

= Hypacrosaurus =

Hypacrosaurus (meaning " near the highest lizard " [Greek ???- , hypo- = less + ????? , akros , high] , because it was almost but not quite as large as Tyrannosaurus) was a genus of duckbill dinosaur similar in appearance to Corythosaurus . Like Corythosaurus , it had a tall , hollow rounded crest , although not as large and straight . It is known from the remains of two species that spanned 75 to 67 million years ago , in the Late Cretaceous of Alberta , Canada , and Montana , USA , and is the latest hollow @-@ crested duckbill known from good remains in North America . It was an obscure genus until the discovery in the 1990s of nests , eggs , and hatchlings belonging to *H. stebingeri* .

= = Description = =

Hypacrosaurus is most easily distinguished from other hollow @-@ crested duckbills (lambeosaurines) by its tall neural spines and the form of its crest . The neural spines , which project from the top of the vertebrae , are 5 to 7 times the height of the body of their respective vertebrae in the back , which would have given it a tall back in profile . The skull 's hollow crest is like that of Corythosaurus , but is more pointed along its top , not as tall , wider side to side , and has a small bony point at the rear . Unlike other lambeosaurines , the passages for the airways do not form an S @-@ curve in the crest (at least not in *H. altispinus*) . The animal is estimated to have been around 9 @. @ 1 meters (30 feet) long , and to have weighed up to 4 @. @ 0 tonnes (4 @. @ 4 tons) . As with most duckbills , its skeleton is otherwise not particularly remarkable , although some pelvic details are distinctive . Like other duckbills , it was a bipedal / quadrupedal herbivore . The two known species , *H. altispinus* and *H. stebingeri* , are not differentiated in the typical method , of unique characteristics , as *H. stebingeri* was described as transitional between the earlier *Lambeosaurus* and later *Hypacrosaurus* . Photographs of an adult *H. stebingeri* skull show an animal that looks very similar to *H. altispinus* .

= = Classification = =

Hypacrosaurus was a lambeosaurine hadrosaurid , and has been recognized as such since the description of its skull . Within the Lambeosaurinae , it is closest to *Lambeosaurus* and *Corythosaurus* , with Jack Horner and Phil Currie (1994) suggesting that *H. stebingeri* is transitional between *Lambeosaurus* and *H. altispinus* , and Michael K. Brett @-@ Surman (1989) suggesting that *Hypacrosaurus* and *Corythosaurus* are the same genus . These genera , particularly *Corythosaurus* and *Hypacrosaurus* , are regarded as the " helmeted " or " hooded " branch of the lambeosaurines , and the clade they form is sometimes informally designated *Lambeosaurini* . Although Suzuki et al . ' s 2004 redescription of *Nipponosaurus* found a close relationship between *Nipponosaurus* and *Hypacrosaurus stebingeri* , indicating that *Hypacrosaurus* may be paraphyletic , this was rejected in a later , more comprehensive reanalysis of lambeosaurines , which found the two species of *Hypacrosaurus* to form a clade without *Nipponosaurus* , with *Corythosaurus* and *Olorotitan* being the closest relatives .

The following cladogram illustrating the relationships of *Hypacrosaurus* and its close relatives was recovered in a 2012 phylogenetic analysis by Albert Prieto @-@ Márquez , Luis M. Chiappe and Shantanu H. Joshi .

= = Discovery and history = =

The type remains of *Hypacrosaurus* remains were collected in 1910 by Barnum Brown for the American Museum of Natural History . The remains , a partial postcranial skeleton consisting of several vertebrae and a partial pelvis (AMNH 5204) , came from along the Red Deer River near Tolman Ferry , Alberta , Canada , from rocks of what is now known as the Horseshoe Canyon Formation (early Maastrichtian , Upper Cretaceous) . Brown described these remains , in

combination with other postcranial bones , in 1913 as a new genus that he considered to be like *Saurolophus* . No skull was known at this time , but two skulls were soon discovered and described .

During this period , the remains of small hollow @-@ crested duckbills were described as their own genera and species . The first of these that figure into the history of *Hypacrosaurus* was *Cheneosaurus tolmanensis* , based on a skull and assorted limb bones , vertebrae , and pelvic bones from the Horseshoe Canyon Formation . Not long after , Richard Swann Lull and Nelda Wright identified an American Museum of Natural History skeleton (AMNH 5461) from the Two Medicine Formation of Montana as a specimen of *Procheneosaurus* . These and other taxa were accepted as valid genera until the 1970s , when Peter Dodson showed that it was more likely that the " cheneosaurs " were the juveniles of other established lambeosaurines . Although he was mostly concerned with the earlier , Dinosaur Park Formation genera *Corythosaurus* and *Lambeosaurus* , he suggested that *Cheneosaurus* would turn out to be composed of juvenile individuals of the contemporaneous *Hypacrosaurus altispinus* . This idea has become accepted , although not formally tested . The Two Medicine *Procheneosaurus* , meanwhile , was not quite like the other *Procheneosaurus* specimens studied by Dodson , and for good reason : it was much more like a species that would not be named until 1994 , *H. stebingeri* .

= = = Species = = =

H. altispinus , the type species , is known from 5 to 10 articulated skulls with some associated skeletal remains , from juvenile to adult individuals found in the Horseshoe Canyon Formation . *H. stebingeri* is known from an unknown but substantial number of individuals , with an age range of embryos to adults . The hypothesis that *H. altispinus* and *H. stebingeri* form a natural group excluding other known hadrosaur species may be incorrect , as noted in Suzuki et al . ' s 2004 redescription of *Nipponosaurus* ; their phylogenetic analysis found that *Nipponosaurus* was more closely related to *H. altispinus* than *H. stebingeri* was to *H. altispinus* . This was rejected by Evans and Reisz (2007) , though .

The new species *Hypacrosaurus stebingeri* was named for a variety of remains , including hatchlings with associated eggs and nests , found near the top of the late Campanian (Upper Cretaceous) Two Medicine Formation in Glacier County , Montana , and across the border in Alberta . These represent " the largest collection of baby skeletal material of any single species of hadrosaur known " .

= = Paleoecology = =

H. altispinus shared the Horseshoe Canyon Formation with fellow hadrosaurids *Edmontosaurus* and *Saurolophus* , hypsilophodont *Parksosaurus* , ankylosaurid *Anodontosaurus* , nodosaurid *Edmontonia* , horned dinosaurs *Montanoceratops* , *Anchiceratops* , *Arrhinoceratops* , and *Pachyrhinosaurus* , pachycephalosaurid *Stegoceras* , ostrich @-@ mimics *Ornithomimus* and *Struthiomimus* , a variety of poorly known small theropods including troodontids and dromaeosaurids , and the tyrannosaurs *Albertosaurus* and *Daspletosaurus* . The dinosaurs from this formation are sometimes known as Edmontonian , after a land mammal age , and are distinct from those in the formations above and below . The Horseshoe Canyon Formation is interpreted as having a significant marine influence , due to an encroaching Western Interior Seaway , the shallow sea that covered the midsection of North America through much of the Cretaceous . *H. altispinus* may have preferred to stay more landward .

The slightly older Two Medicine Formation , home to *H. stebingeri* , was also populated by another well @-@ known nesting hadrosaur , *Maiasaura* , as well as the troodontid *Troodon* , which is also known from nesting traces . The tyrannosaurid *Daspletosaurus* , caenagnathid *Chirostenotes* , dromaeosaurids *Bambiraptor* and *Saurornitholestes* , armored dinosaurs *Edmontonia* , *Oohkotokia* , and *Scolosaurus* , hypsilophodont *Orodromeus* , hadrosaur *Prosaurolophus* , and horned dinosaurs *Achelousaurus* , *Brachyceratops* , *Einiosaurus* , and *Rubeosaurus* were also present . This

formation was more distant from the Western Interior Seaway , higher and drier , with a more terrestrial influence .

= = Paleobiology = =

As a hadrosaurid , *Hypacrosaurus* would have been a bipedal / quadrupedal herbivore , eating a variety of plants . Its skull permitted a grinding motion analogous to chewing , and its teeth were continually replacing and packed into dental batteries that contained hundreds of teeth , only a relative handful of which were in use at any time . Plant material would have been cropped by its broad beak , and held in the jaws by a cheek @-@ like organ . Its feeding range would have extended from the ground to about 4 m (13 ft) above .

= = = Nests and growth = = =

H. stebingeri laid roughly spherical eggs of 20 by 18 @.@ 5 cm (7 @.@ 9 by 7 @.@ 3 in) , with embryos 60 cm (24 in) long . Hatchlings were around 1 @.@ 7 m (5 @.@ 6 ft) long . Young and embryonic individuals had deep skulls with only slight expansion in the bones that would one day form the crest . Growth was faster than that of an alligator and comparable to ratite growth , for several years , based on the amount of bone growth seen between lines of arrested growth (analogous to growth rings in trees) . Research by Lisa Cooper and colleagues on *H. stebingeri* indicates that this animal may have reached reproductive maturity at the age of 2 to 3 years , and reached full size at about 10 to 12 years old . The circumference of the thigh bone at postulated reproductive maturity was about 40 % that of its circumference at full size . The postulated growth rate of *H. stebingeri* outpaces those of tyrannosaurids (predators of hypacrosaurs) such as *Albertosaurus* and *Tyrannosaurus* ; rapidly growing hypacrosaurs would have had a better chance to reach a size large enough to be of defensive value , and beginning reproduction at an early age would also have been advantageous to a prey animal . Secondary cartilage has been found in the skull of a hatchling specimen of *H. stebingeri* .

= = = Crest functions = = =

The hollow crest of *Hypacrosaurus* most likely had social functions , such as a visual signal allowing individuals to identify sex or species , and providing a resonating chamber for making noises . The crest and its associated nasal passages have also figured in the debate about dinosaur endothermy , specifically in discussions about nasal turbinates .

Turbinates are thin bones or cartilages that come in two types , with two functions . Nasal olfactory turbinates are found in all living tetrapods and function in smell . Respiratory turbinates function to prevent water loss through evaporation and are found only in birds and mammals , modern endotherms (warm @-@ blooded animals) who could lose a great deal of water while breathing because they breathe more often than comparably sized ectotherms (cold @-@ blooded animals) to support their higher metabolism . Ruben and others in 1996 concluded that respiratory turbinates were probably not present in *Nanotyrannus* , *Ornithomimus* or *Hypacrosaurus* based on CT scanning , thus there was no evidence that those animals were warm @-@ blooded .

= = = Paleopathology = = =

The discovery of tooth marks in the fibula of a *Hypacrosaurus* specimen inflicted by a bite from the teeth of *Tyrannosaurus* indicated that this , and other hadrosaurids were either preyed upon or scavenged by large theropod dinosaurs during the Late Cretaceous period .

= = = Thermoregulation = = =

Examining the oxygen @-@ isotope ratio from the bones from different parts of an extinct animal 's

body should indicate which thermoregulation mode an animal used during its lifetime . An endothermic (warm @-@ blooded) animal should maintain a very similar body temperature throughout its entire body (which is called homeothermy) and therefore there should be little variation in the oxygen @-@ isotope ratio when measured in different bones . Alternatively , the oxygen @-@ isotope ratio differs considerably when measured throughout the body of an organism with an ectothermic (cold @-@ blooded) physiology . Oxygen @-@ isotope ratios calculated for Hypacrosaurus suggesting that the ratios varied little , indicating that Hypacrosaurus was a homeotherm , and likely was endothermic . This is in contrast to the Ruben et al . (1996) finding that Hypacrosaurus was not warm @-@ blooded , which was based on the absence of nasal turbinates (see Crest functions subsection , above) .

= = Taphonomy = =

Taphonomy is the study of the processes an organism ? s body undergoes after it dies , which includes a study of preservation , the cause of death , and the circumstances of burial . The large , monospecific assemblage of Hypacrosaurus stebingeri in Montana was interpreted as a group of dinosaurs that was killed by a volcanic ashfall . This assemblage is considered autochthonous , meaning that the remains are thought to have been buried on or near the same spot where the individuals died . The variety of ages in this group supports that this was a biocoenosis- an actual life assemblage of animals . The cause of death in a volcanic ashfall is suffocation by the ash and by the gases released from volcanic eruptions . The preservation of this diverse group of dinosaurs provides researchers with a growth series , which is a sequence of growth stages from juvenile to adult .