Lesson 10: Palaeogeography and Plate Tectonics

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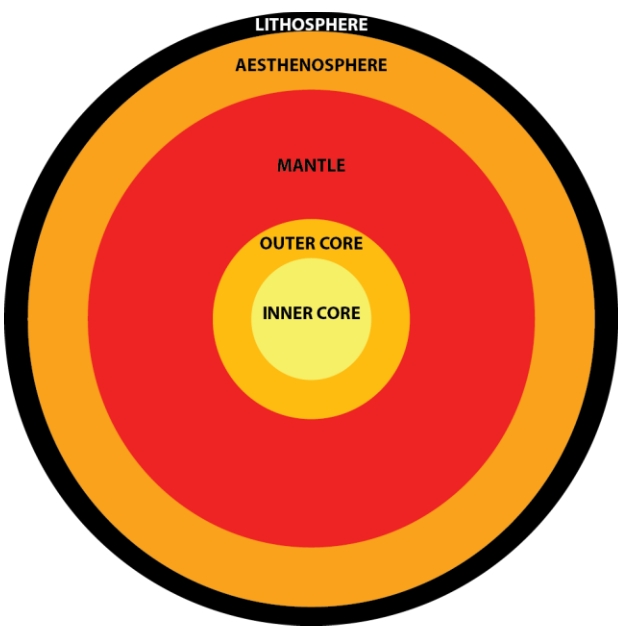
Learning objective for lesson 10: Students will understand basic concepts of plate tectonics and the evolution of the Earth's surface

Learning objective 10.1: Summarize the evidence for plate tectonics.

Today, the Earth has several continents: North America and South America, Europe and Asia, Africa, Australia, and Antarctica. In addition to these continents are large islands like Greenland, New Zealand, Madagascar, and the southeast Asian islands. However, if you were to travel back in time to the Permian period and observe the Earth from a distance, you would immediately notice a huge difference. Instead of multiple continents, only a single, enormous continent was present on Earth at that time. This was a supercontinent called Pangaea. How do we know that there was only one continent at that time? And how did the continents change positions through time?

In 1912, a German researcher named **Alfred Wegener** drew the scientific community's attention to several curious facts. Wegener had noticed that the eastern coastline of South America and the western coastline of Africa looked like two connectable puzzle pieces, that the fossils of many ancient animals (which, as far as anyone could tell, were not animals that would have been capable of swimming across the Atlantic Ocean) could be found in both South America and Africa, and that several geologic formations in South America had seemingly identical twins in Africa. Wegener suggested that Africa, South America, and possibly other continents had once been connected and had since drifted apart. Wegener's reasoning was sound and his evidence was tantalizing, but his theory of continental drift had a huge hole in it: Wegener could not offer a convincing mechanism for how land masses as big and as seemingly immobile as continents could move. Many years later, Wegener's idea of moving continents was vindicated, and an explanation for how such a massive phenomenon occurs was discovered.

Below its surface, the earth is not a uniform mass of rock. The outermost layer of the earth consists of the continents and ocean basins and is called the **crust**. The thickness of the crust varies but is usually between 5 and 25 kilometers deep. By comparison to the other layers of the earth, the crust is thin. Below the crust is a layer called the mantle. The **mantle** is a layer over 2,500 kilometers deep. The uppermost portion of the mantle is solid. Along with the crust, this upper solid portion of the mantle is called the **lithosphere**. The lithosphere is not one unbroken layer, but is actually composed of many discrete pieces, or plates, that fit together. Below the lithosphere is a portion of the mantle called the **asthenosphere**. While the lithosphere is rigid, the asthenosphere is viscous, slowly flowing, and its shape may be deformed under the uneven weight of the lithosphere. Although it flows, the mantle is not a liquid, but a viscous solid that flows. The intense heat and pressure at great depths causes the solid mantle to behave like a fluid – similar to plasticine or play-doh that is a solid at rest, but that squishes when you squeeze it. Below the mantle is the **core**. The core is primarily composed of iron and nickel and is subdivided into the outer core and the inner core. The **outer core** is molten liquid, while the **inner core** is a solid ball. The temperature of the inner core is estimated to be roughly 5,700° C (the same as the surface temperature of the sun).



Stylized diagram showing the layers of the Earth – note that the layers are not to scale! By V. Arbour.

The extreme heat of the inner layers of the earth creates convection currents in the viscous asthenosphere. Lower portions of the asthenosphere slowly heat, expand, rise upwards, and then slowly cool and sink. **Plates**, or pieces of the lithosphere, are affected by these currents. The currents pull along the undersurfaces of the lithosphere's various pieces, causing them to slowly move. Additionally, the cool crust is more solid and dense than the layers below it. This causes lithosphere plates to slowly sink and to melt into the lower layers. This sinking does not happen all at once, but occurs gradually along one of the edges of a plate. As one edge sinks, a small gap is created along the opposite edge, and, through this gap, molten rock is free to escape. This rock then cools, solidifies, and adds its own mass to the edge of the plate. This cycle continues and, ever so slowly, the newly erupted rock will eventually progress to the sinking edged and be melted once more. The movement of the lithosphere is called **plate tectonics**, and it provides the explanation for the drifting continents that Alfred Wegner theorized.

Plate tectonics has now been verified in a variety of ways. The discovery of mid-ocean ridges revealed plate edges where new crust was being formed. Studies of mid-ocean ridges show that the crustal rocks on either side of the ridges have indeed been slowly drifting apart. Advanced global positioning satellites tracking systems can detect the ongoing movements of the continents and even record their speeds.

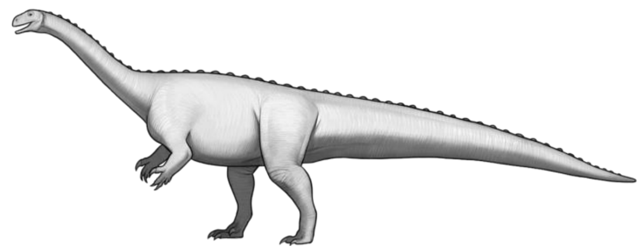
As plates move, they sometimes come into conflict and collide. The boundary where two plates collide can be a place where tremendous pressure builds. Such plate boundaries are often sites of sudden pressure releases, in the form of volcanoes and earthquakes, and/or of gradual pressure releases, which can slowly build mountain ranges.

Learning objective 10.5 – Identify palaeogeographic features.

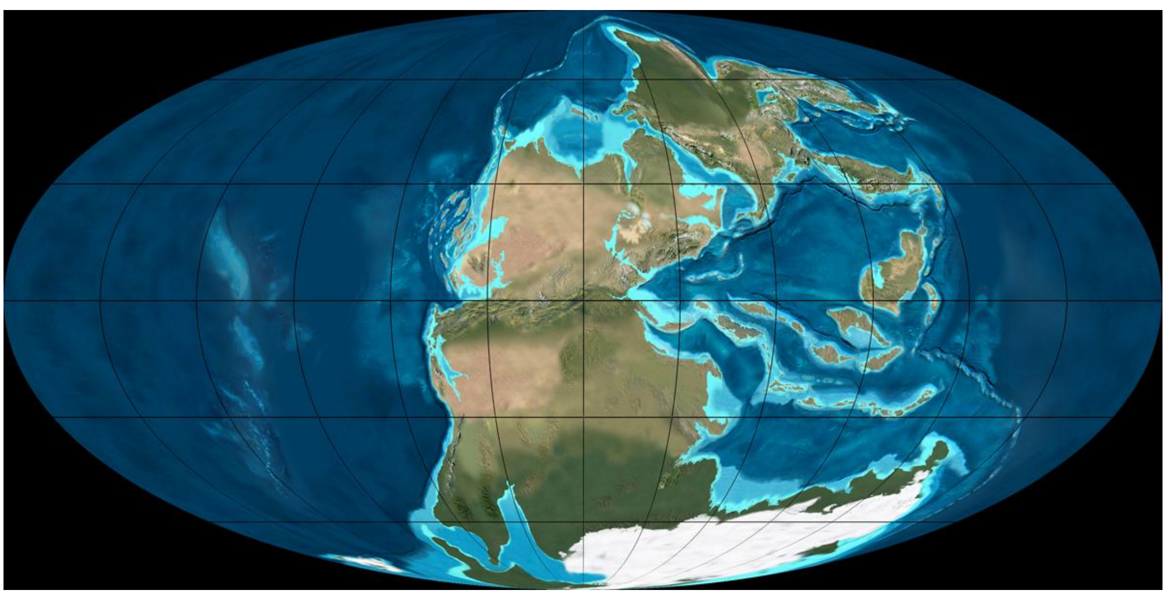
and

Learning objective 10.6 – Classify types of dinosaurs based on the geographic area where they were most common.

Due to the actions of plate tectonics, Earth during the Age of Dinosaurs was different from what it is today. By the end of the Permian period and the beginning of the Triassic period, all the world's continents had collided together and formed the single supercontinent **Pangaea**. This meant that all the world's oceans were also one. We call this single super-ocean **Panthalassa**. Because Pangaea was a single unbroken land mass, the first dinosaurs that appeared during the Triassic were able to spread across the entire planet, with no major sea barriers standing in their way. For this reason, during the late Triassic and early Jurassic, dinosaurs all across the world are fairly similar. Prosauropods and small theropods similar to *Coelophysis* are found worldwide.



Massospondylus, a typical prosauropod, by Joy Ang.



The Late Permian. All of the continents have collided to form the supercontinent Pangaea. Prosauropods are found worldwide. Paleomaps throughout this lesson are by R. Blakey and used with permission.

This similarity continued into the Jurassic. For example, the 'classic' dinosaurs from the Jurassic Morrison Formation of the western USA have very similar counterparts in the Tendaguru Formation of Tanzania and the Lourinha Formation of Portugal.

The first true sauropods appeared very late in the Triassic, alongside their prosauropod relatives. During the Early Jurassic, while all the continents were still connected, sauropods rose to new heights, surpassing prosauropods in both abundance and body-size. Among the thriving Jurassic long-necks were the **diplodocids**. Even compared with other sauropods, most diplodocids have extremely long necks. They are also characterized by front legs that are much shorter than their hind legs, and by their unusual faces. The skull of a diplodocid is elongated and resembles the general shape of a horse's or a deer's. Diplodocid teeth are simple, peg-like, and are positioned only at the front of the mouth, not on the sides. They are nipping teeth -- good for cropping off leaves and other tender growth.

Diplodocids shared their Jurassic world with another group of sauropods called the **macronarians**. Macronarians do not have the whip-tails of diplodocids. Their bodies are generally more robust, and their front legs are usually not noticeably shorter than their back legs. In fact, in macronarians like *Brachiosaurus* and *Giraffatitan* the front legs were much longer than the back legs. Most macronarians still have the long necks characteristic of sauropods, and they too filled the **ecological niche** of high browsers.

A niche is an animal's way of life. Think of it like the animal's job in the ecosystem – it's how a particular species makes its living, what it must do to survive. With so many kinds of sauropods living side-by-side in the Late Jurassic, it might seem like the niche of high browser would have been filled many times over and that sauropods would have faced excessive competition for their food resources. But that was not the case.

Consider the macronarian *Camarasaurus* and the diplodocid *Diplodocus* (the namesake of the group). The bones of both these sauropods have been found side by side in many fossil quarries from the Morrison Formation, in the American West. In comparison, the snout of *Camarasaurus* is much shorter, and its teeth are not limited to the front. In fact, the teeth of *Camarasaurus* line the entire jaw, and the individual teeth are not simple pegs. They are broad, robust, and look like the heads of spoons. While *Diplodocus* has the mouth of a selective nipper, *Camarasaurus* has the mouth of a powerful muncher.

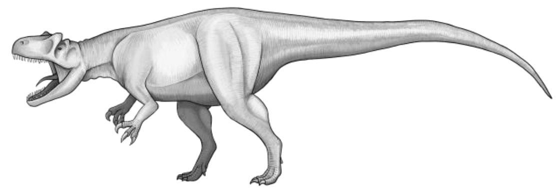
Camarasaurus, at the Royal Tyrrell Museum.

Diplodocids were adapted to reach high and prune off the most delectable Jurassic foliage, while macronarians were less picky eaters. They could crunch much harder, even woody, vegetation, and they could eat what the diplodocids left behind. Thus, these two rather similar animals avoided direct competition for food resources. This is an example of a common ecological phenomenon called **niche partitioning**.

Grazing and browsing in the shadows of sauropods were a variety of smaller Jurassic herbivores. Among them were the **thyreophorans**, a group that includes the ornithischians with body armor. By far the most well-know of the Jurassic thyreophorans was *Stegosaurus*. Stegosaurs were a widespread group of thyreophorans in the Jurassic, and their fossils have been found in Africa, Asia, Europe, and North America.

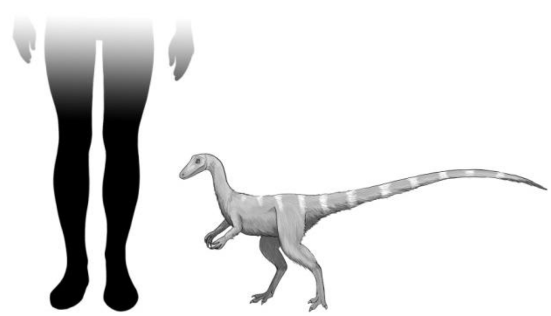
Another group of common Jurassic ornithischians were the ornithopods. Small ornithopods had long legs and appear to have made up for their diminutive size with speed, earning themselves the nickname "Jurassic gazelle". A few Late Jurassic ornithopods obtained greater size, like *Camptosaurus* -- an early iguanodont.

The Jurassic niche of big predator was filled by an array of carnivorous dinosaurs. There were giant megalosaurids and ceratosaurids, both ancient lineages of theropods. But the Late Jurassic was a time of predatory change. A new group of big carnivorous dinosaurs had evolved, and they were mounting an ecological takeover. The **allosauroids** were different from the big predators that had come before them. Allosauroids have vertebrae that interlock more rigidly, so their spines were held stiffer. Their legs are also proportionately longer, suggesting that they were faster than either megalosaurids or ceratosaurids. The allosauroid *Allosaurus* is known from more fossil skeletons than any other big theropod dinosaur, and it was clearly among the most successful of the Late Jurassic's predators.



Allosaurus, by R. Bugeaud.

Not all the Jurassic carnivores were big. The chicken-sized theropod *Compsognathus* is among the smallest of all known dinosaurs. Like *Allosaurus*, *Compsognathus* has a more rigid spine and long legs, but it belongs to another theropod group. It is a coelurosaur. **Coelurosaurs** are characterized by a long series of sacral vertebrae, narrow hands, and tails with back halves that are skinny, stiff, and lightweight. Allosauroids might have been the biggest predators around at the time, but in the Jurassic, it was the coelurosaurs that spawned the dinosaurs' greatest success: birds. And, in the Cretaceous, some coelurosaurs would evolve their way to the very top of the food chain.



Compsognathus, by R. Bugeaud.

During the Jurassic, Pangaea began to split into two massive continents. **Laurasia** was the northern of the two and was composed of what we today call North America, Europe, and Asia (excluding India). Gondwana includes today's **Gondwana** was the southern of the two and was composed of what we today call South America, Australia, Africa, Antarctica, Madagascar, and India. Later, Laurasia and Gondwana also split into smaller continents, but the continents did not assume their modern positions until long after the dinosaur extinction. As the continents drifted apart, so too did the populations of dinosaurs. Some groups went extinct in Laurasia or Gondwana, and some groups diversified.

By the Early Cretaceous, there were significant regional differences among the world's dinosaurs. Iguanodontians, ankylosaurs, and brachiosaurid sauropods were present in North America and Europe. In Africa, the dominant theropods were the spinosaurs and carcharodontosaurids. In Asia, coelurosaurian theropods became common, and the first ceratopsians evolved.

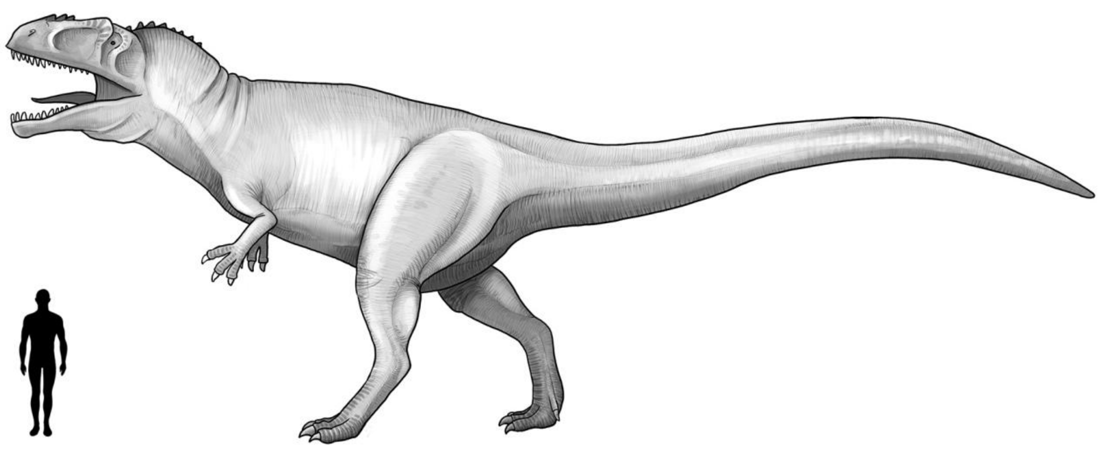
The Early Cretaceous; spinosaurids in Gondwana, ankylosaurs and iguanodonts in Laurasia. (Map by R. Blakey, dinosaurs by J. Sovak).

By the Late Cretaceous, Gondwana had begun to break apart into its constituent continents, but Antarctica and Australia remained connected until close to the end of the Cretaceous. Sauropod dinosaurs went extinct in Laurasia, but thrived in Gondwana. However, they were not the same sauropods that populated the Jurassic. The diplodocids had gone extinct during the beginning of the Cretaceous, and although the macronarians survived, the brachiosaurid macronarians did not. Instead, a new type of macronarian dominated: the titanosaurs.

Titanosaurs are the most robust of all sauropods. Their chests are broad and their hips are wide. Their hind limbs are spaced far apart – giving them a very stable base. Many titanosaurs had osteoderms and some even had large spiky armor. Titanosaurs ranged in size, but among their ranks were animals like *Argentinosaurus* – a sauropod that has been estimated to weigh over a hundred tons, making it the largest creature to ever walk the earth.

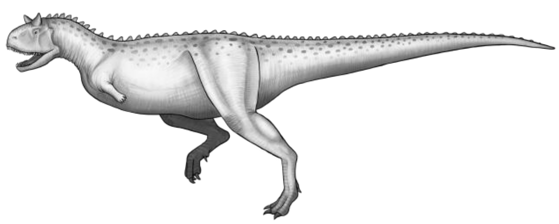
With armor and sheer size to protect them, titanosaurs were not easy prey, but one group of Late Cretaceous theropods may have been specialized giant slayers. The **carcharodontosaurs** are named for the shape of their teeth, which resemble those of the *Carcharodon* – the great white shark. Carcharodontosaurs are a type of allosauroid, so they are descendants of the big theropods that first rose to prominence in the Late Jurassic. However, carcharodontosaurs differ from older allosauroids in a number of ways. Most noticeably, carcharodontosaurs have bigger heads, with longer jaws. As Late Cretaceous titanosaurs got bigger, so did carcharodontosaurs. The largest of all was the South American *Giganotosaurus*. At over thirteen meters in length, *Giganotosaurus* even out sized *Tyrannosaurus rex*.

There was room for more than one kind of big carnivore in the Late Cretaceous of South America. **Abelisaurs**, like the famous horned species *Carnotaurus*, were the last survivors of the ceratosauroid lineage, and some grew to over eight meters in length. In the Cretaceous, the group was strictly limited to Gondwana, but they evidently thrived there, as abelisaur fossils have been found throughout the southern hemisphere.



Giganotosaurus, by R. Bugeaud.

Living alongside carcharodontosaurs must have been tough, and the need for ecological niche partitioning drove abelisaurs to adapt a strikingly different morphology. While carcharodontosaurs have long jaws with big teeth, abelisaurs have short muzzles and proportionately tiny teeth. While carcharodontosaurs tended to have powerful forearms with large hooked claws, abelisaurs had ridiculously short and stubby arms, with small claws. And, while carcharodontosaurs likely preyed on huge titanosaurs, abelisaurs are thought by many paleontologist to have hunted the smaller species of titanosaurs and other less daunting herbivores.



Carnotaurus, by R. Bugeaud.

Hadrosaurs and ankylosaurs were rare in South America, but a few species found in the latest Cretaceous suggest that there was a land bridge late in the evolution of the dinosaurs between North and South America.

While titanosaurs were abundant and diverse in Gondwana, they were far less common in Late Cretaceous Laurasia. In what is now Asia, titanosaurs were present, but comparatively rare components of the ecosystem. In North America, only a handful of titanosaur species are known. This relative under abundance of sauropods in the north is one of the biggest differences between the Late Cretaceous fauna of Laurasia and Gondwana, and meant that northern herbivorous niches were filled by other kinds of plant-eaters.

Although stegosaurs never made it to the Late Cretaceous, another group of thyreophrans did: the ankylosaurs. In Laurasia, ankylosaurs split into two major groups. The **ankylosaurids** are the ankylosaurs with the famous tail clubs. Ankylosaurids also typically have large backwards-pointing horns at the rear of their skulls and a short rounded snout at the front. **Nodosaurids** are the second major group of ankylosaurs. They lacked tail clubs, but some have offensive weapons at the other end, in the form of large osteoderm spikes that project outwards from over their shoulders. Nodosaurids do not generally have the big skull horns of anklosaurids, and their snouts are significantly narrower and more elongated.

After their start in the Jurassic, iguanodont ornithopods thrived and became common across the globe, during the Early Cretaceous. In Laurasia, a new kind of iguanodont evolved: the hadrosaurs. Hadrosaurs flourished in the Late Cretaceous and quickly became the northern hemisphere's most successful herbivorous dinosaurs. We have more fossils of hadrosaurs and know more about hadrosaur biology than any other major dinosaur group.

Among advanced hadrosaurs, there are two major groups. The **lambeosaurine** hadrosaurs had big crest on their heads, which can be thought of as a kind of musical instrument. Inside a lambeosaurine crest is a complex and hollow nasal passageway. Blowing air through this passage and then out the nostrils would have amplified the dinosaur's calls. The hollow crests of lambeosaurines come in a variety of sizes and shapes.

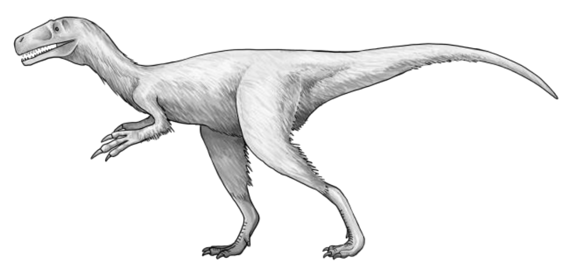
The second major group of advanced hadrosaurs is the **hadrosaurines** (sometimes called the saurolophines). From the skulls of hadrosaurines, it is clear that they do not have the complex sound amplifying crests of the lambeosaurines. However, some hadrosaurines do still have crests. For instance, the hadrosaurine *Saurolophus* had a prominent, but solid, bony crest. Recently, a fossil mummy specimen of the hadrosaurine *Edmontosaurus* was discovered in Alberta, Canada, with a big fleshy crest, like the comb of a rooster, preserved on the top its head. This specimen revealed that at least some hadrosaurines had large crests, even though their skulls provide no record of them.

Running a close second to hadrosaurs, in terms of Laurasian diversity and success, was another group of herbivorous dinosaurs: the **marginocephalians**. That name literally means “fringe heads” and refers to an overhanging lip of bone at the back margin of the skull. Pachycephalosaurs are one of the two major groups within the marginocephalians. The other is the ceratopsians.

The first ceratopsians are a far cry from the later and famous forms, like *Triceratops*. Primitive ceratopsians, like *Psittacosaurus*, are small and bipedal dinosaurs, but they still show a few family resemblances. Like all ceratopsians, they have large beaks and small, jugal cheek-horns projecting from the sides of their face. *Psittacosaurus* and other primitive ceratopsians are well known in Asia, but the larger, more derived ceratopsians, like *Triceratops*, are known almost exclusively from North America.

For much of the Cretaceous, the allosauroids were the top predators throughout Laurasia, just as they were in Gondwana. But they were rivaled by another theropod group. Coelurosaurs blossomed into the most diverse of all theropod groups, and they gave rise to the most infamous of all predatory dinosaurs: the tyrannosaurs.

By the end of the Cretaceous, tyrannosaurs came to dominate the niche of alpha predators throughout Laurasia. To some extent, tyrannosaurs achieved their success by taking to a further extreme the same adaptations that had once set the allosauroids apart from their competitors; that is, tyrannosaurs evolved even longer legs and a much stiffer vertebral column. However, tyrannosaurs also evolved massive skulls with tremendous jaw muscles. The earliest tyrannosauroids, like the Asian species *Dilong* and *Guanlong*, or the European species *Eotyrannus*, have normal head and body proportions, and they look similar to most other small coelurosaurs. But as tyrannosaurs evolved, they grew in absolute size and in the relative size of their heads. These big heads added weight to the front half of their bodies. To compensate, tyrannosaurs reduced weight by shrinking the size of their arms and hands – culminating in the last and largest of all tyrannosaurs *Tyrannosaurus rex*.



Eotyrannus, by R. Bugeaud.

Not all Cretaceous coelurosaurs were huge and predatory. **Ornithomimids** are a kind of coelurosaur that evolved a body plan similar to that of a modern ostrich or emu, but with long clawed forelimbs and a large tail. Another group of coelurosaurs developed a highly specialized wrist bone called a **semilunate carpal**. These crescent-shaped bones allowed the hand to be folded backwards at a sharp angle, and the dinosaurs that possess them are called the **maniraptorans**. Birds are one group of maniraptorans, and the semilunate carpals of birds allow them to delicately fold their wings when not flying.

As close relatives of birds, the sickle-clawed dromaeosaurs are also maniraptorans, and so are the **oviraptorosaurs**. Like ornithomimids, oviraptorosaurs are a group of theropods that adapted to a mostly vegetarian life and lost their teeth in favor of large beaks. Many oviraptorosaurs had cranial crests and fans of feathers on the ends of their tails.

Citipati, an oviraptorosaur, by R. Bugeaud.

Perhaps the strangest of all Laurasian coelurosaurs are the **therizinosaurs**. Theriznosaurs are also probably the most confusing. The first theriznosaur fossil to be found was a huge claw, over 60 cm long. Paleontologists had no particular reason to think the claw belonged to a dinosaur. It certainly did not look like the claw of any dinosaur that had ever been found before. Instead, it was mistaken for the claw of a giant turtle. Even after more fossils were found, and it was clear that therizinosaurs were dinosaurs, not turtles, no one was quite sure what kind of dinosaurs they were. Therizinosaurs have small skulls on the end of long necks and hind feet with four forward pointing toes, so some paleontologists thought they might be prosauropods. Therizinosaurs also have a backwards-directed pubis and jaws with small herbivorous teeth in the back and a beak in the front, so some researchers classified them as ornithischians. Several fossil skeleton discoveries and a lot of research later, paleontologists are now in agreement that therizinosaurs are maniraptoran theropods (close relatives of oviraptorosaurs).

Therizinosaurus, by R. Bugeaud.

The movement of the continents does not always lead to geographic isolation – sometimes, plate tectonics brings continents that were once separate back together. When this happens, dinosaurs from one region can move into another, leading to similar species in both regions. This phenomenon is called **faunal interchange.** The Late Cretaceous dinosaurs of Alberta are very similar to those found in Mongolia, which suggests that there was immigration between these two areas during the Late Cretaceous; Asia and North America were probably intermittently connected via Alaska at this time. Theropods are represented by tyrannosaurs, dromaeosaurs, therizinosaurs, ornithomimids, and oviraptorosaurs; ornithischians in both areas include hadrosaurs, ceratopsians, ankylosaurs, and pachycephalosaurs.

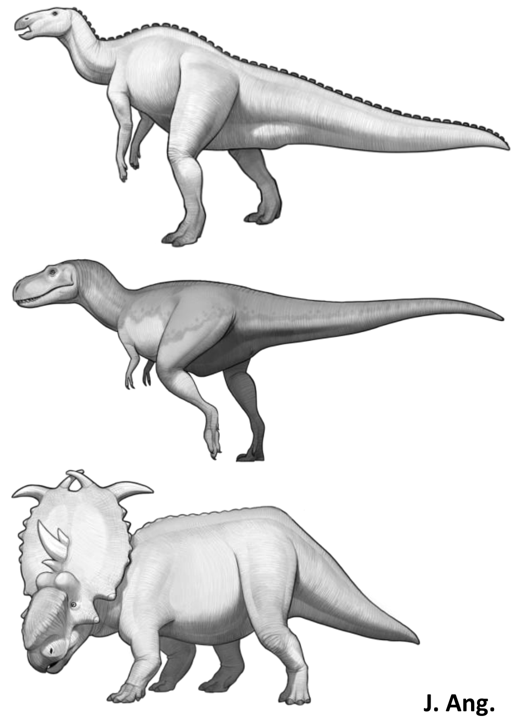
Learning objective 10.6 – Summarize evidence for warmer climates during the Mesozoic.

The average global climate was also different during the Age of Dinosaurs. Temperatures were, on average, much higher. This warmer global climate was largely caused by high volcanic activity, which released large quantities of carbon dioxide into the atmosphere. Carbon dioxide is a greenhouse gas that holds in solar heat. The concentration of all Earth's land masses in only one or two supercontinents may have also been a factor that contributed to the high average temperatures, because it affected the circulation of both air and water currents through the polar regions.Ocean currents are extremely important to distributing and moving heat from one part of the earth to another. Today, the Gulf Stream is an ocean current that flows from the Gulf of Mexico to the western coast of Europe. Gulf Stream water is warmed in the Gulf of Mexico and this heat is carried north as it flows. The Gulf Stream makes many European countries much warmer than places of similar latitudes on the other side of the Atlantic. This is why the maritime provinces of Canada are frigid places in winter, while Italy and Spain rarely see snow. Today a strong and cold ocean current encircles much of Antarctica, and this current helps to keep Antarctica cold. However, 70 million years ago, when Antarctica was still attached to Australia, this current had to go up and around Australia. As the current moved through more equatorial areas, it become warmer, and then, as it flowed back down, carried this heat to Antarctica.

As a consequence of the high global temperatures, there were no polar icecaps or glaciers during the Mesozoic. Antarctica and Australia were located within the Antarctic Circle, and parts of North America were located above the Arctic Circle (North America was actually located further north than it is today). The discovery of lush plant fossils in polar regions indicates that the climate there must have been much warmer than today.

Although it was once assumed that dinosaurs were limited to warm tropical climates, it is now known that many varieties of dinosaurs thrived in polar regions. The Early Jurassic theropod *Cryolophosaurus*, and the prosauropod *Glacialisaurus*, were discovered in Antarctica, along the Transantarctic Mountains. The small ornithopod *Laeallynasaura* inhabited what were then polar forests in the Early Cretaceous of Australia. The Late Cretaceous of Alaska was home to a diverse assemblage of dinosaurs similar to what is found in Alberta, including the hadrosaur *Edmontosaurus*, the tyrannosaurid *Albertosaurus*, and the ceratopsian *Pachyrhinosaurus*.

Although the climate was warmer and supported lush polar forests, the polar regions would still have experienced periods of reduced sunlight or total darkness, as they do today. Presumably photosynthesis would have been reduced during these darker periods. There is debate over whether during these periods polar dinosaurs overwintered at the poles or migrated to lower latitudes (south, for North America, or north, for Antarctica and Australia).

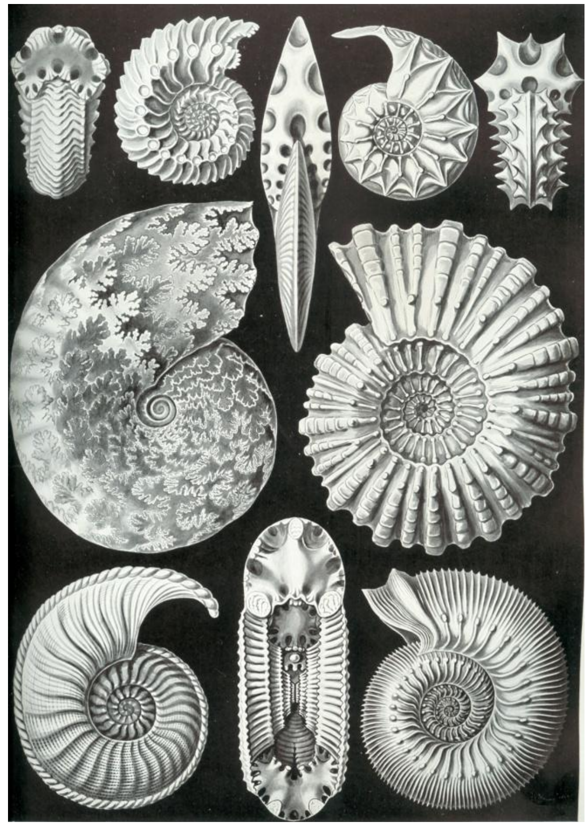


J. Ang.

The Jurassic-aged Hanson Formation of Antarctica. *Cryolophosaurus* (the large theropod in the foreground), small theropods, and the prosauropod *Glacialisaurus* all lived in the south polar region. J. Sovak.

Learning objective 10.7 – Summarize evidence for changing sea levels during the Mesozoic.

Today, polar icecaps and glaciers hold large quantities of water, but, during the Mesozoic, this water was liquid and contributed significantly to high global sea levels. The warm climate also made the average global ocean temperature higher, which led to thermal expansion, causing the world's oceans to further swell and rise. During the Mesozoic, sea levels were up to 250 m higher than they are today. This resulted in the flooding of vast regions of the earth, limiting the amount of exposed land and splitting areas that are now connected into isolated islands. For example, during the Late Cretaceous, much of the interior of North America was covered by a massive inland sea. This vast waterway, called the Western Interior Seaway, spread from the Arctic Ocean to the Gulf of Mexico. At various points during the Mesozoic, North America was subdivided into two separate island subcontinents – Laramidia in the west, from which the majority of North American dinosaur species are known, and Appalachia in the east, from which far fewer dinosaurs are currently known. Because of this ancient sea, Mesozoic marine fossils can be found in parts of Alberta and throughout the American Midwest, because these regions were underwater during much of the Mesozoic. In southern Alberta, marine sediments called the Bearpaw Formation have produced the remains of marine reptiles like mosasaurs and plesiosaurs, and invertebrates like ammonites (relatives of today's nautilus).



Ammonite fossils by Ernst Haeckel, 1904.

Supplementary Materials.

Blakey Palaeomaps. The maps that you see during this week's lesson were created by Ron Blakey, a geologist in Colorado. Spend some time at his website checking out the palaeomaps for different time periods, including some maps not featured in this week's videos.

Cretaceous North America:
University of Colorado at Boulder - Geologic Evolution of North America: 600 Million Years to Present. [video]

Whirlpool of Life - Dinosaurs of the Lost Continent [blog post]

Lalaeps - All Hail the Gore King [blog post]

Smithsonian – Where have all the sauropods gone? [blog post]

Polar Dinosaurs:

Laelaps – L is for *Leaellynasaura* [blog post]

The Field Museum - Polar Dinosaurs [video]

The Field Museum – Antarctica Video Report 8, Sampling Ancient Plant Spores & Pollen [video; We haven't gotten to see much of Dr. Eva Koppelhus in this course, but she has been an important contributor to Dino101! This is one segment of a series on an expedition to Antarctica that Dr. Currie and Dr. Koppelhus participated in during the winter of 2010/2011. The entire series is really fun if you're interested in seeing what fieldwork in Antarctica looks like!]