

HORNS, SPIKES, & ARMOR

Plant-eating dinosaurs were often slow-moving, trudging along on all fours. It would be hard for them to run away from a fierce meat-eater, so some grew armor plates and sharp, protective spikes.

Morrison Formation ⑦ STEGOSAURUS

Stegosaurus had a fearsome weapon called a "thagomizer" at the end of its tail, with long, sharp spikes sticking out on each side. It could use this to swipe an attacking dinosaur. One Allosaurus fossil shows an injury to the tail probably caused by a bashing from a Stegosaurus.

④ Hell Creek ANKYLOSAURUS



Ankylosaurus's skull was protected by bony scales.

Ankylosaurus was entirely covered in hard, bony plates called osteoderms. Four spikes at the back of the head protected the neck, and even its eyelids were armored. The large club of fused bone at the end of the tail could deliver a nasty thump.



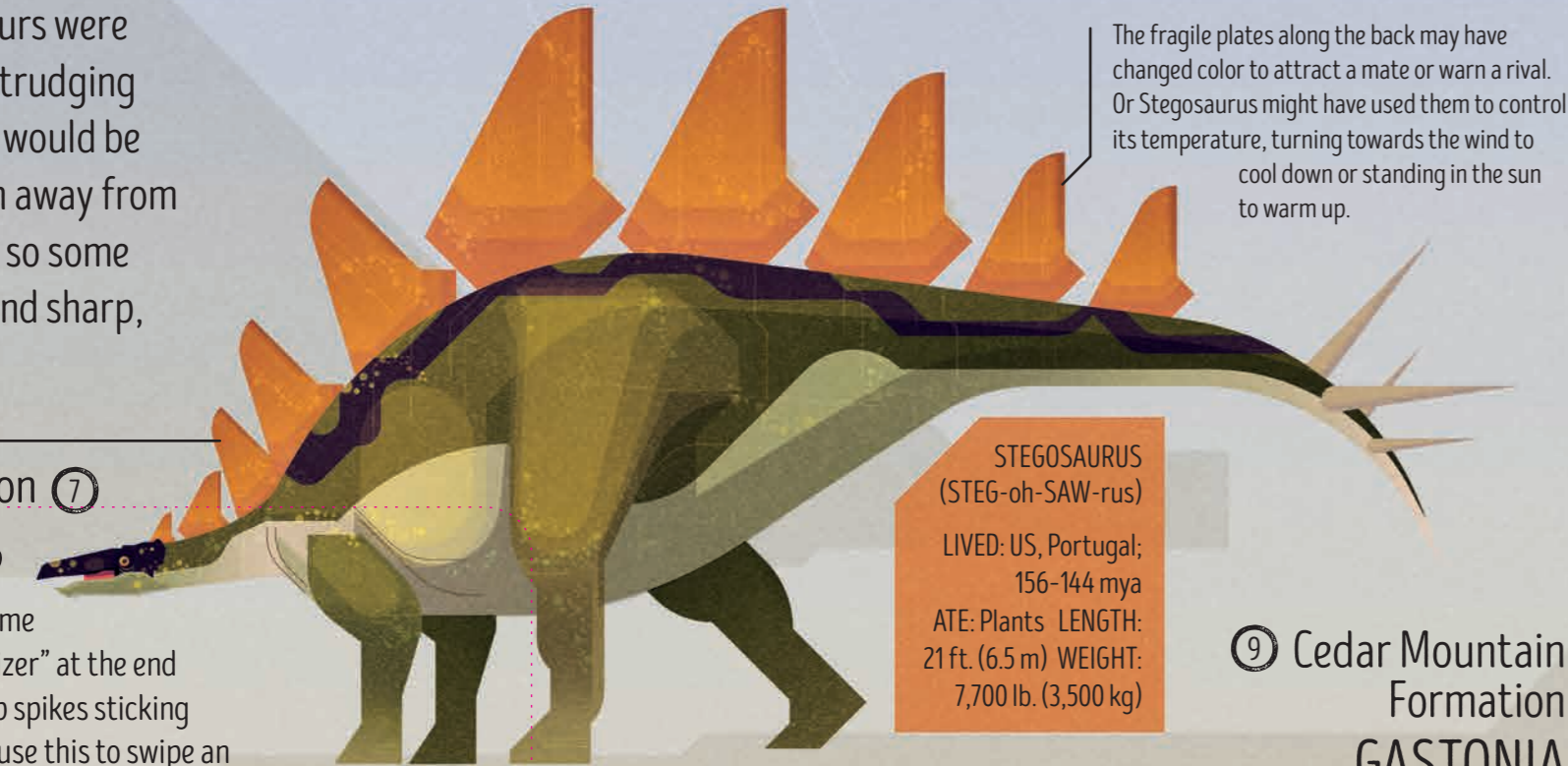
ANKYLOSAURUS
(an-KILE-oh-SAW-rus)
LIVED: Canada, US; 74-67 mya
ATE: Low-growing plants
LENGTH: 23 ft. (7 m)
WEIGHT: 13, 200 lb. (6,000 kg)

Gastonia had short legs and couldn't outrun its attackers. It relied on its thick armor for defense.

⑨ Cedar Mountain Formation GASTONIA

Gastonia had spikes and armored plates to keep it super-safe. Any predator trying to get close ran the risk of receiving a nasty injury from Gastonia as it swiped its spiked tail.

GASTONIA
(gas-TOE-nee-ah)
LIVED: US; 142-126 mya
ATE: Plants
LENGTH: 16 ft. (5 m)
WEIGHT: 4,200 lb. (1,900 kg)



STEGOSAURUS
(STEG-oh-SAW-rus)
LIVED: US, Portugal; 156-144 mya
ATE: Plants
LENGTH: 21 ft. (6.5 m)
WEIGHT: 7,700 lb. (3,500 kg)

The fragile plates along the back may have changed color to attract a mate or warn a rival. Or Stegosaurus might have used them to control its temperature, turning towards the wind to cool down or standing in the sun to warm up.

BEAKS, FRILLS, AND CRESTS

Many plant-eating dinosaurs had beaks, rather like the beak of a tortoise. They used their beaks for shearing through plant matter or for gripping and tugging at it. Beaked dinosaurs often had dramatic frills or crests on their heads.

Frenchman Formation ③ TRICERATOPS

Triceratops had three horns and a distinctive neck frill. Channels for blood vessels on the frill suggest it could be flooded with blood to change color, either to attract a mate or scare a rival or predator.



TRICERATOPS
(try-SER-ah-tops)
LIVED: Canada, US; 68-66 mya
ATE: Plants
LENGTH: 26 ft. (8 m)
WEIGHT: 24, 200 lb. (11,000 kg)

Lance Formation ⑩ PACHYCEPHALOSAURUS

Pachycephalosaurus was a bonehead - literally. Adult skulls were topped with a dome of bone up to 10 in. (25 cm) thick. The dinosaur may have used its hard head for butting the flanks of rivals when fighting for territory or a mate.

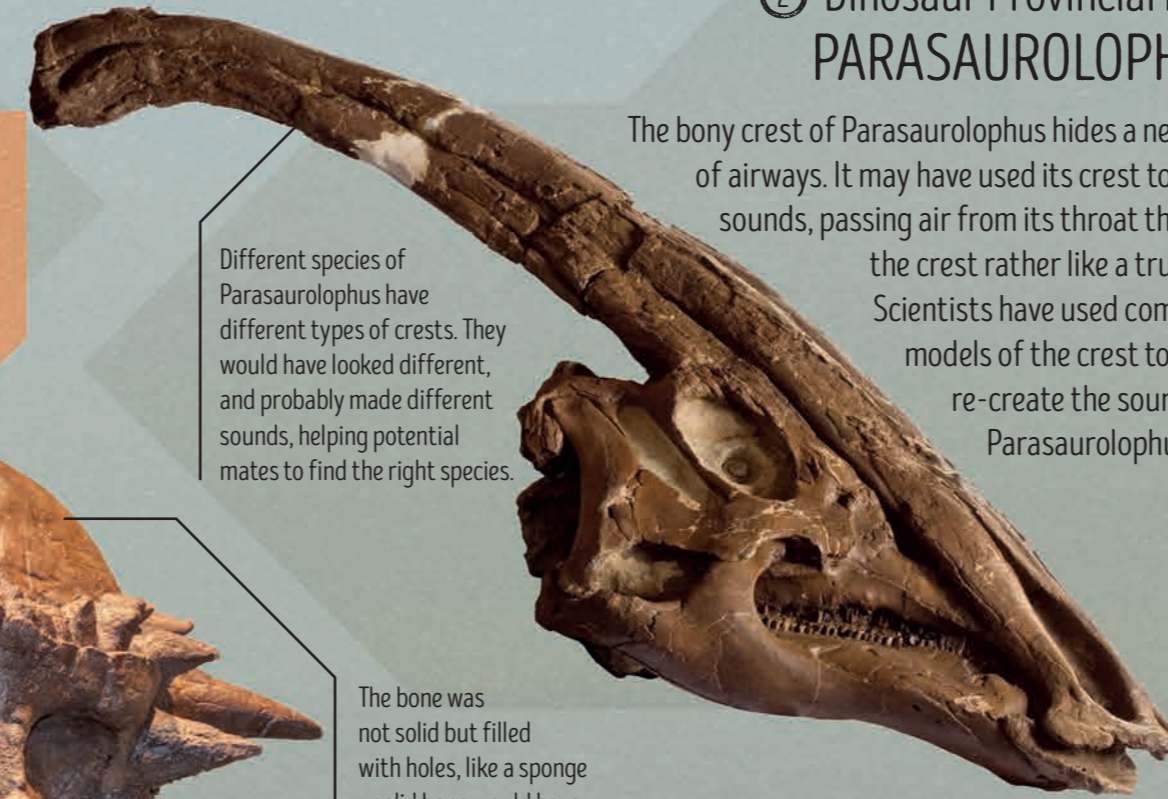
PACHYCEPHALOSAURUS
(pak-ee-SEF-ah-loh-SAW-rus)
LIVED: US; 70-66 mya
ATE: Plants
LENGTH: 4.8 ft. (4.5 m)
WEIGHT: 90 lb. (450 kg)



The bone was not solid but filled with holes, like a sponge - solid bone would have been very heavy. Babies may have had a flat head, growing bony domes as they matured.

② Dinosaur Provincial Park PARASAUROLOPHUS

The bony crest of Parasaurolaphus hides a network of airways. It may have used its crest to make sounds, passing air from its throat through the crest rather like a trumpet. Scientists have used computer models of the crest to try to re-create the sound of a Parasaurolaphus call.



Different species of Parasaurolaphus have different types of crests. They would have looked different, and probably made different sounds, helping potential mates to find the right species.

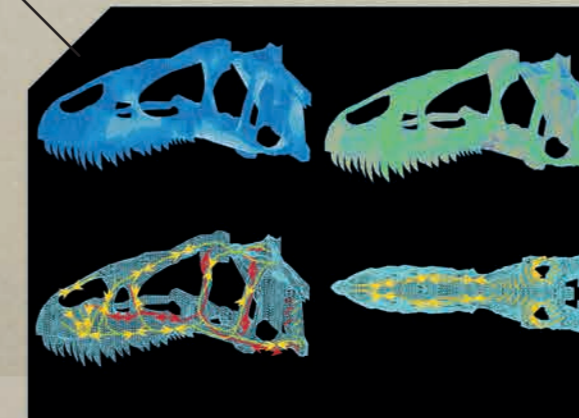
PARASAUROLOPHUS
(PAR-ah-SAW-oh-LOH-fus)
LIVED: Canada, US; 76-74 mya
ATE: Plants
LENGTH: 24.5 ft. (7.5 m)
WEIGHT: 5,700 lb. (2,600 kg)

FIERCE DINOSAURS

All those spikes and armored plates gave protection against terrifying carnivorous dinosaurs. These predators came in all sizes, but shared good eyesight, speed, fearsome teeth, slashing claws - and often feathers!

Morisson Formation ⑧ ALLOSAURUS

Allosaurus was one of the first dinosaurs investigated using computer modeling. It made swift bites, slashing and tearing at its prey with sharp, backwards-curving teeth. It could easily kill small animals, and might even have attacked heavier animals like Stegosaurus by relying on speed.

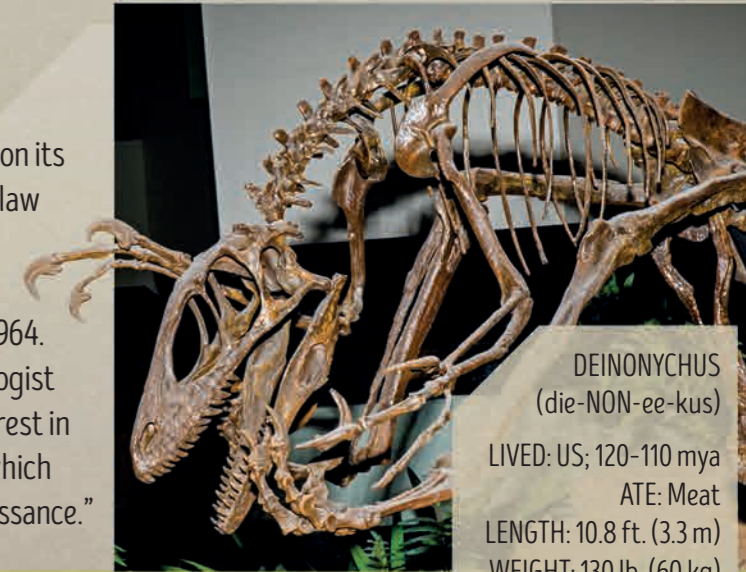


This computer model of an Allosaurus skull was used to study how the dinosaur used its teeth to tackle its prey.

ALLOSAURUS
(AL-oh-SAW-rus)
LIVED: US; 150 mya
ATE: Meat
LENGTH: 28 ft. (8.5 m)
WEIGHT: 3,300 lb. (1,500 kg)

Antlers Formation ⑪ DEINONYCHUS

Deinonychus had giant, curved claws on its feet to hold its prey still. The largest claw could rotate, so Deinonychus could hold it out of the way while walking. This bird-like dinosaur was found in 1964. Work on it by the American paleontologist John Ostrom sparked a revival of interest in the study of dinosaurs in the 1970s, which became known as the "Dinosaur Renaissance."



DEINONYCHUS
(die-NON-ee-kus)
LIVED: US; 120-110 mya
ATE: Meat
LENGTH: 10.8 ft. (3.3 m)
WEIGHT: 130 lb. (60 kg)



Albertosaurus's 3.3 ft. (1 m) long skull was packed with sharp, saw-edged teeth.

ALBERTOSAURUS
(al-BERT-oh-SAW-rus)
LIVED: Canada; 76-74 mya
ATE: Meat
LENGTH: 29.5 ft. (9 m)
WEIGHT: 2,900-3,700 lb. (1,300-1,700 kg)

① Horseshoe Canyon Formation ALBERTOSAURUS

Albertosaurus was smaller than Tyrannosaurus but just as fast and deadly. Young Albertosaurus grew quickly, and were the largest predators in their area by the age of just two. They might have hunted in packs - that would have been a fearsome sight!

Tyrannosaurus rex is the dinosaur everyone has heard of - it's the most famous dinosaur of all, and one of the largest meat-eaters that has ever lived.

TYRANNOSAURUS REX (tie-RAN-oh-SAW-rus REX)
LIVED: US; 68-66 mya
ATE: Meat LENGTH: 39 ft. (12 m) WEIGHT: 13,200 lb. (6,000 kg)

The dinosaur needed a heavy tail to balance its enormous head so that it didn't tip over.

BARNUM BROWN

The first Tyrannosaurus fossil was found in 1902 in Hell Creek by the American fossil-hunter Barnum Brown (1873-1963).

Brown uncovers dinosaur bones in Wyoming during a dig in the 1930s.



FOSSILIZED FIGHT

The fossil on the right was found in 2006 and shows two dinosaurs tangled up together. The one on the left is probably a young Tyrannosaurus and the other a large ceratopsian. Some paleontologists think they may have battled to the death. So did the ceratopsian fall victim to the Tyrannosaurus? There is a tooth wedged in its neck.



Tyrannosaurus would have held its tail out horizontally behind it as it walked.

Tyrannosaurus had the longest legs for its size of any dinosaur. They were powerful enough to let it run at around 19 mph (30 kph).

The teeny, tiny arms were too short to reach the mouth. No one knows how Tyrannosaurus used them - perhaps to hold smaller animals while biting them.

Fossilized Tyrannosaurus poop contains bits of bone and muscle from its meals. Tyrannosaurus probably hunted other dinosaurs and ate any dead animals it found lying around.

It's odd to think of something so fierce covered in feathers - but Tyrannosaurus probably had at least some feathers. The babies may have been covered in down, like bird chicks! Sweet, but savage...

BATTLING TEENS

Bite marks on the skull of a young Tyrannosaurus found in 2001 are from the teeth of another young - probably teenage - Tyrannosaurus. The bite healed, so perhaps it wasn't a very serious fight. Could they have been squabbling siblings?

The enormous head had a narrow snout, making the eyes close together. This meant Tyrannosaurus had good binocular vision, just like we do.

The largest T-rex tooth ever found was 12 in. (30.5 cm) long, including the root that held it in the jaw.

ACTUAL SIZE TOOTH!

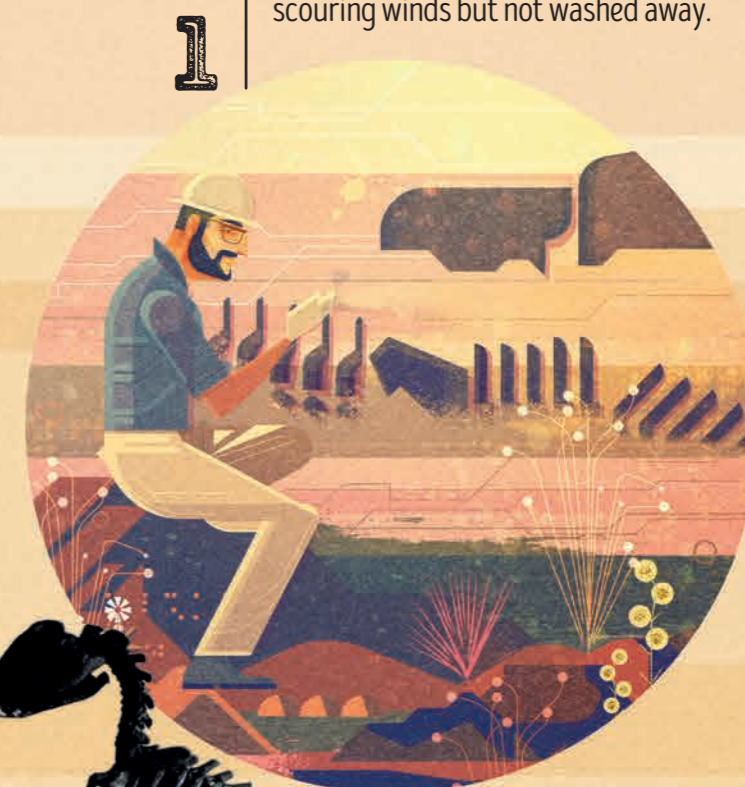
The powerful jaw and teeth of T-rex could rip large chunks out of other dinosaurs. The front teeth curved backwards, so they wouldn't be pulled out when Tyrannosaurus tore at flesh.



NORTH AMERICA

FOSSIL-HUNTING

Dinosaurs lived 242-66 million years ago, so to find their fossils paleontologists need to look in rocks of that age. In North America, rocks the right age are near the surface in a band running through the middle of the continent. In the northeast and midwest, the rocks are too old for dinosaur fossils, while in the southeast, they are too new.



DINOSAUR HUNT

Once they've found some suitable rocks, paleontologists look for clues that might reveal dinosaur remains. They may find fragments of bone in riverbeds, fossilized footprints, or bits of bone sticking out of the rock. Desert areas are often the best places to look, as fossils are exposed by scouring winds but not washed away.



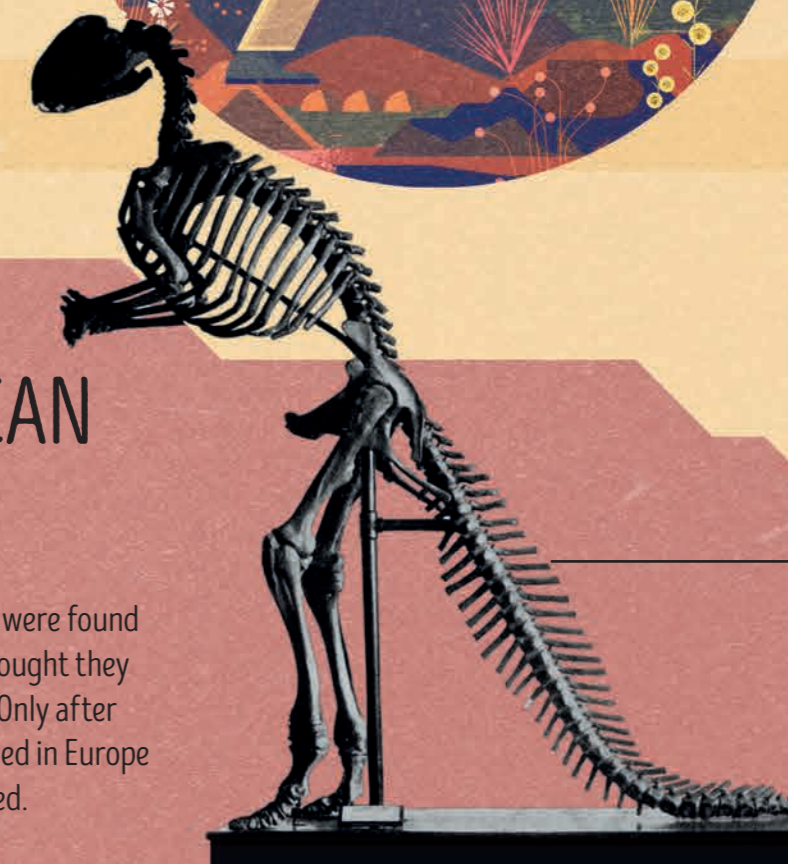
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DIGGING AWAY

When they find a large skeleton, fossil-hunters first remove large chunks of surrounding rock, called overburden. Then they carefully scrape and brush away the remaining rock and soil to reveal the bones. It can take weeks. They photograph the positions of all the bones before moving them.

FIRST AMERICAN DINOSAURS

When the first dinosaur footprints were found in North America in 1802, people thought they were the footprints of giant birds. Only after dinosaurs had been found and named in Europe were American dinosaurs recognized.



This American Hadrosaurus was the first dinosaur skeleton to be reassembled and mounted for display anywhere in the world. The paleontologist Joseph Leidy and artist Benjamin Waterhouse Hawkins put the bones back together in 1868.

JIGSAW PUZZLE

Putting a dinosaur back together can be like tackling a very challenging jigsaw puzzle. Fossil-hunters collect and label every tooth, claw, and bone - even tiny fragments of shattered bones. Only later will they figure out which go together. Sometimes, several animals are jumbled together.

Paleontologists can tell from the size, structure, and shape of the head, tail, and limbs what type of dinosaur they have found. Can you guess what sort of dinosaur this jumble of bones may be? Lift the flap to find out.



WHERE DOES THE HEAD GO?

In 1868, Edward Drinker Cope sketched a reconstruction of a newly discovered marine reptile, *Elasmosaurus*. However, he made a major mistake, putting the head on the wrong end - on its tail rather than on its neck. Lift the flap to see what happened.



ACTUAL SIZE SCUTE!
This is just the tip of a Stegosaurus scute (bony back plate), which is over 24 in. (60 cm) across at its widest point.



WHO'S THAT DINOSAUR?

Fossils don't come out of the ground labeled. Paleontologists often have to figure out what type of animal they have found from a few mixed up or broken fossilized bones. They compare the pieces with previous finds to decide if it is a completely new, unknown type of dinosaur or one that has already been described.

A paleontologist cleans and reassembles fragments of fossilized dinosaur bone.



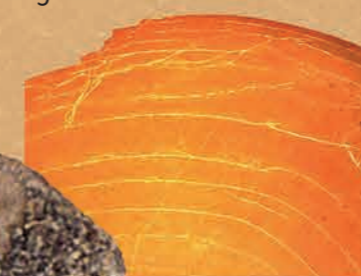
FROM BONES TO BODIES

From the size of one bone, we can figure out the size of a whole dinosaur! Suppose a type of dinosaur that is 32 ft. (10 m) long has a leg bone 3.2 ft. (100 cm) long - so its leg bone is a tenth of its body length. If paleontologists find a leg bone 2.9 ft. (90 cm) long, they can guess the whole dinosaur would have been 29 ft. (9 m) long, or ten times the length of the bone.

Scientists would only need to see a single leg bone of this *Allosaurus* to figure out roughly how big it was.

GROWTH RINGS

Bones have growth rings, just like trees. Counting the growth rings in a fossilized bone shows how old an animal was when it died. The image on the left shows growth rings in a thighbone from an unknown species of dinosaur.



PICK UP YOUR TAIL

Not all fossils are made from body parts. "Trace" fossils are created when an impression made by an animal in soft mud or sediment hardens. They are often footprints or marks made by a tail dragging in the mud. Fossilized footprints can show whether dinosaurs walked on two or four legs, their speed, and even whether they moved together in groups. Stride length (the distance between footprints) can reveal whether dinosaurs were running or plodding along.

GLEN ROSE TRACKWAY

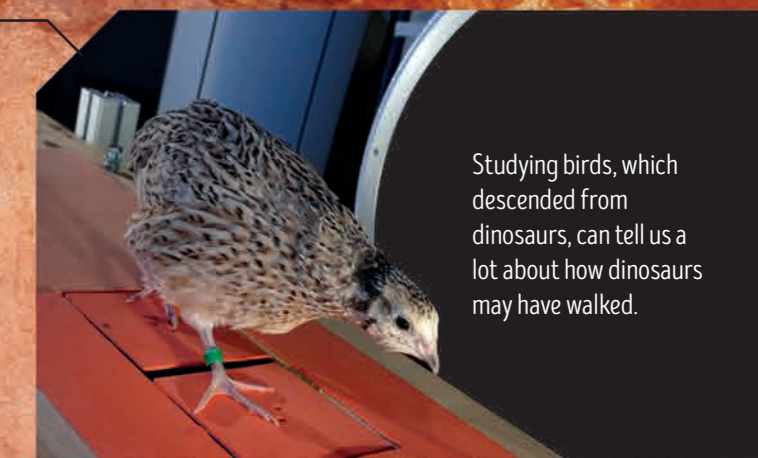
The Glen Rose Formation preserves tracks made 107 million years ago. They are now in the Paluxy River, Texas. Some sauropod footprints are 3.3 ft. (1 m) long and 10-12 in. (25-30 cm) deep, showing the heavy dinosaur was sinking into the mud. In other places, three-toed footprints 10-12 in. (25-30 cm) long were produced by large theropods that walked on just their back legs.



Situated on the riverbed, the footprints of the Glen Rose Trackway are often underwater.

DINOSAURS IN ACTION

Fossils can show us how dinosaurs moved. Muscles attach to bones, so experts can figure out from the shape of the bones what the muscles were like. Computer models can compare dinosaurs with living animals to show how they held their heads and tails.



Studying birds, which descended from dinosaurs, can tell us a lot about how dinosaurs may have walked.

Around 10 in. (25 cm) long, these 150-million-year-old footprints were found in Arizona and may have been left by an *Allosaurus*.

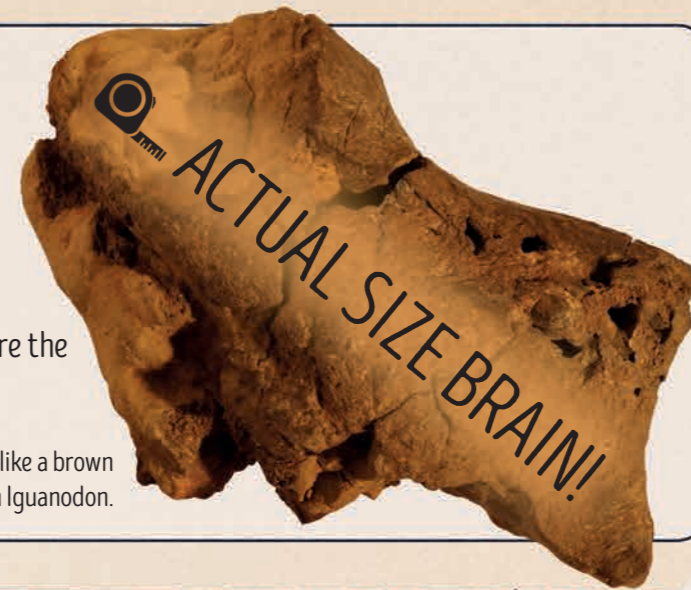
Bernissart Calcirudites Formation, Belgium ⑦
THUMB SPIKES

The creature now called Iguanodon was similar to the animal Mantell found. It was a lumbering, heavy plant-eater with a large spike on each of its thumbs.

NO-BRAINER

Dinosaurs had very small brains for their body size. Does that mean they were stupid? It's hard to tell. If a small brain makes for a dumb dino, Iguanodon, with a brain the size of a couple of walnuts, was pretty stupid - but the sauropods were even more stupid. Theropods were the smartest, being about as brainy as a modern ostrich.

This "pickled" dinosaur brain looks like a brown pebble; it may be from an Iguanodon.



GETTING IT WRONG

It's hard to figure out from just a few fossilized bones what an animal might have looked like and how it lived. It's become easier as we've found more dinosaurs, and now have computers to model how their bodies worked, but in the past people sometimes got it very wrong. For instance, early paleontologists portrayed the dinosaur that Mantell had named Iguanodon (now known as Mantellodon) with its spike on its nose rather than on its thumb. Lift the flap to see how our reconstructions of dinosaurs have improved over the years.

At Crystal Palace, the Megalosaurus was shown as a squat, stocky, four-legged lizard. We now know this to be incorrect.



Trossingen Formation, Germany ⑩
DIFFERENT SIZES

There's more variety in the size of adult Plateosaurus than in any other dinosaurs yet discovered. They grew big if things were going well (if they had lots of food), and stayed smaller if times were hard. Plateosaurus possibly lived in herds, roaming across large areas.

Always walking on two legs, Plateosaurus was probably the first dinosaur to be able to eat leaves from high in the trees.

PLATEOSAURUS
(PLAY-tee-oh-SAW-rus)
LIVED: Germany; 210 mya
ATE: Plants
LENGTH: 16-33 ft. (5-10 m)
WEIGHT: 1,900 lb. (900 kg)

⑫ Sânpetru Formation, Romania
SHRINKING DINOSAURS

On the islands of Cretaceous Europe, large dinosaurs shrank! Types of dinosaurs that grew large elsewhere became smaller in Europe. It's a trend called "insular dwarfism" and has happened with other types of animals stranded on islands, too. Magyarosaurus is the smallest adult sauropod yet found, and is believed to have grown no taller than a horse.

MAGYAROSAURUS
(mag-YAR-oh-SAW-rus)
LIVED: Romania; 71-65 mya
ATE: Plants
LENGTH: 16-20 ft. (5-6 m)
WEIGHT: 1,600 lb. (750 kg)

An adult human male - to scale.

Rögling Formation, ⑧
Germany
FURRY FEATHERS

The theropod Scieurumimus had fuzzy feathers all over. Unlike bird feathers, these were single strands (or filaments) that looked more like fur. The only Scieurumimus found so far is a youngster that was just 2.4 ft. (72 cm) long. We don't know how big an adult would have grown.

SCIURUMIMUS
(skee-ORE-ooH-MY-muss)
LIVED: Germany; 150 mya
ATE: Meat
LENGTH: Unknown
WEIGHT: Unknown



The Scieurumimus fossil showed it was covered in hair-like feathers.

Sebeș Formation, Romania ⑪
EITHER/OR

Balaur is a bit of a mystery. It had two large claws on each hind foot rather than the usual single claw of theropods - were they for holding on to branches or for gripping prey? Balaur may have been an early plant-eating bird, a bit like a modern goose or a hoatzin, or it may have been a meat-eater that would have hunted small prey - like a flightless eagle.

BALOUR
(BAL-lor)
LIVED: Romania; 80 mya
ATE: Meat
LENGTH: 6.5 ft. (2 m)
WEIGHT: 51 lb. (23 kg)



Eichstätt Formation, Germany ⑨
BIRDS AS DINOSAURS

The dinosaurs around today are all birds, but the first bird-like dinosaurs flew around Europe 150 million years ago.

Archaeopteryx is seen as a link between modern birds and dinosaurs. It had lots of features that birds don't have, but it could fly. First, a single fossil feather was found in around 1861, then a bird with no head, and finally a complete fossil.

ARCHAEOPTERYX
(AR-key-op-ter-iks)
LIVED: Germany; 150 mya
ATE: Almost anything!
Plants, seeds, insects, crustaceans, small reptiles, and perhaps fish
LENGTH: 1.6 ft. (50 cm)
WEIGHT: 7 oz. (200 g)

Unlike modern birds, Archaeopteryx had teeth.



The legs were more feathery than those of most modern birds.

The tail was long and had a bone running through it - modern birds have no tailbones.

WHY FLY?

No one is quite sure why birds first took flight. One idea is that they began by using their wings to help them run and hop upwards to escape from predators. Then they might have taken to gliding or flapping down again when danger passed. Archaeopteryx lived on dry, barren islands with low shrubs, so it probably didn't launch itself from trees.



MARINE REPTILES

Marine reptiles swam in the warm Jurassic-Cretaceous seas that covered much of Europe. They were the descendants of land-going reptiles, and had to rise to the surface to breathe. Their fossils formed on seabeds that have since become dry land.

Lias Group, ④ England FOSSIL-HUNTER

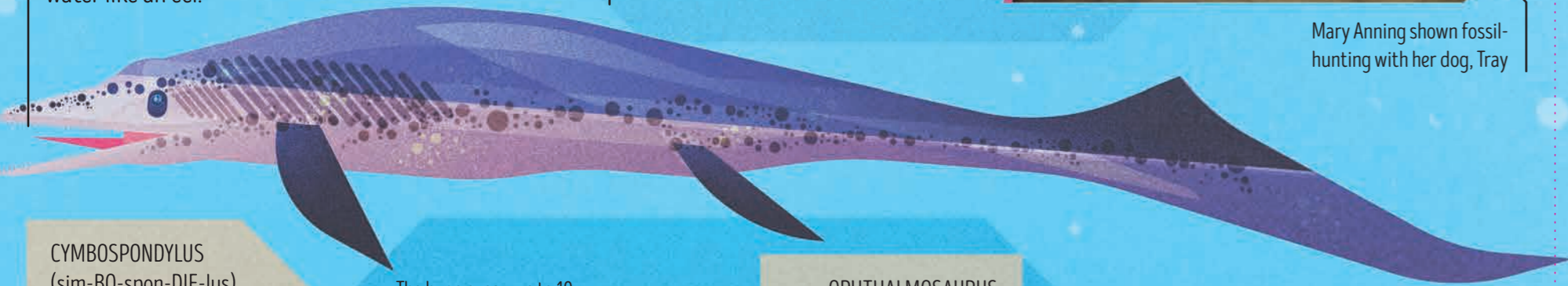
From early childhood, Mary Anning (1799-1847) hunted for fossils along England's Dorset coast, and sold them as souvenirs to tourists. She taught herself how to extract and reassemble fossils, and became one of the most successful and knowledgeable fossil-hunters of her time.



Mary Anning shown fossil-hunting with her dog, Tray

Besano Formation, Switzerland ⑬ EEL-LIKE

The earliest Ichthyosaurs, such as Cymbospondylus, were long and thin, and swam by wriggling through the water like an eel.

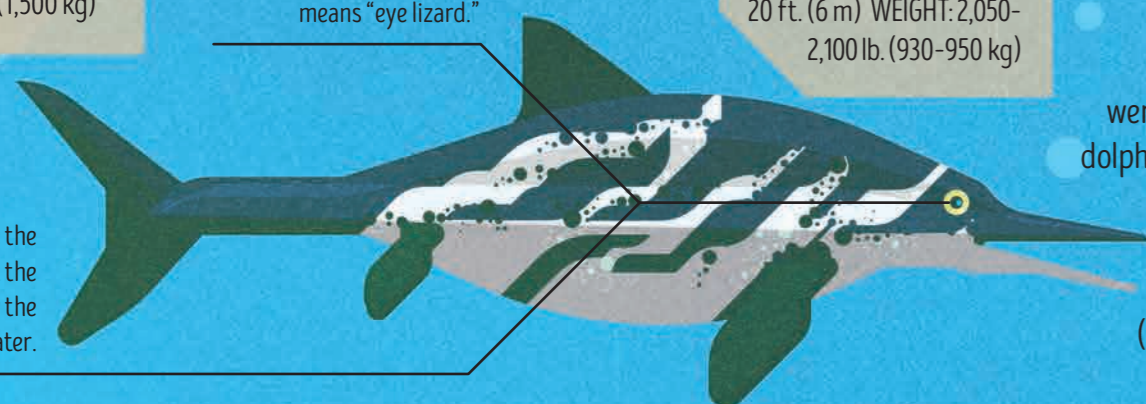


CYMBOSPONDYLUS
(sim-BO-spon-DIE-lus)
LIVED: Switzerland, Germany, US; 240-210 mya
ATE: Fish and other marine reptiles
LENGTH: 20-33 ft. (6-10 m)
WEIGHT: 3,300 lb. (1,500 kg)

The huge eyes - up to 10 in. (26 cm) across - are the largest of any known creature, and allowed Ophthalmosaurus to see well in dim light deep underwater. Its name means "eye lizard."

OPHTHALMOSAURUS
(off-THAL-moh-SAW-rus)
LIVED: Norway, Germany, England, US, Russia; 165-145 mya
ATE: Squid, fish LENGTH: 20 ft. (6 m) WEIGHT: 2,050-2,100 lb. (930-950 kg)

A ring of bone inside the eyeball helped prevent the eye being squashed by the pressure of deep water.

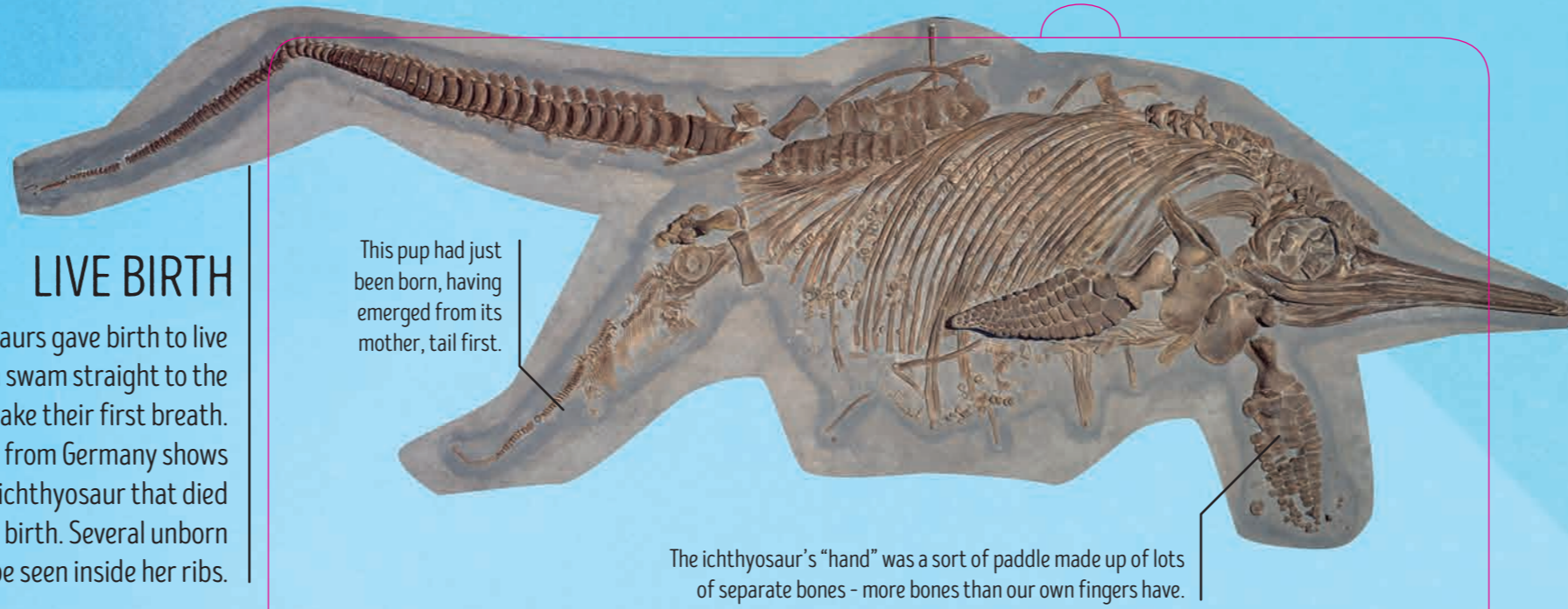


① Oxford Clay Formation, England LOOKING FISHY

Later ichthyosaurs, like Ophthalmosaurus, were more fish-shaped and resembled modern dolphins. Ophthalmosaurus probably swam like a tuna, keeping the front part of its body steady and moving the back part from side to side. It could dive to 2,000 ft. (600 m) and stay submerged for 20 minutes.

LIVE BIRTH

Ichthyosaurs gave birth to live pups which swam straight to the surface to take their first breath. This fossil from Germany shows a female ichthyosaur that died while giving birth. Several unborn pups can be seen inside her ribs.



This pup had just been born, having emerged from its mother, tail first.

The ichthyosaur's "hand" was a sort of paddle made up of lots of separate bones - more bones than our own fingers have.

LONG AND SHORT NECKS

Plesiosaurs adapted to life in the water by turning their limbs into flippers. Most had long necks and small heads, but a subgroup called pliosaurs had short necks, large heads, and mouths full of fearsome teeth.

Lias Group, England ④

Plesiosaurus was the first plesiosaur discovered, found by Mary Anning in 1823. Plesiosaurs gave birth to a single, large baby; today, whales do the same.

The paddle-like limbs were stiff and good for pushing quickly through the water, but probably could not move the plesiosaurus over land.

PLESIOSAURUS
(PLEE-zee-oh-SAW-rus)
LIVED: England; 199-175 mya
ATE: Fish, squid LENGTH: 1.5 ft. (3.5 m) WEIGHT: 990 lb. (450 kg)



Narrow, needle-like teeth point forwards - ideal for snapping small fish as the reptile swam through a shoal.

The long neck was not bendy and was held nearly straight.

Oxford Clay Formation, France ⑥

Liopleurodon was a pliosaur and well-equipped as a savage killer. The size of a killer whale, with pointed teeth 8 in. (20 cm) long, it was the top predator in the Jurassic seas of Europe.

Liopleurodon's head was about a fifth of its body length.

Like other plesiosaurs, it had lots and lots of vertebrae packed into its backbone.

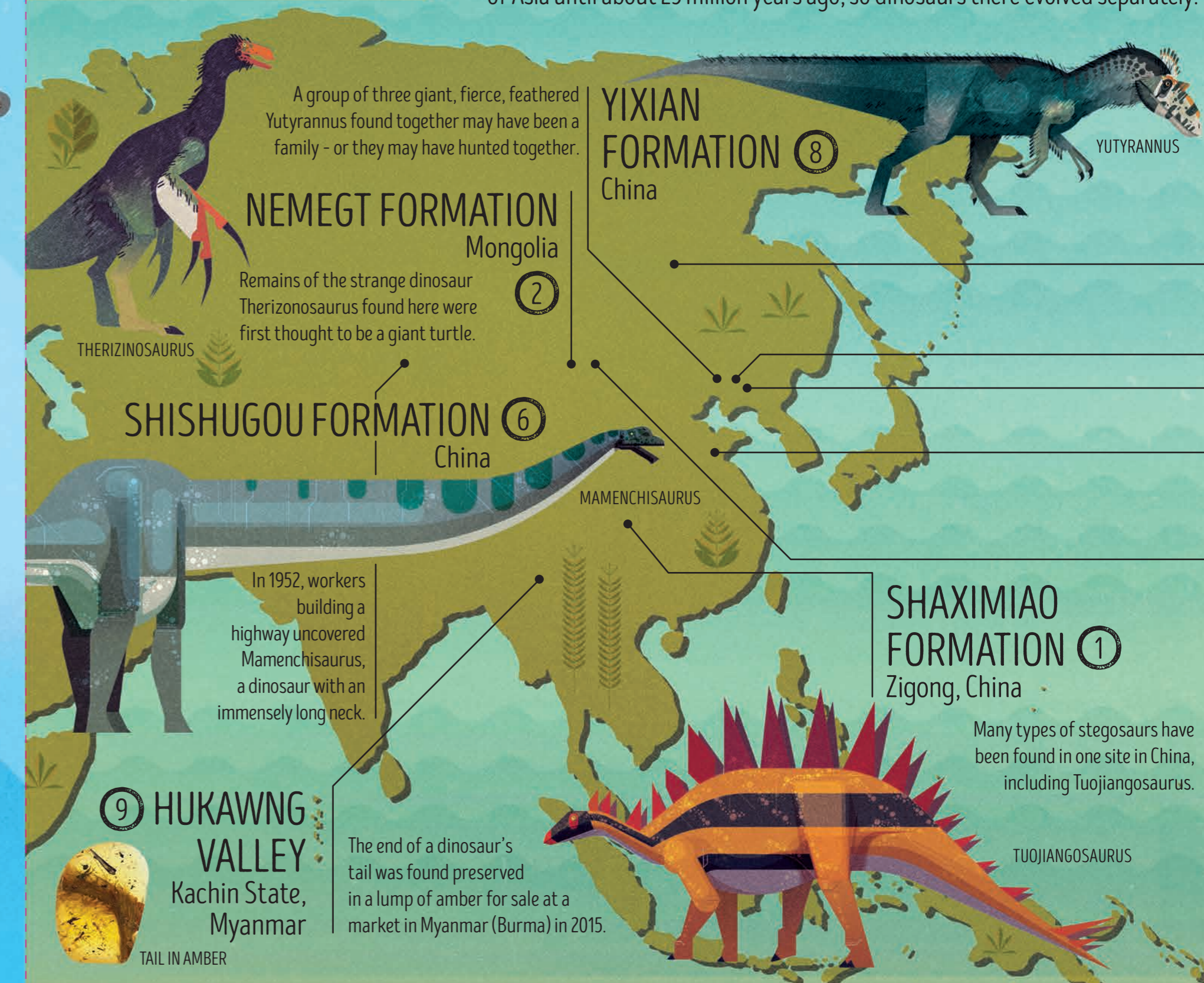


LIOPLEURODON
(LIE-oh-PL00-roh-don)
LIVED: England, France; 160-150 mya
ATE: Fish, marine reptiles LENGTH: 23 ft. (7 m) WEIGHT: 5,500 lb. (2,500 kg)

The reptile's nostrils were adapted to smell underwater. Liopleurodon could even tell the direction a smell came from.

ASIA

China and Mongolia are rich in dinosaur fossils, as the dry deserts there have preserved them over millions of years. India was not joined to the rest of Asia until about 25 million years ago, so dinosaurs there evolved separately.



A group of three giant, fierce, feathered Yutyrannus found together may have been a family - or they may have hunted together.

NEMEGT FORMATION ② Mongolia

Remains of the strange dinosaur Therizinosaurus found here were first thought to be a giant turtle.

SHISHUGOU FORMATION ⑥ China

In 1952, workers building a highway uncovered Mamenchisaurus, a dinosaur with an immensely long neck.

⑨ HUKAWNG VALLEY Kachin State, Myanmar

The end of a dinosaur's tail was found preserved in a lump of amber for sale at a market in Myanmar (Burma) in 2015.

YIXIAN FORMATION ⑧ China

SHAXIMIAO FORMATION ① Zigong, China

Many types of stegosaurs have been found in one site in China, including Tuojiangosaurus.

TUOJIANGOSAURUS

YUTYRANNUS

MAMENCHISAURUS

TAIL IN AMBER