two very long, flat, curved upper canine teeth; the name means “knife tooth” (say “SMY-lo-don”).

canine tooth

A long pointed tooth near the front of the mouth, used for gripping or stabbing. Dogs, cats and people all have canines.

gape

How wide an animal can open its mouth, measured as an angle.

serrated

Having tiny saw-like bumps along an edge, like a steak knife.

pathology

In fossils, a sign of injury or disease in a bone, such as a healed break.

CORE IDEAS

Bones in the caves of Brazil. In the 1830s and 1840s, a Danish naturalist named Peter Wilhelm Lund explored hundreds of limestone caves near Lagoa Santa in Brazil. In them he found bones of giant ground sloths, armadillo-like glyptodonts and a big cat with enormous front teeth. In 1842 he named it **Smilodon**, “knife tooth.” Later finds showed three kinds: the giant *Smilodon populator* of South America, which may have weighed over 800 pounds (400 kg); *Smilodon fatalis* of North America; and a smaller *Smilodon gracilis*.

Not a tiger. People often say “saber-toothed tiger,” but *Smilodon* was not a tiger and not closely related to any living cat. *Smilodon fatalis*, the kind found at La Brea, weighed about 350 to 600 pounds (160 to 280 kg), as much as a big lion, but was built differently: a short bobtail, very thick, muscular front legs, and a powerful neck. Its upper **canine teeth** were about 7 inches (18 cm) long showing below the gum, flat from side to side like a knife blade, with finely **serrated** edges.

How it hunted. A lion holds prey with its paws and kills with a strong crushing bite. *Smilodon*’s bite was actually weaker than a lion’s, and its long, thin sabers could snap if they struck bone. So scientists think it used its mighty arms to wrestle a large animal such as a bison, horse or young mammoth to the ground and hold it still, and then, with its jaws opened to a huge **gape** of about 110 degrees, drove its sabers into the soft throat using the force of its neck muscles. It was an ambush hunter that sprang from cover, not a long-distance runner.

California’s cat. More than 2,000 individual *Smilodon* have been dug from the La Brea Tar Pits in Los Angeles, more than anywhere else on earth (Stop E9). In 1973, California made *Smilodon fatalis* its state fossil. Because there are so many skeletons, scientists can study how the cats grew. Cubs had baby sabers first; their adult sabers grew in slowly, over about three years.

Did they live in groups? Many La Brea *Smilodon* bones show **pathologies**: healed broken legs, damaged hips and twisted backs. Some injured cats lived for months or years after injuries that would have kept them from hunting. Some scientists say this means they lived in groups, like lions, and shared food with the hurt. Others reply that a hurt cat could live on stored fat or scavenge. The evidence is real; how to read it is still being argued.

Other saber cats. *Homotherium*, the “scimitar cat,” had shorter, broader sabers and longer legs for chasing. In 2024 Russian and other scientists described a frozen *Homotherium* cub, about three weeks old, found in the permafrost of Yakutia in Siberia, with its dark fur, paws and face still preserved.

PICTURE STUDY



Rancho La Brea Tar Pool (Smilodon) (Field Museum mural), Charles R. Knight, 1926-1930 · Oil on canvas (mural) · Field Museum of Natural History, Chicago
Wikimedia Commons · Public domain

In this mural Charles Knight painted the La Brea tar pools as he imagined them, with Smilodon, a giant bird called Teratornis and other Ice Age animals, such as an extinct kind of horse. Knight was careful to base the animals on real skeletons from La Brea, which he studied closely.

Look closely

- Find Smilodon. How wide is its mouth open? Compare it with a house cat's yawn.
- Find the birds. Why might they be waiting near the pool?
- Look at the background: hills, trees, sky. Does it look like Los Angeles today?

Talk about it

1. Knight shows Smilodon with a short tail and very strong front legs. Which parts of the skeleton tell us this?
2. Knight paints a dramatic moment. Which parts of the scene are evidence and which are storytelling?

HANDS-ON: GAPE GAUGE

Make a cardboard jaw model and a protractor chart to compare how wide different animals can open their mouths.

You will need

- Two strips of stiff cardboard, about 20 cm by 4 cm
- One brass paper fastener
- A protractor
- Paper triangles or toothpicks for the sabers
- Pencil and markers

Steps

1. Join the two strips at one end with the paper fastener to make an upper and lower jaw.
2. Glue two long paper sabers (about 6 cm) to the upper jaw near the front, pointing down.
3. Close the jaw. Can the sabers fit? Open the jaw slowly and use the protractor to find the angle where the sabers clear the lower jaw.
4. On a sheet of paper, draw angles for: a person, about 45°; a lion, about 65–70°; Smilodon, about 110°. Label each.
5. Write a sentence: “Smilodon needed a wide gape because”

Check your work

- My jaw model opens on a hinge and has two sabers.
- I measured the angle where the sabers clear the jaw.
- My chart shows three labeled angles.

FIELD NOTEBOOK

1. **Diagram.** Draw a Smilodon skull from the side with its jaw opened wide. Label: upper canine (saber), serrated edge, lower jaw, the small flange of bone at the front of the lower jaw beside the saber tips, eye socket, nose opening and the jaw hinge. Mark the gape angle (about 110°) with a curved arrow and the saber length (about 18 cm).
2. **Notebook entry.** Write a paragraph: “Did Smilodon Care for the Injured?” State the observation (healed injuries), give both interpretations, and say which you find more convincing and why.

Did you know? The Smilodon skull at La Brea shows that adult sabers pushed in beside the baby canines, so for a short time a young cat had four long teeth at once. Scientists can tell a cat’s age from which teeth are present.

Map or diagram. On a map of the Americas, mark Lagoa Santa in Minas Gerais, Brazil (Lund’s caves, 1842) and Los Angeles, California (La Brea). Shade North America for *Smilodon fatalis* and eastern South America for *Smilodon populator*. Then on a map of Asia mark Yakutia, Siberia, for the frozen *Homotherium* cub (2024).

Goes deeper in. Life Science, mammals, predators and prey (coming soon); Trail C, Stop C1 “Teeth tell diet.” Stop E9 visits the La Brea Tar Pits.

For families. Sizes follow the La Brea Tar Pits and Museum and Christiansen and Harris (2005). The 110° gape and the weaker-than-lion bite follow McHenry et al. (2007). Tooth growth over about three years follows Wysocki et al. (2015). The social-behavior debate is presented with both sides (Carbone et al. 2009 for social; critics such as Kiffner 2009). The Homotherium cub is Lopatin et al., *Scientific Reports* (November 2024). Wounds and hunting are described plainly without gore, as the course requires.

PRACTICE

1. **EASY** What does “Smilodon” mean, and why is “saber-toothed tiger” not quite right?
2. **EASY** Who first named Smilodon, where and when?
3. **MEDIUM** Smilodon’s bite was weaker than a lion’s. How could it still kill large animals?
4. **MEDIUM** A person’s gape is about 45°, and Smilodon’s about 110°. How many degrees wider could Smilodon open? Is that more or less than a right angle?
5. **CHALLENGE** Many La Brea Smilodon had healed injuries. Give one argument that this shows group living and one argument against.

Make it a game • Ambush!. One player is Smilodon and hides behind a chair or bush. Others walk slowly past as “bison.” Smilodon may spring out and tag only once, from no more than three steps away; if it misses, it must go back to hiding. Talk about why an ambush hunter needs cover and patience. Play gently with a light tag.

Scripture. “Wilt thou hunt the prey for the lion? or fill the appetite of the young lions, When they couch in their dens, and abide in the covert to lie in wait?” (Job 38:39–40, KJV)

God reminds Job that He provides even for the great cats that lie in wait. The saber-toothed cat, an ambush hunter, was fed by the same Lord.

Practice: answers

1. “Knife tooth.” Smilodon was a cat, but not a tiger and not closely related to any living cat.
2. Peter Wilhelm Lund, from cave bones near Lagoa Santa, Brazil, in 1842.
3. It used its very strong front legs to wrestle prey down and hold it still, then drove its sabers into the throat with the force of its neck muscles.
4. $110 - 45 = 65$ degrees wider. Smilodon’s 110° is more than a right angle (90°).
5. For: a cat too badly hurt to hunt for months could survive only if others let it share their kills, as lions do. Against: an injured cat might survive on stored fat, by scavenging or by hunting small prey, and the tar pits may have trapped more injured animals than healthy ones.

5.8 GIANT GROUND SLOTHS

OBJECTIVES

- Compare three giant ground sloths (Megatherium, Megalonyx and the Shasta ground sloth) by size, home and evidence.
- Tell how Thomas Jefferson changed his mind about the Megalonyx claws in 1797, and why that was good science.
- Explain what fossil dung and footprints add to what bones tell us.

Warm-up. Hang from a bar or a low tree branch (with a grown-up nearby) and count how long you can hold on. Today’s tree sloths hang for hours with their curved claws. Their giant cousins were too heavy for any tree: some weighed as much as an elephant.

Video slot. Video coming. Giant ground sloths: Megatherium skeleton, Jefferson’s Megalonyx, ground sloth dung and footprints at White Sands. Search approved channels (National Park Service, Smithsonian, Natural History Museum London, Answers in Genesis once vetted); preview first.

KEY TERMS

ground sloth

An extinct relative of today’s tree sloths that lived on the ground; some grew as big as elephants.

Megatherium

The largest ground sloth, from South America, about 20 feet (6 m) long; the name means “great beast” (say “meg-a-THEER-ee-um”).

Megalonyx

A North American ground sloth named by Thomas Jefferson; the name means “great claw.”

osteoderm

A small bony plate or pebble set in the skin. Some ground sloths had thousands of them, like chain mail.

coprolite

Fossilized or preserved dung. It shows what an animal ate.

CORE IDEAS

A great beast for a king. In 1787 a Dominican friar, Manuel Torres, dug a huge skeleton from a riverbank near Luján in what is now Argentina. It was shipped to the Royal Cabinet of Natural History in Madrid, where Juan Bautista Bru, the museum’s artist, put the bones together into a standing skeleton, one of the first mounted fossil skeletons in the world. A well-known story says King Charles III asked for a living one to be sent to him, alive or

stuffed. In 1796 Georges Cuvier, working from Bru's drawings, showed it was a giant relative of the tree sloths and named it **Megatherium**, "great beast."

Jefferson's great claw. Meanwhile, saltpeter miners in a cave in Greenbrier County, Virginia (now West Virginia), found huge claw and arm bones and sent them to Thomas Jefferson. Jefferson thought they came from a giant lion and called it **Megalonyx**, "great claw." Days before he was to speak about it to the American Philosophical Society, he read Cuvier's paper on Megatherium and saw that his claws matched. In March 1797, now Vice President, he gave his talk with a more careful conclusion. In 1822 the animal was named *Megalonyx jeffersonii*, and in 2008 West Virginia made it the state fossil.

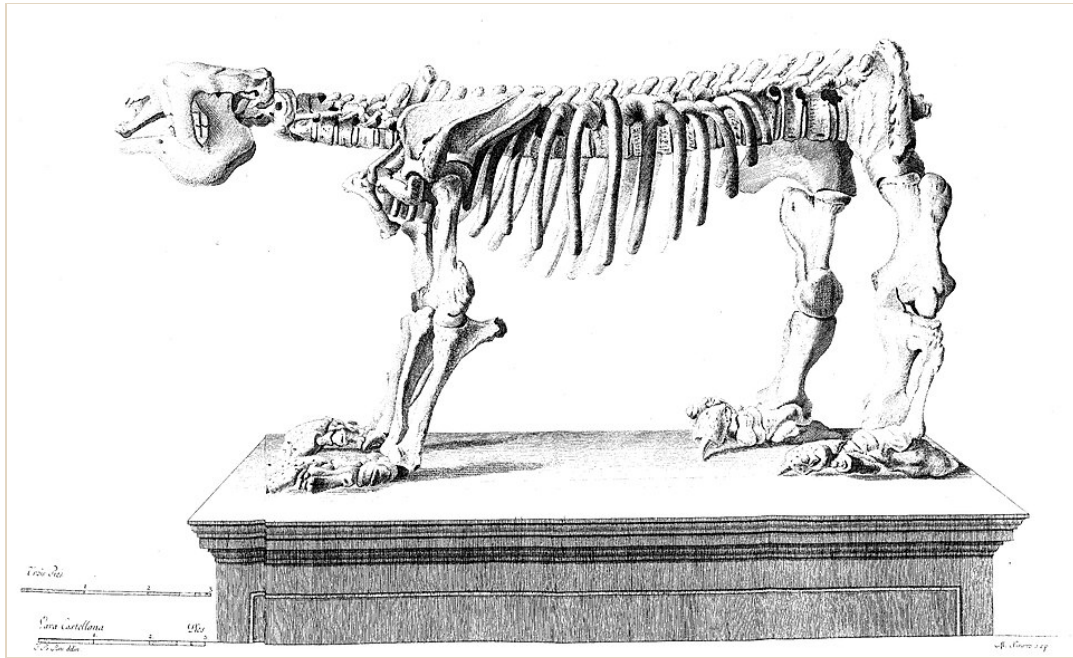
How big? Megatherium grew to about 20 feet (6 m) long and up to about 4 tons. It could rear up on its hind legs, bracing with its thick tail like a tripod, to pull down branches with its long arms and claws. Its claws were so long it walked on the sides of its hind feet and the knuckles of its hands. Megalonyx was about 10 feet (3 m) long and around a ton. Harlan's ground sloth, common at La Brea, had thousands of bony **osteoderms** in its skin.

Dung tells the menu. In dry caves of the American Southwest, the dung of the smaller Shasta ground sloth was preserved so well that it looks almost fresh. In Rampart Cave in the Grand Canyon, a deep layer of sloth dung held seeds and stems of globemallow, Mormon tea, yucca and other desert plants. Sadly, in 1976 a careless fire set inside the cave burned the dung layer for months. Still, these **coprolites** tell us exactly what the sloths ate.

Footprints tell a story. At White Sands National Park in New Mexico, a line of ground sloth tracks runs across an old lakebed, and human footprints step right inside them. Where the people's tracks come close, the sloth's tracks swerve and form circles, as if it reared up and turned to face them. Bones show what an animal was; tracks show what it did.

Not lazy. The word "sloth" is an old English word for laziness, one of the sins warned against in Proverbs. But the ground sloths were not lazy. Their strong limbs, grinding teeth and long claws were well fitted for pulling down and chewing the tough plants God provided.

PICTURE STUDY



The skeleton of Megatherium as mounted in Madrid, Juan Bautista Bru de Ramón (drawing); Manuel Navarro (engraving), Drawn about 1793–1795; engraved and published 1796 · Engraving after Bru's drawing · From José Garriga, *Descripción del esqueleto de un cuadrúpedo muy corpulento y raro* (Madrid, 1796); copy in the National Library of Spain. The skeleton still stands in the National Museum of Natural Sciences, Madrid.

Wikimedia Commons · Public domain

Juan Bautista Bru drew the great skeleton he had assembled in Madrid, along with drawings of each bone, and Manuel Navarro engraved his drawings for printing. Prints of them reached Paris, and Cuvier used them to name *Megatherium* without ever seeing the bones. This is one of the first scientific pictures of a mounted fossil skeleton.

Look closely

- Find the claws. How long are they compared with the feet?
- Look at how the skeleton stands. Do you think Bru got the posture right? (Today it is shown standing more upright.)
- Find the tail and the hips. Why would a wide hip help an animal that reared up?

Talk about it

1. Cuvier never saw the real bones. What did he have to trust in order to name it?
2. Why is it important that a scientific drawing show every bone exactly as it is?

Safety first. Use only a sterilized owl pellet or a homemade dung ball; wear gloves and wash your hands afterward.

HANDS-ON: READ THE DUNG (OWL PELLET OR SEED TEST)

Scientists learn what extinct sloths ate by picking apart their dung. Practice the same careful method on a safe substitute.

You will need

- A sterilized owl pellet (from a science supply store), or a homemade “dung ball” of soil mixed with birdseed, dried grass and a few small twigs
- Toothpicks and tweezers
- A paper plate and a magnifying glass
- Gloves

Steps

1. Put on gloves. Gently pull the pellet or dung ball apart with toothpicks on the paper plate.
2. Sort everything you find into groups: seeds, grass, twigs, bones or hair.
3. Count each group and make a tally chart.
4. Write a “menu” for the animal: what did it eat most?
5. Compare with the Shasta ground sloth’s menu: globemallow, Mormon tea, yucca and other desert plants.

Check your work

- I sorted everything into at least three groups.
- My tally chart has numbers for each group.
- I can explain how dung tells scientists about diet.

FIELD NOTEBOOK

1. **Diagram.** Draw Megatherium rearing on its hind legs, pulling down a branch, beside a person drawn to scale (Megatherium about 12 feet tall when standing up). Label: skull, long arms, curved claws, hips, thick tail used as a prop, hind feet (walked on their sides). Add a small inset of a tree sloth hanging from a branch for comparison.
2. **Notebook entry.** Write a paragraph: “Jefferson Changes His Mind.” Tell what Jefferson first thought, what made him change, and why changing your mind when the evidence is better is a sign of wisdom, not weakness (Proverbs 1:5).

Did you know? Jefferson hoped that living Megalonyx might still roam the unexplored West. When he sent Lewis and Clark west in 1804, he asked them to watch for rare or unknown animals. They found many new animals but no giant sloths.

Map or diagram. On a map of the Americas, mark: Luján, Argentina (Megatherium, 1787); Greenbrier County, West Virginia (Megalonyx, 1796); Rampart Cave in the Grand Canyon, Arizona (sloth dung); White Sands, New Mexico (footprints); and Los Angeles

(Harlan's ground sloth at La Brea). Draw an arrow from Luján to Madrid across the Atlantic.

Goes deeper in. History, Thomas Jefferson and the early republic (coming soon); Life Science, mammals and plant-eaters. Trail C, Stop C3 covers footprints and trackways.

For families. Megatherium history follows the National Museum of Natural Sciences, Madrid, and Cuvier (1796). The Jefferson story follows Ohio State's Orton Museum and Jefferson's paper (read March 1797, published 1799); the species name is Desmarest (1822). The Rampart Cave fire (1976) is documented by the National Park Service. The White Sands tracks are Bustos et al., *Science Advances* (2018). Museum signs give dates for these finds; this stop uses none.

PRACTICE

1. **EASY** What do "Megatherium" and "Megalonyx" mean?
2. **EASY** What did Jefferson first think the Megalonyx claws belonged to, and what changed his mind?
3. **MEDIUM** Name three kinds of evidence about ground sloths besides bones.
4. **MEDIUM** Megatherium weighed up to about 4 tons (8,000 pounds). A tree sloth weighs about 10 pounds. How many tree sloths equal one Megatherium?
5. **CHALLENGE** At White Sands, human footprints step inside sloth tracks, and the sloth tracks swerve and circle. What is observed, and what is interpreted?

Make it a game · Track Detective. One player walks across a sandbox, snowy yard or floor covered in flour paper with wet feet, doing something secret: running, stopping, turning, hopping or walking backward. The others study the tracks and say what happened. Then compare with what really happened.

Scripture. "Go to the ant, thou sluggard; consider her ways, and be wise:" (Proverbs 6:6, KJV)

"Sloth" and "sluggard" name laziness, a fault in people. The ground sloths, though, worked hard to live, as God made them to. Like the ant, they can teach us to be diligent.

Practice: answers

1. Megatherium: "great beast." Megalonyx: "great claw."
2. A giant lion. He read Cuvier's paper on Megatherium and saw the claws matched a giant sloth.
3. Preserved dung (coprolites), footprints and trackways, and skin with bony osteoderms (also hair from dry caves).
4. $8,000 \div 10 = 800$ tree sloths.
5. Observed: human prints inside sloth prints; sloth tracks that change direction and form circles. Interpreted: that people were following or hunting the sloth and that it reared up to

face them. The order of the tracks (human prints on top) is an observation that supports the idea that people walked there after the sloth.

5.9 THE LA BREA TAR PITS

OBJECTIVES

- Tell the history of the La Brea Tar Pits from the Portolá expedition (1769) to Project 23 (2008 to today).
- Explain how a sticky asphalt seep could trap animals and why meat-eaters far outnumber plant-eaters there.
- Draw a labeled cross-section of an asphalt seep and read a La Brea museum sign, separating observation from interpretation.

Warm-up. Spread a spoonful of honey or syrup on a plate and gently press a toy animal's foot into it. Try to pull it out. Now imagine the syrup hidden under a layer of dust and leaves. That is how the sticky asphalt of La Brea caught animals.

Video slot. Video coming. La Brea Tar Pits: excavations at Project 23, how animals were trapped, dire wolf skull wall, Lake Pit mammoths. Search approved channels (La Brea Tar Pits and Museum, Natural History Museum of Los Angeles County, PBS Eons with preview, Answers in Genesis once vetted); preview first.

KEY TERMS

asphalt

A thick, sticky, black form of petroleum (oil) that oozes from the ground. People often call it tar; in Spanish it is “brea.”

seep

A place where a liquid, such as oil, water or asphalt, slowly oozes out of the ground.

predator trap

A place where one trapped animal draws in hunters and scavengers, which are then trapped too, so that meat-eaters pile up.

dire wolf

A large extinct wolf, heavier than a gray wolf, with a big head and strong teeth. It is the most common large mammal at La Brea.

radiocarbon dating

A method that estimates age from the amount of carbon-14 left in bone, wood or shell, based on assumptions about how much was there at the start.

CORE IDEAS

Springs of tar. On August 3, 1769, a Spanish expedition led by Gaspar de Portolá camped near what is now Los Angeles. Father Juan Crespí, a Franciscan priest, wrote in his diary of “geysers of tar” bubbling from the ground. Native Tongva people had long used the **asphalt** to seal baskets and canoes, and Spanish settlers later used it to waterproof roofs. The land

became the Rancho La Brea, “the tar ranch.” (So “the La Brea Tar Pits” really means “the the tar tar pits”!)

Not cattle bones. For years, ranch workers who dug asphalt found bones and assumed they came from cattle that had wandered in. In 1901 an oil geologist, William Orcutt, looked closely and recognized the teeth of a saber-toothed cat. From 1913 to 1915 the Los Angeles County Museum, with permission from the landowner G. Allan Hancock, dug 96 pits and pulled out more than 750,000 bones. In 1924 Hancock gave the land to Los Angeles County; today it is Hancock Park, and the museum on it opened in 1977.

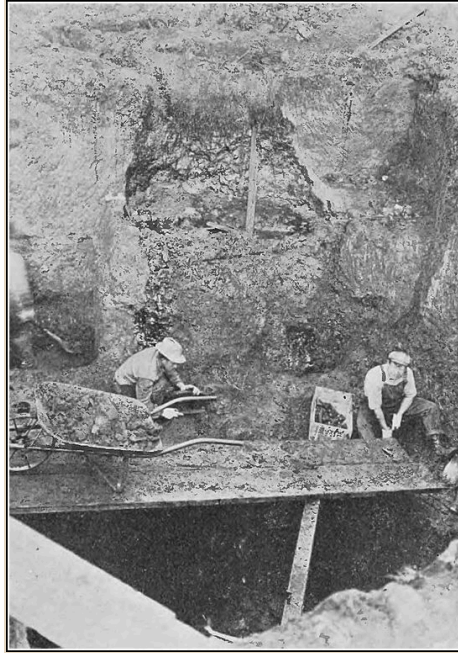
How the trap worked. The asphalt **seeps** up from oil deposits deep underground. On warm days it softens; a thin layer could hide under water, dust or leaves. A horse, bison or camel that stepped in was stuck, like a fly on flypaper. Its struggles drew wolves, cats and vultures, which became stuck as well. This **predator trap** explains a surprising fact: about nine of every ten large mammals found at La Brea are meat-eaters.

Millions of fossils. More than 3.5 million specimens from over 600 kinds of animals and plants have come out of La Brea. There are more than 4,000 individual **dire wolves** and more than 2,000 saber-toothed cats (Stop E7), along with Columbian mammoths, ground sloths, camels, horses, bison, coyotes, the giant short-faced bear, the American lion, birds, insects, seeds and pollen. Because the asphalt soaked into the bones, they are a dark brown and very well preserved.

Project 23. In 2006, workers digging an underground parking garage next to the park hit 16 new fossil deposits. Instead of stopping construction, scientists packed the deposits into 23 huge wooden boxes, some weighing more than 100,000 pounds, and moved them beside the museum. Since 2008, workers and volunteers have been digging through the boxes in public view. One box held a nearly complete Columbian mammoth nicknamed “Zed.” Visitors can watch the work through a fence today.

A miry pit. Scripture often describes trouble as being stuck in a pit or “miry clay” (Psalm 40:2). At La Brea, animals could not pull themselves out. People who sink in sin cannot pull themselves out either; it is the Lord who lifts us up and sets our feet on a rock.

PICTURE STUDY



Excavating in a Rancho La Brea fossil bed, L. E. Wyman (photographer), About 1913–1914 · Black-and-white photograph · Published in *The Popular Science Monthly*, vol. 84 (March 1914), courtesy of the Los Angeles Museum of History, Science and Art
Wikimedia Commons · Public domain

This photograph shows the great dig of 1913–1915, when the new Los Angeles museum sent crews to Rancho La Brea. Its caption says that ten feet down, one “nest of bones” held the remains of a bison, two lions, a wolf, a horse and other animals. The workers pried the bones from the sticky asphalt with picks, shovels and their hands.

Look closely

- Find the workers. What tools can you see?
- Look at the walls of the pit. How deep do you think it is?
- Look at the bones. Are they lying in neat skeletons or jumbled together?

Talk about it

1. Why would bones in a predator trap be jumbled together rather than lying as whole skeletons?
2. What would be hard about digging in sticky asphalt on a hot day?

Safety first. Do the experiment on a covered table and wash the toys and your hands afterward. At the real La Brea, stay behind the fences: the asphalt is still sticky and can be hot.

HANDS-ON: ASPHALT TRAP EXPERIMENT

Model how a hidden sticky layer traps animals of different weights and feet.

You will need

- A shallow baking pan
- Corn syrup or molasses (about 1 cup), or slime made from glue
- A thin layer of water and some cocoa powder or dirt for dust
- Small plastic animals: one with big feet, one with small hooves, one light, one heavy
- Paper towels

Steps

1. Pour the syrup into the pan to make a layer about 1 cm deep.
2. Sprinkle cocoa or dirt over it, or float a thin layer of water on top, to hide it.
3. Press each animal in gently with the same push and let go. Count to ten and then try lifting it out with one finger.
4. Record which animals were hardest to free. Did heavy animals or small-footed animals stick worse?
5. Add a “predator” to the pan next to a trapped animal. What happens?

Check your work

- I tested at least four animals the same way.
- I recorded my results in a table.
- I can explain why so many meat-eaters were trapped at La Brea.

FIELD NOTEBOOK

1. **Diagram.** Draw a cross-section of an asphalt seep. Label from bottom to top: oil deposit deep underground, a crack where oil rises, the asphalt pool, a thin layer of water and leaves on top, a trapped bison, a dire wolf approaching, a vulture overhead, and buried bones in older asphalt below. Add an arrow showing the asphalt rising.
2. **Notebook entry.** Write a paragraph: “Why Wolves Outnumber Bison at La Brea.” Use the words asphalt, predator trap and scavenger, and include at least two numbers from this stop.

Did you know? The museum has a wall of more than 400 dire wolf skulls, all from La Brea. Asphalt still seeps up in the park today; workers mark fresh seeps with orange cones, and bubbles of methane gas rise in the big Lake Pit, where statues of a mammoth family stand.

 **What the sign says / What we observe / How Christians read it.**  **What the sign says:** “Animals were trapped here from about 50,000 to 11,000 years ago, during the last Ice Age.” **What we observe:** millions of bones of Ice Age animals and plants in

pockets of asphalt, many with tooth marks and wear; radiocarbon tests that give different amounts of carbon-14 in different bones. **How Christians read it:** many young-earth Christians place these animals in the centuries after the Flood, during the one post-Flood Ice Age. Radiocarbon dating assumes the amount of carbon-14 in the air has stayed about the same; if the Flood and Ice Age changed it, ages come out too old. Everyone agrees on the observation: the bones are from animals trapped one or a few at a time, not all in one disaster; how many years that took is the interpretation.

Map or diagram. On a map of California, mark Los Angeles and draw a small square for Hancock Park on Wilshire Boulevard. Then trace the Portolá expedition of 1769 from San Diego north to the Los Angeles area.

Goes deeper in. Earth Science, oil, rocks and dating units; History, Spanish California and the missions (coming soon). Stops E6–E8 meet the mammoths, saber cats and ground sloths found here.

For families. Facts follow the La Brea Tar Pits and Museum (tarpits.org) and the Natural History Museum of Los Angeles County: 3.5 million+ specimens and 600+ species (1992 census, still growing); over 4,000 dire wolves and over 2,000 Smilodon. The Crespí diary entry is August 3, 1769. The museum opened in 1977 as the George C. Page Museum. The “about nine in ten” carnivore share is the museum’s common figure for large mammals. The 🕒 box gives the mainstream radiocarbon range with the young-earth reading.

PRACTICE

1. **EASY** What does “brea” mean, and who wrote the first known description of the tar springs?
2. **EASY** What is the most common large mammal at La Brea?
3. **MEDIUM** Explain what a predator trap is and how it explains the large number of meat-eaters at La Brea.
4. **MEDIUM** Project 23 has 23 boxes. If workers have finished 7 boxes, what fraction is left? What percent is that, rounded to the nearest whole number?
5. **CHALLENGE** La Brea bones are usually jumbled, not whole skeletons. Give two reasons this could happen.

Make it a game • Stuck!. Mark a “seep” on the floor with a blanket. One player is the first trapped animal and must freeze on the blanket. Others are wolves and cats who try to tag the trapped animal; anyone who steps on the blanket is stuck too and must freeze. Count how many predators got stuck for each plant-eater. Then talk about what the score shows.

Scripture. “He brought me up also out of an horrible pit, out of the miry clay, and set my feet upon a rock, and established my goings.” (Psalm 40:2, KJV)

No animal at La Brea could pull itself out of the sticky pit. David knew that only the Lord could lift him out of his trouble and set him on solid ground.

Practice: answers

1. “Tar” (asphalt) in Spanish. Father Juan Crespí of the Portolá expedition, in 1769.
2. The dire wolf (more than 4,000 individuals).
3. One stuck plant-eater attracts many hunters and scavengers, which get stuck too. So each trapped plant-eater could add several meat-eaters to the fossil record.
4. 16 of 23 boxes are left: $16 \div 23 \approx 0.70$, about 70 percent.
5. Any two: scavengers pulled bodies apart; trapped animals were trampled by others; bones sank and shifted in the soft, moving asphalt; flowing asphalt and gas bubbles mixed the bones over time.

5.10 BUILD A MUSEUM DISPLAY

OBJECTIVES

- Name the parts of a good museum display: a big idea, a specimen or model, a label, a picture or diagram, and a question for visitors.
- Tell how Bru, Hawkins, Carl Akeley and Charles R. Knight each changed how museums show ancient animals.
- Plan, build and label a small display about one animal from this trail, with an honest three-part sign.

Warm-up. Think of the last museum you visited, or look at a museum website. Which display do you still remember? Was it the object, the picture, the sign or something you could touch? Write down one reason it stuck with you.

Video slot. Video coming. How museums build fossil exhibits: mounting skeletons, making casts, painting murals and writing labels. Search approved channels (Field Museum, American Museum of Natural History, Smithsonian National Museum of Natural History “Deep Time” behind the scenes, Answers in Genesis Creation Museum once vetted); preview first.

KEY TERMS

exhibit

A display in a museum that teaches one main idea using objects, pictures and words.

specimen

A real object kept for study, such as a fossil bone, with a catalog number that tells where and when it was found.

cast

A copy of a fossil made by filling a mold with plaster or resin. Many skeletons in museums are casts, so the real bones can be kept safe.

diorama

A three-dimensional scene with models in front of a painted background that shows an animal in its home.

label

The short written sign beside an exhibit. A good label is clear, short and honest about what is known and what is interpreted.

CORE IDEAS

Standing the bones up. For centuries, fossils sat in drawers or cabinets of curiosities. In the 1790s Juan Bautista Bru stood the bones of *Megatherium* upright in Madrid (Stop E8), one of the first times anyone showed an extinct animal as a whole creature. In 1854

Benjamin Waterhouse Hawkins went further and built life-size concrete models of dinosaurs, ichthyosaurs and plesiosaurs for the Crystal Palace park in London (Trail B, Stop B5). Thousands of visitors saw ancient animals “alive” for the first time. Some of his models were wrong, but they made people curious.

The painter of the past. Charles R. Knight (1874–1953) loved animals from childhood and studied them at the Bronx Zoo and in the American Museum of Natural History in New York. He had very poor eyesight: one eye was badly hurt by a thrown rock when he was a boy, and the other was weak. Still, working closely with scientists like Edward Drinker Cope and Henry Fairfield Osborn, he painted and sculpted ancient animals so carefully that his pictures hung in museums across America. His 28 murals for the Field Museum (1926–1930) appear in Stops E6 and E7.

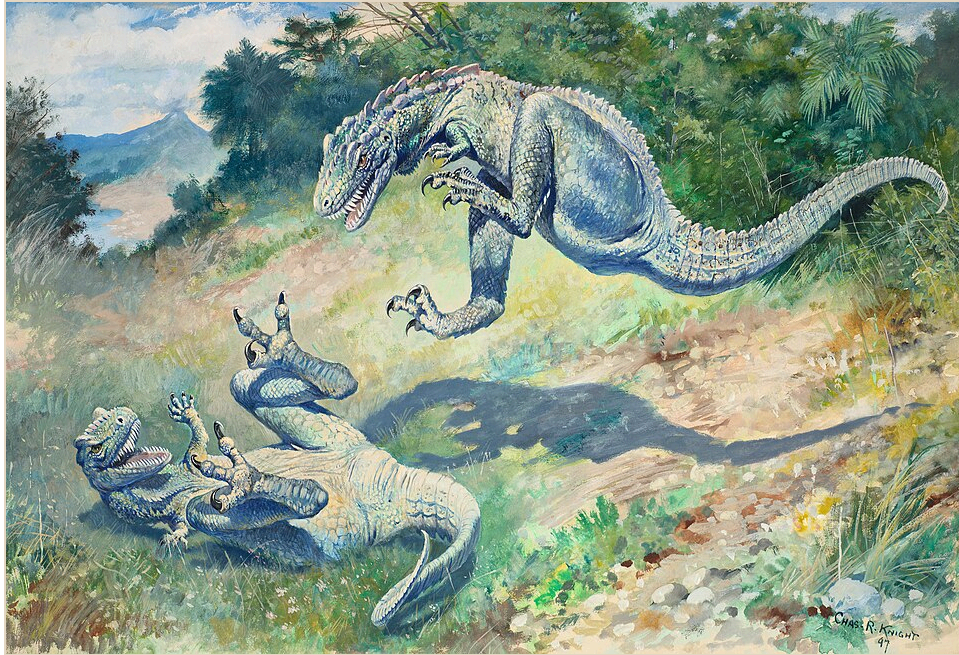
The habitat diorama. In 1890 the taxidermist Carl Akeley built a scene of muskrats in their pond for the Milwaukee Public Museum, with real plants, water and a painted background. It is often called the first modern habitat **diorama**. Museums soon used dioramas to show extinct animals too, so visitors could see not just bones but a whole world.

Real or copy? Many skeletons on display are **casts**, copies made from molds of the real bones. The real **specimens** are kept in climate-controlled rooms where scientists study them. Each has a catalog number, such as MOR 1125 for “B. rex” (Trail B, Stop B10), that links it to records of who found it, where, in which layer and when. A good museum tells you which bones are real and which are cast or sculpted.

Writing an honest label. Museum designers say most visitors read a **label** for only a few seconds, so the best labels are short, often under 75 words, with one big idea. A good fossil label tells what the object is, what we observe and what it means. It should also be honest about which parts are interpretations, especially dates. On this track you have practiced the three-part 🕒 box. Now you will write one yourself.

Your turn. In this stop you will plan and build a small **exhibit** about one animal from Trail E: an ichthyosaur, plesiosaur, mosasaur, pterosaur, Quetzalcoatlus, woolly mammoth, Smilodon, ground sloth or a La Brea scene. Psalm 145:4 says, “One generation shall praise thy works to another.” A museum display does exactly that: it shows the next generation the works of God.

PICTURE STUDY



Leaping Laelaps, Charles R. Knight, 1897 · Watercolor (gouache) on paper · American Museum of Natural History, New York
Wikimedia Commons · Public domain

Knight painted *Leaping Laelaps* in 1897 under the guidance of Edward Drinker Cope, who had named the dinosaur. At a time when most pictures showed dinosaurs as slow, dragging lizards, Knight showed them as quick and active. Laelaps is now called *Dryptosaurus*, because the name Laelaps had already been given to a mite.

Look closely

- Find the leaping dinosaur. What is it doing with its legs and arms?
- Look at the background and sky. How does Knight make the scene feel real?
- Look at the skin. Did Knight give these animals scales, feathers or smooth skin?

Talk about it

1. Knight's painting made people think about dinosaurs in a new way. What "big idea" does this picture teach?
2. If you hung this picture in your display, what would your label say about what is known and what is imagined?

HANDS-ON: MY TRAIL E MUSEUM DISPLAY

Plan and build a tabletop or shoebox display about one animal from this trail, then give a tour to your family.

You will need

- A shoebox or a section of table with a trifold board
- Clay, paper, cardboard and paints or colored pencils
- Index cards for labels
- A ruler and graph paper for the floor plan
- Any real items: a fossil, a cast, a library book, photos you printed

Steps

1. **Choose** one animal from Stops E1-E9 and write one big idea in a single sentence (for example: “The mosasaur was built to swallow large prey whole”).
2. **Plan** on graph paper: draw a floor plan from above, showing where the model, background, labels and diagram will go. Mark where visitors will stand.
3. **Build** a model or diorama: a clay model in front of a painted background showing its home (sea, sky, steppe or tar pit). Add a scale bar showing how your model compares with the real size.
4. **Write** three labels: (1) a specimen tag with the animal’s name, where it was found and who found it; (2) a main sign of 75 words or fewer with your big idea; (3) a three-part box: “What the sign says / What we observe / How Christians read it,” if a date comes up.
5. **Add** one labeled diagram from your Field Notebook and one question for visitors to answer.
6. **Open your museum.** Give a two-minute tour to your family. Ask them to answer your visitor question.

Check your work

- My display has a big idea, a model, a background, three labels, a diagram and a visitor question.
- My main sign is 75 words or fewer and keeps observation and interpretation separate.
- My floor plan is drawn on graph paper and labeled.
- I gave a tour and answered at least one question.

FIELD NOTEBOOK

1. **Diagram.** Draw a floor plan of your display from above on graph paper. Label: the model, background, scale bar, main sign, specimen tag, three-part box, diagram, visitor question and the spot where visitors stand. Add a compass rose and a scale (1 square = 5 cm).
2. **Notebook entry.** Write a paragraph: “What I Learned Building My Museum.” Tell which animal you chose and why, what was hardest about writing a short label, and one thing you would change next time.

Did you know? Some museum skeletons are mounted with heavy steel frames inside or behind the bones. Newer mounts hold each real bone in its own small cradle so it can be lifted off for study without taking the whole skeleton apart.

 **What the sign says / What we observe / How Christians read it.**  Use this as a model for your own three-part box. **What the sign says:** “Woolly mammoths roamed the cold plains of Siberia until about 10,000 years ago.” **What we observe:** mammoth bones, tusks, hair and frozen bodies are found in the permafrost of Siberia and Alaska; one baby, Lyuba, still had milk in her stomach. **How Christians read it:** many young-earth Christians place the mammoths in the centuries after the Flood, during one Ice Age, and treat radiocarbon dates as interpretations based on assumptions. Write yours in the same three parts and keep each part to one or two sentences.

Map or diagram. On a world map, mark the museums named on this trail: Natural History Museum, London; National Museum of Natural History, Paris; National Museum of Natural Sciences, Madrid; Field Museum, Chicago; American Museum of Natural History, New York; La Brea Tar Pits and Museum, Los Angeles. Which one is closest to your home?

Goes deeper in. Art, drawing animals and painting backgrounds; Literature, writing clearly and briefly; Earth Science, the fossils and dating units (coming soon). Trail D, Stop D8 “Reading a museum sign” practices the other side: reading a label well.

For families. Knight’s eye injury and life follow the Charles R. Knight biography by Richard Milner (2012). The Akeley muskrat diorama (1890) follows the Milwaukee Public Museum. The 75-word label guide follows common museum practice (Beverly Serrell, *Exhibit Labels*). If possible, visit a local museum and let your child compare a real label with their own. A parent may photograph the finished display for the portfolio.

PRACTICE

1. **EASY** What is a cast, and why do museums use them?
2. **EASY** Who built the first modern habitat diorama, and of what animal?
3. **MEDIUM** Name four parts of a good museum display.
4. **MEDIUM** Put in order: Knight’s Leaping Laelaps; Hawkins’ Crystal Palace models; Bru’s Megatherium mount; Knight’s Field Museum murals.
5. **CHALLENGE** Rewrite this label in 40 words or fewer, keeping observation and interpretation apart: “Quetzalcoatlus, the largest animal ever to fly, soared over Texas 68 million years ago, hunting dinosaurs.”

Make it a game • Museum Guide. Each player secretly picks one animal from Trail E and gives a 30-second “museum tour” about it without saying its name. The others guess. A correct guess scores a point for both the guide and the guesser. Take turns until everyone has been the guide.

Scripture. “One generation shall praise thy works to another, and shall declare thy mighty acts.” (Psalm 145:4, KJV)

A museum display passes what we have learned about God's creation on to others, especially younger children. Your display is a way to declare His works.

Practice: answers

1. A copy of a fossil made from a mold. Museums use casts so the real specimens can be kept safe and studied, and so several museums can show the same skeleton.
2. Carl Akeley, of muskrats, for the Milwaukee Public Museum in 1890.
3. Any four: a big idea, a specimen or model, a label, a picture or diagram, a background or setting, a scale bar, a question for visitors.
4. Bru's Megatherium (1790s); Hawkins' Crystal Palace (1854); Leaping Laelaps (1897); Field Museum murals (1926-1930).
5. Sample: "Quetzalcoatlus. Observed: wing bones from Big Bend, Texas, suggest a wingspan near 10-11 m, among the largest flyers known. Interpreted: its age (the sign says 68 million years) and its diet, likely small animals caught on the ground." Any answer that separates the two and stays short is correct.

TRAIL 5 BADGE QUIZZES

The badge quizzes are optional. The student answers in writing, in full sentences. Four right out of five earns each badge; a parent may accept a spoken answer for any question. Badges and the certificate are earned by doing the stops, not by scores.

Badge quiz 1 (Stops 1–5)

1. Give two pieces of evidence that ichthyosaurs gave birth to live young.
2. What mistake did Edward Drinker Cope make with *Elasmosaurus*, and who corrected it?
3. Name two features of a mosasaur's jaws that helped it swallow large prey, and tell what "*Mosasaurus*" means.
4. How was a pterosaur's wing different from a bat's wing?
5. About how wide was Quetzalcoatlus's wingspan, and where and when was it found?

Badge quiz 2 (Stops 6–10)

6. How can you tell a mammoth molar from a mastodon molar, and what does each tell about diet?
7. *Smilodon*'s bite was weaker than a lion's. How did it bring down large animals?
8. Why is Thomas Jefferson's *Megalonyx* a good example of changing your mind with evidence?
9. Why are about nine in ten large mammals at La Brea meat-eaters?
10. Name the three parts of the  box and give one example of each for a La Brea sign.

TRAIL CERTIFICATE: MY SEA, SKY AND ICE AGE FIELD NOTEBOOK AND TRAIL E CERTIFICATE

Gather the Field Notebook pages from this trail into one booklet with a cover: "Sea and Sky Reptiles, and the Ice Age," your name and the dates you started and finished. Include all ten labeled diagrams and ten notebook paragraphs.

Add a photograph or drawing of your museum display from Stop E10, with its main label and three-part  box.

Add a world map page marking at least eight places from the trail: Lyme Regis, Holzmaden, Maastricht, Solnhofen, Big Bend, the Yamal Peninsula, Greenbrier County and Los Angeles.

When the booklet is done, a parent signs the Trail E certificate.

- **Ten stops:** A labeled diagram and a paragraph of at least five sentences for each stop, each with a title and a date.
- **Accuracy:** Names, numbers and dates in the paragraphs and diagrams match the stops; sea and sky reptiles are not called dinosaurs.
- **Observation and interpretation:** The museum label and  box keep what is observed apart from how it is interpreted, and present dates as interpretations without

mocking any view.

- **Care:** Diagrams are neat, labeled and drawn with scale bars where asked; the map is clear.

Answer key

1. Fossil mothers from Holzmaden, Germany, with small skeletons inside them, and at least one baby partly born, tail first; and flippers that could not carry them onto land to lay eggs.
2. He put the head on the end of the tail. Joseph Leidy (with Othniel Marsh) showed in 1870 that it belonged on the long neck.
3. A hinge in the middle of each lower jaw and extra rows of backward-pointing teeth on the roof of the mouth. "Lizard of the Meuse."
4. A pterosaur's wing membrane hung from one very long fourth finger and ran back to the leg; a bat's wing is skin stretched between several long fingers.
5. About 10–11 m (33–36 feet). In Big Bend National Park, Texas, in 1971, by Douglas Lawson.
6. A mammoth molar has flat ridges for grinding grass; a mastodon molar has cone-shaped bumps for twigs and leaves.
7. It wrestled prey down with its very strong front legs, then opened its jaws about 110 degrees and drove its sabers into the throat with its neck muscles.
8. He first thought the claws were from a giant lion, but after reading Cuvier's paper on Megatherium he saw they matched a giant ground sloth and changed his conclusion (1797).
9. It was a predator trap: one stuck plant-eater drew many hunters and scavengers, which got stuck too.
10. What the sign says ("trapped 50,000 to 11,000 years ago"); what we observe (millions of bones in asphalt, mostly meat-eaters); how Christians read it (animals of the post-Flood Ice Age; radiocarbon dates rest on assumptions).