Lesson 11: Dinosaur Origins

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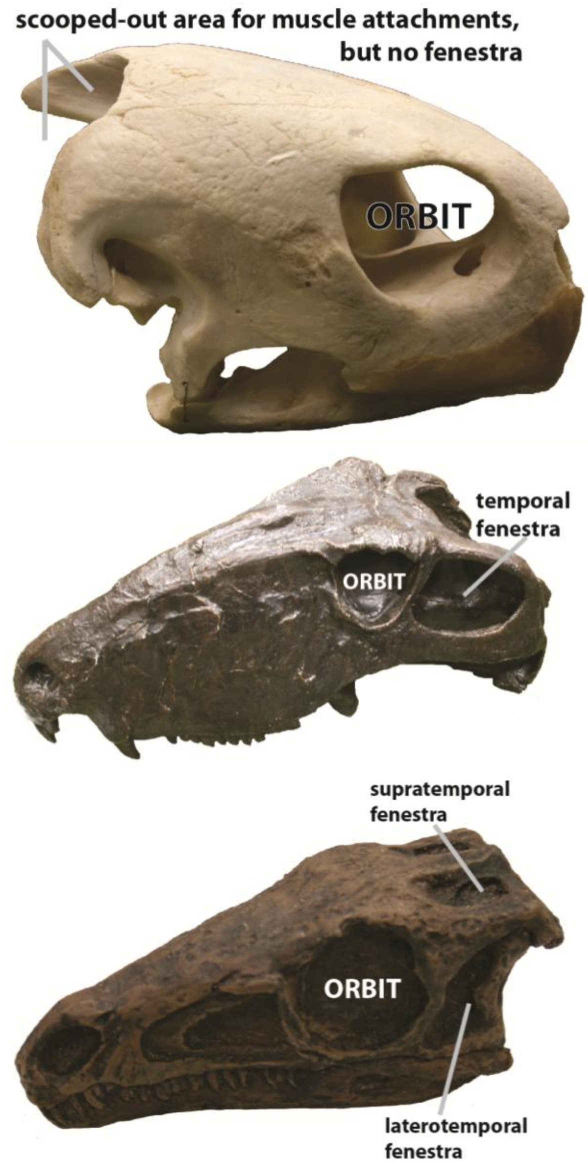
Learning objective for lesson 11: Students will be able to describe the evolution of dinosaurs from non-dinosaurian archosaurs

Learning objective 11.1: Identify features that differentiate anapsids, synapsids, and diapsids.

Recall that fenestrae are additional openings in the skull that do not house sensory organs. Usually, fenestrae provide an open area for large muscles to fill. The number and arrangement of fenestrae are key characters that are used to help classify amniotes into their major lineages.

Amniotes that completely lack fenestrae are called **anapsids**. Modern turtles are one example, but anapsids are relatively rare today, and were more common earlier in the history of amniotes.

Synapsids are amniotes with one fenestra on each lateral side of their skull. All mammals are synapsids and so were our close reptilian ancestors, like the famous sail-backed synapsid ***Dimetrodon***. Although it is commonly misidentified as dinosaur, *Dimetrodon* is more closely related to you and me than it is to any dinosaur. *Dimetrodon* lived during the Permian period, so it was millions of years older than the first dinosaurs.



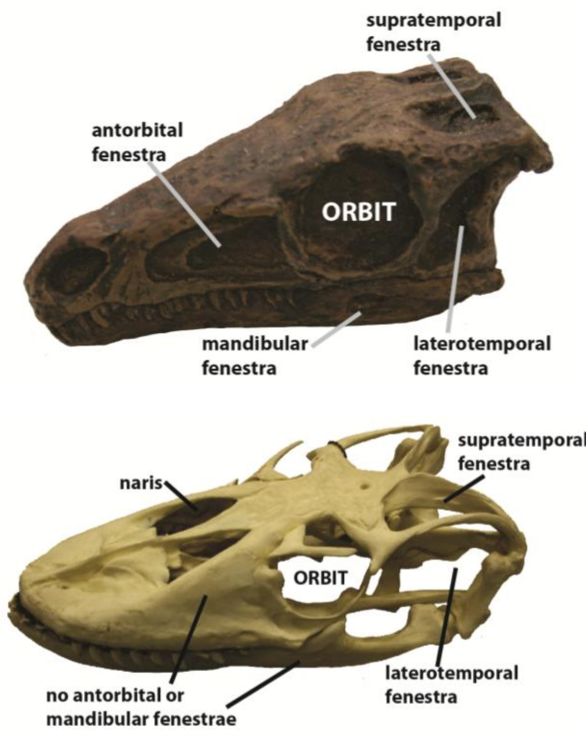
Top: the skull of a green sea turtle (*Chelonia mydas*), an anapsid. Middle: the skull of *Dimetrodon*, a synapsid. Bottom: the skull of *Eoraptor*, a diapsid. Photos by V. Arbour.

Amniotes with one set of fenestrae on the lateral sides of their skulls and one set on the top surfaces of their skulls are called **diapsids**.

Learning objective 10.2 – Identify features that differentiate lepidosauromorph diapsids and archosauromorph diapsids .

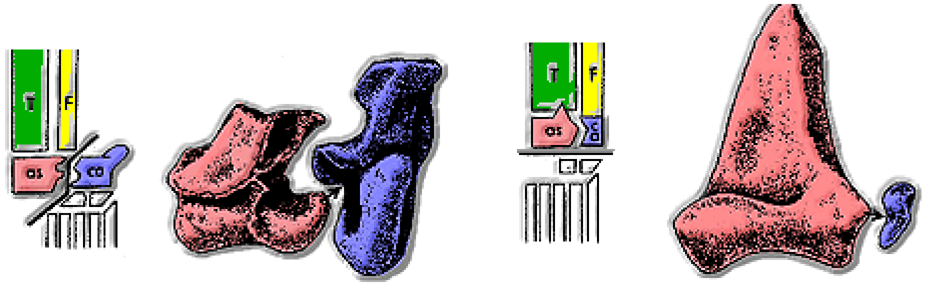
Diapsids are further subdivided into two groups, again based on fenestrae. **Lepidosauromorphs** (or lepidosaurs, as we'll also refer to them here) are diapsids with no additional fenestrae. Modern lepidosaurs include lizards, snakes, and tuataras. **Archosauromorphs** (or archosaurs, as we'll also refer to them here) are diapsids with an additional fenestra in front of each orbit (the **antorbital fenestra**) and an additional fenestra on the rear of the lower jaw (the **mandibular fenestra**). Crocodilians, birds, dinosaurs, and the extinct flying reptiles called pterosaurs are all archosaurs. Note that some lineages of archosaurs, such as modern crocodilians, have secondarily lost their antorbital fenestra and some, like the pterosaurs, secondarily lost their mandibular fenestra. This does not mean that crocodilians or pterosaurs lose their status as archosaurs, because "archosaur" is a name applied to the evolutionary lineage. As long as the ancestors of crocodilians and pterosaurs had the characters that define an archosaur (and they did), crocodilians, pterosaurs, and all other such descendants will be classified as part of this evolutionary group.

Learning objective 11.3 – Identify features that differentiate pseudosuchian archosaurs from avemetatarsalian archosaurs.

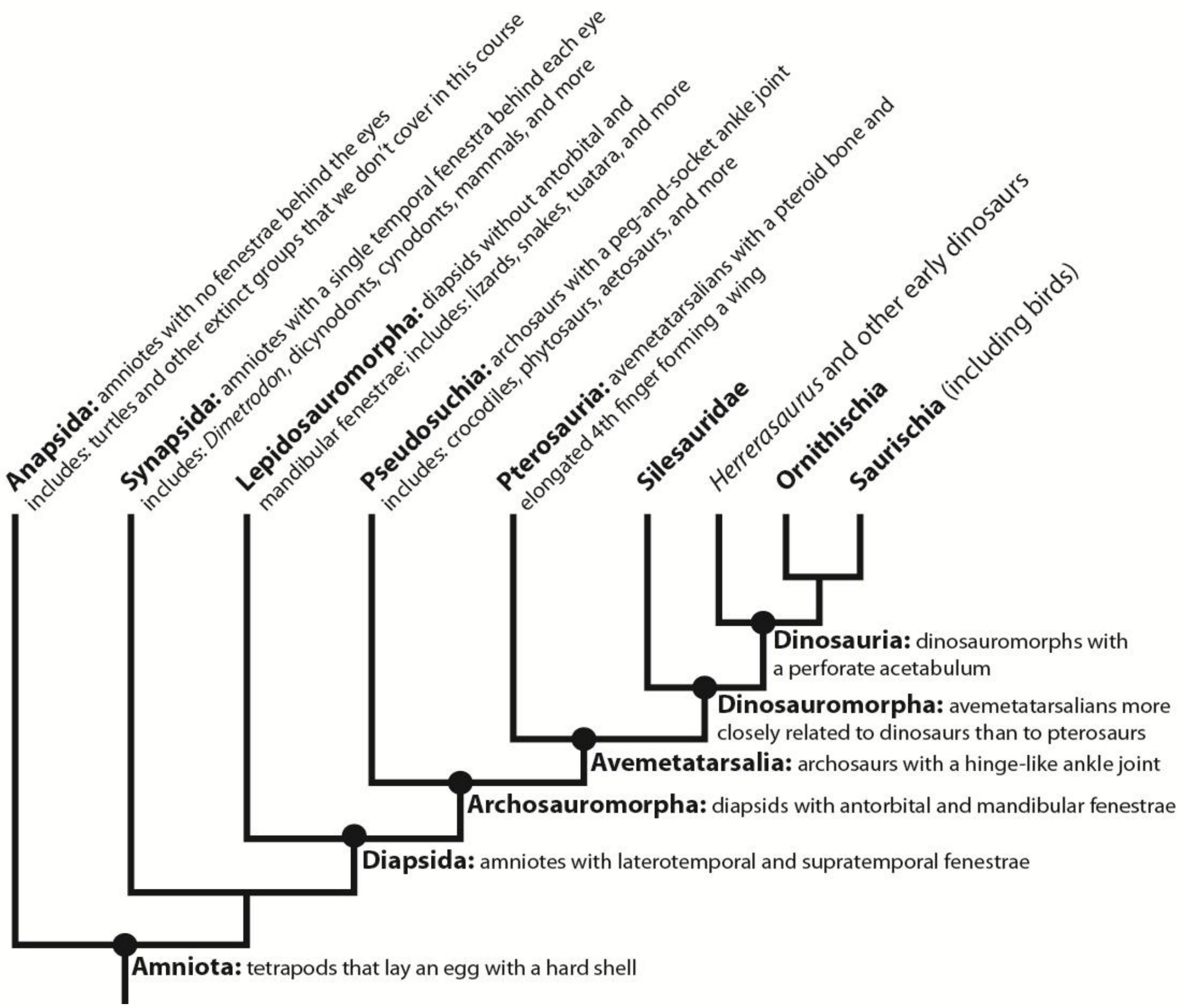


Top: *Eoraptor*, an archosauromorph.
Bottom: Komodo dragon (*Varanus komodoensis*), a lepidosauromorph. Photos by V. Arbour.

Dinosaurs, pterosaurs, and a few of their close relatives belong to a special group of archosaurs, and are known as **avemetatarsalians**. Avemetatarsalians are characterized by having ankles that flex like ahinge, while other archosaurs have ankles that rotate like a ball-and-socket. This adaptation gave avemetatarsalians stiffer ankles, which were better able to safely support their weight while running and were better suited to locomotion on upright (non-sprawling) limbs. The archosaurs are thus divided into two main lineages: the pseudosuchian archosaurs, which include today's living crocodiles, their ancestors, and many unusual extinct groups that we'll cover in greater detail shortly, and the avemetatarsalian archosaurs, which include dinosaurs and their immediate ancestors, pterosaurs, and birds.



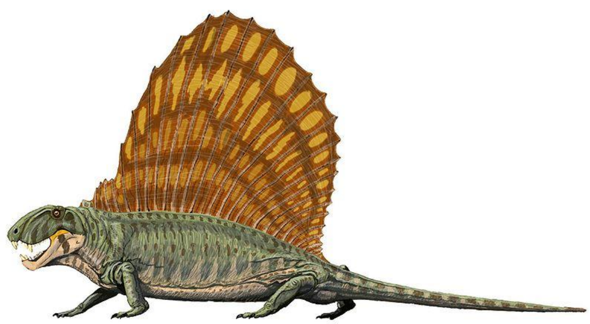
Left: The pseudosuchian ankle condition, where the astragalus (pink) and calcaneum (blue) interlock like a peg-and-socket, rotating around each other during locomotion. Right: The avemetatarsalian condition results in a simple hinge joint. Illustrations released into the public domain by Philip Chalmers, via Wikimedia Commons.



A simplified phylogenetic tree of the Amniota. Dinosaurs are dinosauromorphan, avemetatarsalian, archosaurian diapsids. As an aside: the phylogenetic placement of turtles and other anapsids, is still hotly debated; for simplicity, all anapsids have here been grouped as a single clade outside of Synapsida+Diapsida here. Remember that each node includes all of the clades above it on the tree (i.e. those that are more derived). Diagram by V. Arbour.

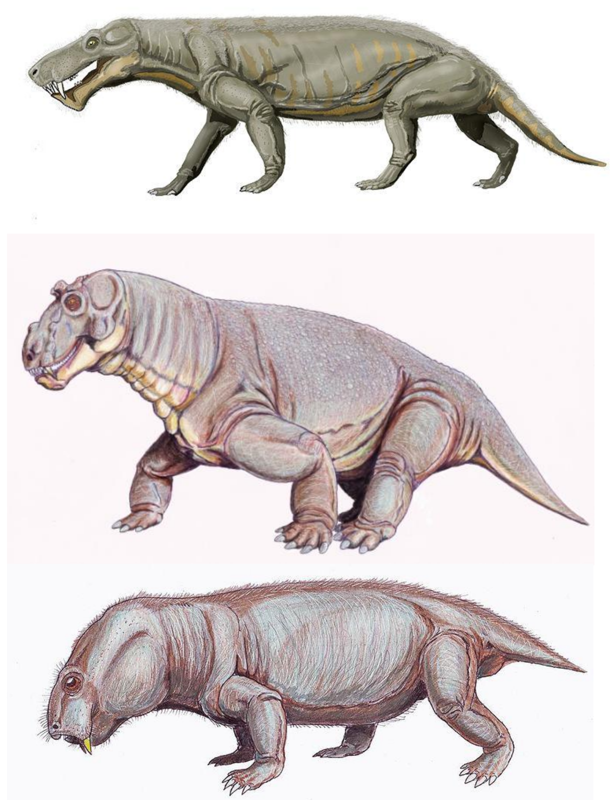
Learning objective 11.4 – Describe the characteristic vertebrates of the Permian Period and the changes in vertebrate community structure at the Permian-Triassic boundary.

In the Permian (299 to 252 million year ago), all the world's landmass was part of the supercontinent Pangaea. This single continent had an arid interior, with rapidly fluctuating temperatures and climates. The first group of amniotes to evolve large body size and to dominate the ecological roles of mega-herbivores and mega-carnivores across Pangaea was not the dinosaurs. It was the synapsids - our own lineage! Reptile-like synapsids, including *Dimetrodon*, became common and thrived for millions of years.



***Dimetrodon*, one of the earliest synapsids, seems to have little in common with its living relatives the mammals at first glance. Image by Dmitry Bogdanov and used under the GNU Free Documentation License, via Wikimedia Commons.**

Gradually, these early synapsids become more mammal-like. Late in the Permian, large saber-toothed synapsids, called **gorgonopsids,** were the top predators, and synapsids, like the tusked **dicynodonts,** were the top herbivores. There was a diverse array of small and medium-sized synapsids, including the cynodonts. **Cynodonts** would go on to evolve into true mammals, and the early forms looked a little like short-legged dogs. Then, 252 million year ago, disaster struck the world of the synapsids.



Permian synapsids. *Gorgonops* (top), a carnivorous gorgonopsid from South Africa, *Estemmenosuchus* (middle), one of the larger early synapsids at 3 m (10 feet) in length, a herbivore from Russia, and *Dicynodontoides* (bottom), a small herbivorous dicynodont from Africa and India. Images by Dmitry Bogdanov and used under the GNU Free Documentation License, via Wikimedia Commons.

The end-Permian mass extinction was the most devastating extinction event in the history of life. The exact percentage of species that went extinct varies according to different researchers (think back to the problems palaeontologists can face when identifying fossil species), but palaeontologists agree that about 70% of all terrestrial vertebrate species, and 90-95% of all marine species, went extinct in a short span of time. This is a truly colossal loss of life and diversity.

The cause (or causes) of the end-Permian mass extinction remains uncertain. Huge lava deposits, known as the Siberian Traps, formed at this time. The volcanic eruptions that formed these deposits may have been ongoing for 200 000 years or more! These long-lasting eruptions must have released large quantities of volcanic gases into the atmosphere, leading to a greenhouse effect and increased global temperatures. Increased global temperatures may have also resulted in the melting of frozen chemicals called methane hydrates deep in the ocean, which in turn would have contributed to more global warming and even more melting of methane hydrates, and so on. Global temperatures may have increased by at least 6 degrees right at the end of the Permian. Some scientists have hypothesized that the extinction may have been brought about by a comet or meteorite impact, although a crater from such an impact has yet to be found. Whatever the cause, the end-Permian mass extinction was the single greatest extinction event ever, and it took millions of years for Earth's ecosystems to recover.

Learning objective 11.5 – Describe the characteristic vertebrates of the Triassic Period and the changes in vertebrate community structure at the Triassic-Jurassic boundary.

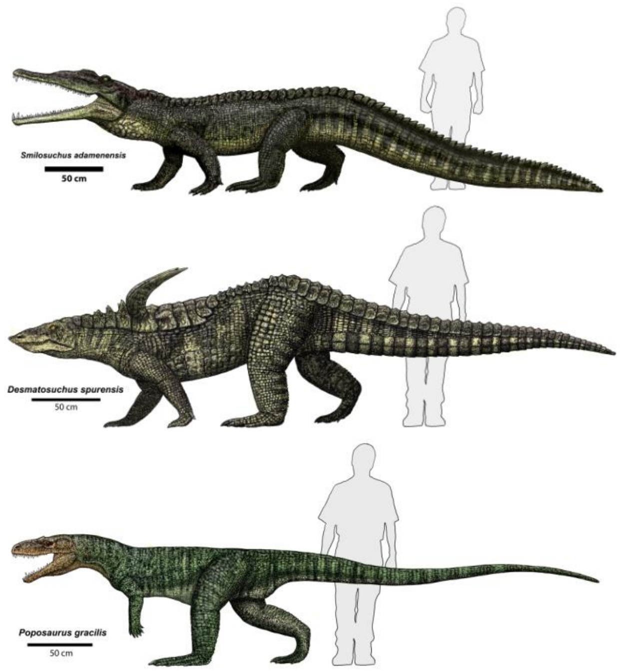
and

Learning objective 10.6 – Assess competing hypotheses for the rise of dinosaurs as the dominant terrestrial vertebrates.

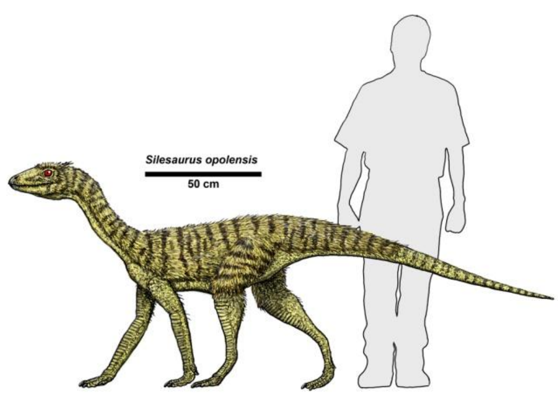
The synapsids had been cut down in their evolutionary prime, and this left vacant the ecological roles that they had previously filled. At first, the synapsid lineages that had managed to survive the extinction slowly rebounded and some groups re-evolved large body sizes and reassumed their roles as top predators and herbivores. Cynodonts and dicynodonts were among the synapsids that succeeded in rebounding, and it is during the Triassic that the first true mammals appeared. However, at the same time, a new group of diapsids, the archosaurs, also began to diversify and grow. Gradually, large archosaurs became more abundant, while large synapsids became less abundant.

***Kannemeyeria*, a large Triassic dicynodont that had a nearly worldwide distribution. Image by Dmitry Bogdanov and used under the GNU Free Documentation License, via Wikimedia Commons.**

The first widely successful group of archosaurs was a lineage that would later go on to evolve into modern crocodilians. These crocodile-line archosaurs are called **pseudosuchians**. The pseudosuchians of the Triassic include the often huge and slender-snouted phytosaurs, which were semiaquatic predators like their distant crocodile relatives; the heavily armored and herbivorous aetosaurs; the rauisuchids and prestosuchians, which were terrestrial predators with upright limb posture; and the poposauroids, some of which were sail-backs



Non-dinosaurian archosaurs from the Triassic of Arizona: *Smilosuchus* (a phytosaur), *Desmatosuchus* (an aetosaur), and *Poposaurus* (a poposauroid) Images by Jeff Martz and used under the CC-BY 2.0 license, via PetrifiedForestNPS on Flickr.



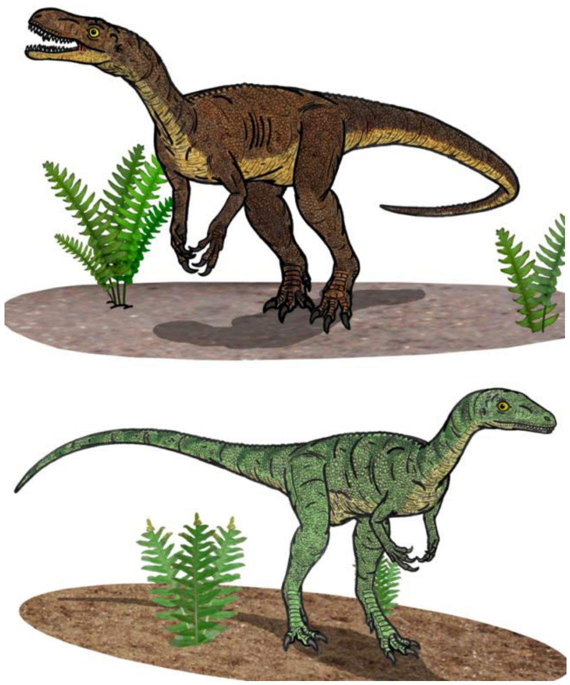
***Silesaurus* was a herbivorous, quadrupedal, non-dinosaurian dinosauromorph. It is known from the Triassic of Poland, but silesaurids are also known from many other locations worldwide. Image by Jeff Martz and used under the CC-BY 2.0 license, via PetrifiedForestNPS on Flickr.**

and demonstrate convergent evolution with the earlier *Dimetrodon*.

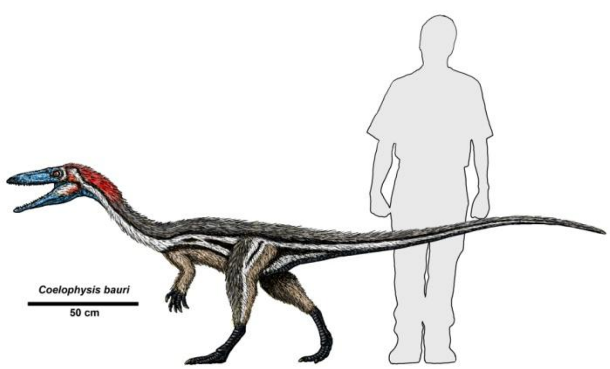
Where were the dinosaurs? The oldest record of dinosaur-like archosaurs comes from footprints that have been dated at roughly 250 million years old. The earliest dinosaur-like archosaurs were small and bipedal and looked a lot like the true dinosaurs, but they lacked some of the specializations that characterize true Dinosauria, such as a hip socket with a hole through it – for this reason, we call these animals dinosauromorphs. Some early dinosauromorphs were quadrupedal, like the silesaurids.

The best record of early dinosaur bones comes from 228 million year old fossil beds of Argentina. *Eoraptor*, *Eodromaeus*, *Herrerasaurus*, and *Panphagia* are examples of early carnivorous saurischian dinosaurs, and *Pisanosaurus* is an early herbivorous ornithischian dinosaur. It seems clear that early dinosaurs were more successful and diverse as carnivores than as herbivores. *Eoraptor*, *Eodromaeus*, *Panphagia,* and *Pisanosaurus* are all relatively small (under a meter in length), but *Herrerasaurus* was significantly larger (comparable in size to a modern tiger). Compared to the many other archosaurs, these early dinosaurs were rare components of their ecosystems.

As the Triassic drew to a close, dinosaurs were gaining ground. *Coelophysis* was a wolf-sized Triassic theropod that has been found in large bonebeds in New Mexico. *Coelophysis* appears to have been one of the most common predators of its time and place. Prosauropods evolved late in the Triassic and also were hugely successful. *Plateosaurus* is the best known of the prosauropods and would have weighed more than three tons. In the Triassic,



***Eodromaeus* and *Eoraptor* are both known from the Triassic of Argentina; *Eodromaeus* is thought to be an early member of the theropod lineage, and *Eoraptor* is thought to be an early member of the sauropod lineage. Early representatives of any given clade often look very 'primitive' and unspecialized. CC-BY 3.0 license by Conty via Wikimedia Commons.**



***Coelophysis*, a Triassic theropod dinosaur. Image by Jeff Martz and used under the CC-BY 2.0 license, via PetrifiedForestNPS on Flickr.**

prosauropods were record breakers, the largest herbivores that had ever evolved up to that time.

Did dinosaurs suddenly appear and dominate their environment? Not at all. The story of the dinosaurs' rise to power was a slow, but steady one, pushed along by the misfortune of others. For example, after the end Permian extinction, pseudosuchian archosaurs diversified and became very common. The earliest dinosaurs coexisted alongside more primitive dinosauromorphs for some time, and many pseudosuchians had evolved dinosaur-like body plans.

At the end of the Triassic another mass extinction event of unknown cause occurred. This extinction was not nearly as severe as the extinction at the end of the Permian. Still, it hit many of the thriving archosaur groups hard . . . but not dinosaurs. The story of the origin of dinosaurs is not so much one of dinosaurs conquering and defeating other groups, but rather one of chance and opportunity. Right now there isn't any evidence to suggest that dinosaurs outcompeted the pseudosuchians. Both pseudosuchians and dinosaurs were well adapted for their Triassic environments, and dinosaurs did not gradually replace pseudosuchians in their ecosystems. Instead, dinosaurs 'got lucky' – some aspect of their biology made them better able to survive the end-Triassic extinction than the pseudosuchians. The extinction left several ecological roles vacant, and dinosaurs quickly evolved to fill them. This success, at the time of Pangaea, allowed dinosaurs to spread to the far edges of every continent, without ever having to swim. As Pangaea broke apart, dinosaurs rode the plates, and different dinosaur groups had the opportunity to evolve and diversify in geographic isolation. With the start of the Jurassic, the Age of Dinosaurs had truly begun. As we'll see in the next lesson, however, the odds caught up with dinosaurs in the end.

Supplementary Materials.

Laelaps – *Lystrosaurus*, the most humble badass of the Triassic [blog post]

Laelaps – *Poposaurus*, *Postosuchus*, and the dinosaur mimic croc walk [blog post]

Smithsonian – Why a pterosaur is not a dinosaur. [blog post]

Pterosaur.net – Spend some time on this website reading about pterosaur origins, anatomy, and diversity.

Smithsonian - Scientists Discover Oldest Known Dinosaur [blog post].

American Museum of Natural History – What is the earliest-known dinosaur? [video]

Tetrapod Zoology – The surprising and hitherto undocumented late survival of non-dinosaurian dinosauromorphs [blog post]

University of California – Rise of dinosaurs not so rapid at all. [video]

The University of Chicago – Paul Sereno talks about *Eodromaeus* the "Dawn Runner" [video]