

= Gorgosaurus =

Gorgosaurus (/ ˈɡɔːrɡoʊˈsɔːr / GOR @-@ g? @-@ SOR @-@ ?s ; meaning " dreadful lizard ") is a genus of tyrannosaurid theropod dinosaur that lived in western North America during the Late Cretaceous Period , between about 76 @.@ 6 and 75 @.@ 1 million years ago . Fossil remains have been found in the Canadian province of Alberta and possibly the U.S. state of Montana . Paleontologists recognize only the type species , *G. libratus* , although other species have been erroneously referred to the genus .

Like most known tyrannosaurids , Gorgosaurus was a bipedal predator weighing more than two metric tons as an adult ; dozens of large , sharp teeth lined its jaws , while its two @-@ fingered forelimbs were comparatively small . Gorgosaurus was most closely related to *Albertosaurus* , and more distantly related to the larger *Tyrannosaurus* . Gorgosaurus and *Albertosaurus* are extremely similar , distinguished mainly by subtle differences in the teeth and skull bones . Some experts consider *G. libratus* to be a species of *Albertosaurus* ; this would make Gorgosaurus a junior synonym of that genus .

Gorgosaurus lived in a lush floodplain environment along the edge of an inland sea . It was an apex predator , preying upon abundant ceratopsids and hadrosaurs . In some areas , Gorgosaurus coexisted with another tyrannosaurid , *Daspletosaurus* . Although these animals were roughly the same size , there is some evidence of niche differentiation between the two . Gorgosaurus is the best @-@ represented tyrannosaurid in the fossil record , known from dozens of specimens . These plentiful remains have allowed scientists to investigate its ontogeny , life history and other aspects of its biology .

= = Description = =

Gorgosaurus was smaller than *Tyrannosaurus* or *Tarbosaurus* , closer in size to *Albertosaurus* and *Daspletosaurus* . Adults reached 8 to 9 m (26 to 30 ft) from snout to tail . Paleontologists have estimated full @-@ grown adults to weigh about 2 @.@ 5 tonnes (2 @.@ 8 short tons) , perhaps approaching 2 @.@ 8 tonnes (3 @.@ 1 short tons) . The largest known skull measures 99 cm (39 in) long , just slightly smaller than that of *Daspletosaurus* . As in other tyrannosaurids , the skull was large compared to its body size , although chambers within the skull bones and large openings (fenestrae) between bones reduced its weight . *Albertosaurus* and Gorgosaurus share proportionally longer and lower skulls than *Daspletosaurus* and other tyrannosaurids . The end of the snout was blunt , and the nasal and parietal bones were fused along the midline of the skull , as in all other members of the family . The eye socket was circular rather than oval or keyhole @-@ shaped as in other tyrannosaurid genera . A tall crest rose from the lacrimal bone in front of each eye , similar to *Albertosaurus* and *Daspletosaurus* . Differences in the shape of bones surrounding the brain set Gorgosaurus apart from *Albertosaurus* .

Gorgosaurus teeth were typical of all known tyrannosaurids . The eight premaxillary teeth at the front of the snout were smaller than the rest , closely packed and D @-@ shaped in cross section . In Gorgosaurus , the first tooth in the maxilla was also shaped like the premaxillary teeth . The rest of the teeth were oval in cross section , rather than blade @-@ like as in most other theropods . Along with the eight premaxillary teeth , Gorgosaurus had 26 to 30 maxillary teeth and 30 to 34 teeth in the dentary bones of the lower jaw . This number of teeth is similar to *Albertosaurus* and *Daspletosaurus* but is fewer than those of *Tarbosaurus* or *Tyrannosaurus* .

Gorgosaurus shared its general body plan with all other tyrannosaurids . Its massive head was perched on the end of an S @-@ shaped neck . In contrast to its large head , its forelimbs were very small . The forelimbs had only two digits , although a third metacarpal is known in some specimens , the vestigial remains of the third digit seen in other theropods . Gorgosaurus had four digits on each hindlimb , including a small first toe (hallux) which did not contact the ground . Tyrannosaurid hindlimbs were long relative to overall body size compared with other theropods . The largest known Gorgosaurus femur measured 105 cm (41 in) long . In several smaller specimens of Gorgosaurus , the tibia was longer than the femur , a proportion typical of fast @-@ running animals . The two

bones were of equal length in the largest specimens . The long , heavy tail served as a counterweight to the head and torso and placed the center of gravity over the hips .

In 2001 , paleontologist Phil Currie reported skin impressions from the holotype specimen of *G. libratus* . He originally reported the skin as being essentially smooth and lacking the scales found in other dinosaurs , similar to the secondarily featherless skin found in large modern birds . Scales of some sort were present in this specimen , but they are reportedly widely dispersed from each other and very small . Other patches of isolated *Gorgosaurus* skin shows denser , and larger though still relatively fine scales (smaller than hadrosaurid scales and approximately as fine as a *Gila monster* 's) . Neither of these specimens was associated with any particular bone or specific body area . In the *Encyclopedia of Dinosaurs* Kenneth Carpenter pointed out that traces of skin impressions from the tail of *Gorgosaurus* showed similar small rounded or hexagonal scales .

= = Classification and systematics = =

Gorgosaurus is classified in the theropod subfamily *Albertosaurinae* within the family *Tyrannosauridae* . It is most closely related to the slightly younger *Albertosaurus* . These are the only two definite albertosaurine genera that have been described , although other undescribed species may exist . *Appalachiosaurus* was described as a basal tyrannosauroid just outside *Tyrannosauridae* , although American paleontologist Thomas Holtz published a phylogenetic analysis in 2004 which indicated it was an albertosaurine . More recent , unpublished work by Holtz agrees with the original assessment . All other tyrannosaurid genera , including *Daspletosaurus* , *Tarbosaurus* and *Tyrannosaurus* , are classified in the subfamily *Tyrannosaurinae* . Compared to the tyrannosaurines , albertosaurines had slender builds , with proportionately smaller , lower skulls and longer bones of the lower leg (tibia) and feet (metatarsals and phalanges) .

The close similarities between *Gorgosaurus libratus* and *Albertosaurus sarcophagus* have led many experts to combine them into one genus over the years . *Albertosaurus* was named first , so by convention it is given priority over the name *Gorgosaurus* , which is sometimes considered its junior synonym . William Diller Matthew and Barnum Brown doubted the distinction of the two genera as early as 1922 . *Gorgosaurus libratus* was formally reassigned to *Albertosaurus* (as *Albertosaurus libratus*) by Dale Russell in 1970 , and many subsequent authors followed his lead . Combining the two greatly expands the geographical and chronological range of the genus *Albertosaurus* . Other experts maintain the two genera as separate . Canadian paleontologist Phil Currie claims there are as many anatomical differences between *Albertosaurus* and *Gorgosaurus* as there are between *Daspletosaurus* and *Tyrannosaurus* , which are almost always kept separate . He also notes that undescribed tyrannosaurids discovered in Alaska , New Mexico and elsewhere in North America may help clarify the situation . Gregory S. Paul has suggested that *Gorgosaurus libratus* is ancestral to *Albertosaurus sarcophagus* .

Below is the cladogram of *Tyrannosauridae* based on the phylogenetic analysis conducted by Loewen et al. in 2013 .

= = Discovery and naming = =

Gorgosaurus libratus was first described by Lawrence Lambe in 1914 . Its name is derived from the Greek ?????? / gorgos (" fierce " or " terrible ") and ?????? / saurus (" lizard ") . The type species is *G. libratus* ; the specific epithet " balanced " is the past participle of the Latin verb *librare* , meaning " to balance " .

The holotype of *Gorgosaurus libratus* (NMC 2120) is a nearly complete skeleton associated with a skull , discovered in 1913 by Charles M. Sternberg . This specimen was the first tyrannosaurid found with a complete hand . It was found in the Dinosaur Park Formation of Alberta and is housed in the Canadian Museum of Nature in Ottawa . Prospectors from the American Museum of Natural History in New York City were active along the Red Deer River in Alberta at the same time , collecting hundreds of spectacular dinosaur specimens , including four complete *G. libratus* skulls , three of which were associated with skeletons . Matthew and Brown described four of these specimens in

1923 .

Matthew and Brown also described a fifth skeleton (AMNH 5664) , which Charles H. Sternberg had collected in 1917 and sold to their museum . It was smaller than other Gorgosaurus specimens , with a lower , lighter skull and more elongate limb proportions . Many sutures between bones were unfused in this specimen as well . Matthew and Brown noted that these features were characteristic of juvenile tyrannosaurids , but still described it as the holotype of a new species , *G. sternbergi* . Today 's paleontologists regard this specimen as a juvenile *G. libratus* . Dozens of other specimens have been excavated from the Dinosaur Park Formation and are housed in museums across the United States and Canada . *G. libratus* is the best @-@ represented tyrannosaurid in the fossil record , known from a virtually complete growth series .

In 1856 , Joseph Leidy described two tyrannosaurid premaxillary teeth from Montana . Although there was no indication of what the animal looked like , the teeth were large and robust , and Leidy gave them the name *Deinodon* . Matthew and Brown commented in 1922 that these teeth were indistinguishable from those of *Gorgosaurus* , but in the absence of skeletal remains of *Deinodon* , opted not to unequivocally synonymize the two genera , provisionally naming a ? *Deinodon libratus* . Although *Deinodon* teeth are very similar to those of *Gorgosaurus* , tyrannosaurid teeth are extremely uniform , so it cannot be said for certain which animal they belonged to . *Deinodon* is usually regarded as a nomen dubium today . Additional likely synonyms of *G. libratus* and / or *D. horridus* include *Laelaps falculus* , *Laelaps hazenianus* , *Laelaps incrassatus* , and *Dryptosaurus kenabekides* .

Several tyrannosaurid skeletons from the Two Medicine Formation and Judith River Formation of Montana probably belong to *Gorgosaurus* , although it remains uncertain whether they belong to *G. libratus* or a new species . One specimen from Montana (TCM 2001 @-@ 89 @-@ 1) , housed in the Children 's Museum of Indianapolis , shows evidence of severe pathologies , including healed leg , rib , and vertebral fractures , osteomyelitis (infection) at the tip of the lower jaw resulting in permanent tooth loss , and possibly a brain tumor .

= = = Misassigned species = = =

Several species were incorrectly assigned to *Gorgosaurus* in the twentieth century . A complete skull of a small tyrannosaurid (CMNH 7541) , found in the younger , late Maastrichtian @-@ age Hell Creek Formation of Montana , was named *Gorgosaurus lancensis* by Charles Whitney Gilmore in 1946 . This specimen was renamed *Nanotyrannus* by Bob Bakker and colleagues in 1988 . Currently , many paleontologists regard *Nanotyrannus* as a juvenile *Tyrannosaurus rex* . Similarly , Evgeny Maleev created the names *Gorgosaurus lancinator* and *Gorgosaurus novojilovi* for two small tyrannosaurid specimens (PIN 553 @-@ 1 and PIN 552 @-@ 2) from the Nemegt Formation of Mongolia in 1955 . Kenneth Carpenter renamed the smaller specimen *Maleevosaurus novojilovi* in 1992 , but both are now considered juveniles of *Tarbosaurus bataar* .

= = Paleobiology = =

= = = Coexistence with *Daspletosaurus* = = =

In the middle stages of the Dinosaur Park Formation , *Gorgosaurus* lived alongside a rarer species of the tyrannosaurine , *Daspletosaurus* . This is one of the few examples of two tyrannosaur genera coexisting . Similar @-@ sized predators in modern predator guilds are separated into different ecological niches by anatomical , behavioral or geographical differences that limit competition . Niche differentiation between the Dinosaur Park tyrannosaurids is not well understood . In 1970 , Dale Russell hypothesized that the more common *Gorgosaurus* actively hunted fleet @-@ footed hadrosaurs , while the rarer and more troublesome ceratopsians and ankylosaurians (horned and heavily armoured dinosaurs) were left to the more heavy built *Daspletosaurus* . However , a specimen of *Daspletosaurus* (OTM 200) from the contemporaneous Two Medicine Formation of

Montana preserves the digested remains of a juvenile hadrosaur in its gut region , and another bonebed contains the remains of three Daspletosaurus along with the remains of at least five hadrosaurs .

Unlike some other groups of dinosaurs , neither genus was more common at higher or lower elevations than the other . However , Gorgosaurus appears more common in northern formations like Dinosaur Park , with species of Daspletosaurus being more abundant to the south . The same pattern is seen in other groups of dinosaurs . Chasmosaurine ceratopsians and hadrosaurine hadrosaurs are also more common in the Two Medicine Formation of Montana and in southwestern North America during the Campanian , while centrosaurine and lambeosaurines dominate in northern latitudes . Holtz has suggested this pattern indicates shared ecological preferences between tyrannosaurines , chasmosaurines and hadrosaurines . At the end of the later Maastrichtian stage , tyrannosaurines like Tyrannosaurus rex , hadrosaurines like Edmontosaurus and Kritosaurus and chasmosaurines like Triceratops and Torosaurus were widespread throughout western North America , while lambeosaurines were rare , consisting of a few species like Hypacrosaurus , and albertosaurines and centrosaurines had gone extinct ; however , they had thrived in Asia with species like Sinoceratops and Alioramus .

= = = Life history = = =

Gregory Erickson and colleagues have studied the growth and life history of tyrannosaurids using bone histology , which can determine the age of a specimen when it died . A growth curve can be developed when the ages of various individuals are plotted against their sizes on a graph . Tyrannosaurids grew throughout their lives , but underwent tremendous growth spurts for about four years , after an extended juvenile phase . Sexual maturity may have ended this rapid growth phase , after which growth slowed down considerably in adult animals . Examining five Gorgosaurus specimens of various sizes , Erickson calculated a maximum growth rate of about 50 kg (110 lb) per year during the rapid growth phase , slower than in tyrannosaurines like Daspletosaurus and Tyrannosaurus , but comparable to Albertosaurus .

Gorgosaurus spent as much as half its life in the juvenile phase before ballooning up to near @-@ maximum size in only a few years . This , along with the complete lack of predators intermediate in size between huge adult tyrannosaurids and other small theropods , suggests that these niches may have been filled by juvenile tyrannosaurids . This pattern is seen in modern Komodo dragons , whose hatchlings start off as tree @-@ dwelling insectivores and slowly mature into massive apex predators capable of taking down large vertebrates . Other tyrannosaurids , including Albertosaurus , have been found in aggregations that some have suggested to represent mixed @-@ age packs , but there is no evidence of gregarious behavior in Gorgosaurus .

= = = Paleopathology = = =

Several pathologies have been documented in the Gorgosaurus libratus holotype , NMC 2120 . These include the third right dorsal rib , as well as healed fractures on the 13th and 14th gastralia and left fibula . Its fourth left metatarsal bore roughened exostoses both in the middle and at the far end . The third phalanx of the third right toe is deformed , as the claw on that digit has been described as " quite small and amorphous " . The three pathologies may have been received in a single encounter with another dinosaur .

Another specimen cataloged as TMP94.12.602 bears multiple pathologies . A 10 cm (3 @.@ 9 in) longitudinal fracture is present in the middle of the right fibula 's shaft . Multiple ribs bear healed fractures and the specimen had a pseudoarthrotic gastralium . Lesions from a bite received to the face were present and showed evidence that the wounds were healing before the animal died .

TMP91.36.500 is another Gorgosaurus with preserved face bite injuries but also has a thoroughly healed fracture in the right fibula . Also present was a healed fracture in the dentary and what the authors describing the specimen referred to as " a mushroom @-@ like hyperostosis of a right pedal phalanx . " Ralph Molnar has speculated that this may be the same kind of pathology afflicting an

unidentified ornithomimid discovered with a similar mushroom shaped growth on a toe bone . TMP91.36.500 is also preserved in a characteristic death pose .

Another specimen has a poorly healed fracture of the right fibula , which left a large callus on the bone . In a 2001 study conducted by Bruce Rothschild and other paleontologists , 54 foot bones referred to Gorgosaurus were examined for signs of stress fracture , but none were found .

= = Paleoecology = =

Most specimens of *Gorgosaurus libratus* have been recovered from the Dinosaur Park Formation in Alberta . This formation dates to the middle of the Campanian , between 76 @.@ 5 and 74 @.@ 8 million years ago , and *Gorgosaurus libratus* fossils are known specifically from the lower to middle section of the formation , between 76 @.@ 6 and 75 @.@ 1 million years ago . The Two Medicine Formation and Judith River Formation of Montana have also yielded possible *Gorgosaurus* remains . At this time , the area was a coastal plain along the western edge of the Western Interior Seaway , which divided North America in half . The Laramide Orogeny had begun uplifting the Rocky Mountains to the west , from which flowed great rivers that deposited eroded sediment in vast floodplains along the coast . The climate was subtropical with marked seasonality , and periodic droughts sometimes resulted in massive mortality among the great herds of dinosaurs , as represented in the numerous bonebed deposits preserved in the Dinosaur Park Formation . Conifers formed the forest canopy , while the understory plants consisted of ferns , tree ferns and angiosperms . Around 73 million years ago , the seaway began to expand , transgressing into areas formerly above sea level and drowning the Dinosaur Park ecosystem . This transgression , called the Bearpaw Sea , is recorded by the marine sediments of the massive Bearpaw Shale .

The Dinosaur Park Formation preserves a great wealth of vertebrate fossils . A wide variety of fish swam the rivers and estuaries , including gars , sturgeons , sharks and rays , among others . Frogs , salamanders , turtles , crocodilians and champsosaurs also dwelled in the aquatic habitats . Azhdarchid pterosaurs and neornithine birds like *Apatornis* flew overhead , while the enantiornithine bird *Avisaurus* lived on the ground alongside multituberculate , marsupial and placental mammals . A number of species of terrestrial lizards were also present , including whiptails , skinks , monitors and alligator lizards . Dinosaur fossils in particular are found with unrivaled abundance and diversity . Huge herds of ceratopsids roamed the floodplains alongside equally large groups of hadrosaurine and lambeosaurine hadrosaurs . Other herbivorous groups like ornithomimids , therizinosaurs , pachycephalosaurs , small ornithopods , nodosaurids and ankylosaurids were also represented . Small predatory dinosaurs like oviraptorosaurs , troodonts and dromaeosaurs hunted smaller prey than the huge tyrannosaurids ; *Daspletosaurus* and *Gorgosaurus* , which were two orders of magnitude larger in mass . Intervening predatory niches may have been filled by young tyrannosaurids . A *Sauornitholestes* dentary has been discovered in the Dinosaur Park Formation that bore tooth marks left by the bite of a young tyrannosaur , possibly *Gorgosaurus* .