Paleontologists have long depended on fossils of bones to reconstruct how species looked. They recognized that dinosaur skeletons were extremely similar to single few years, many fossils have been found of feathered dinosaurs. This is remarkable in itself because compared to bones, feathers are very slim and fragile resulting in very few fossils.

This poster shows the most important feathered dinosaurs. Species definately shown at right. Scientists believe that all other members of the family also had feathered dinosaurs. This is remarkable in itself because compared to bones, feathers are very slim and fragile resulting in very few fossils. Compsognathidae **Feather Evolution** Compsognathids were small, active hunters of insects and microvertebrates. Many experts believe that the feathered dinosaurs were warm-blooded and that feathers initially provided insulation to help The compsognathid family includes Compsognathus and Huaxiagnathus. No feathers have yet been found for them, but the two genera are very similar. keep them warm. Some dinosaurs had larger feathers than others and they helped them to leap higher off the ground to catch prey. Or, they used them to glide down from trees and other high places to leap on unsuspecting victims. Those with Some experts believe that all compsognathids had feathers. he largest and most effective physical characteristics sulvived while their less fortunate epidermis (skin), which elongated into a hollow Although this looks similar to stage 2, a close It is also possible that the rachis, or stem, was the first to evolve and a large number examination reveals that the barbs have deof barbs radiated outward from it. veloped very tiny branches called barbules. It had short arms with two clawed fingers on each hand. These feathers appear fuzzy or downy. Compsognathus longipes Means: "Elegant Jaw" Pronounced: Komp-so-Nath-us Sinosauropteryx prima Age: Jurassic - 150 MYA. Place: Germany, France Means: "Chinese lizard with feathers" Pronounced: SIEN-o-sawr-OP-ter-iks Length: 3 feet / m. Weight: 6 lbs. / 3 k Sinosauroptervx Forelimba Compsognathus is considered an important link in the study of bird evolution. The Age: Early Cretaceous - 125 MYA. Place: Liaoning, China Barbed Ridge An adapted scapula, or shoulder blade, permitted a original fossil of this dinosaur was found in the same place as Archeopteryx, the early Length: 4 ft. / 1.3 m. Weight: 5 1/2 lbs. / 2.5 kgs **Complete Feather** greater range of movement in the forelimb. This re-There are two possibilities Yegarding what feathered reptile and "Compy" shares a number of characteristics with it. The discovery The 1996 discovery of Sinosauropteryx prima shocked the paleatology world. The fossils show occurred next. The first is that a second layer Regardless of which of the two features sulted in arms. Although many animals, such as horses This was the closed asymmetrical feather of Sinosauropteryx prima has led some authorities to speculate that "Compy" may have hair-like "protofeathers." These are long, filamentous structures that seem to have formed a hair-like came first, their evolution resulted in the first that made flight possible. "Flight feathers" and dogs, have this bone, their forelimbs remained legs. evolved that created a follicle collar. The inner had feathers too, but no fossil record of them has yet been discovered. For many years, double-branched feathers having rachises, covering over most of the body. This is the most most primitive coelurosaur ever found with feathlayer became a barbed ridge and the outer were found all the prehistoric birds and are it was the smallest known dinosaur. ers. This creature was about the size of a large chicke laver became a protective sheath. found on modern hirds **Theriznosauroidea Oviraptorosaurea** Therizinosauroids were a bizarre group of giant feathered dinosaurs related to oviraptors. The 1999 discov-Oviraptorosaurs first appear in the fossil record in the early Cretaceous. We ery of the primitive Beipiaosaurus in Liaoning, China, brought a surprise. It was covered with protofeathers. know they had bird-like feathers because fossil remains of an early member of the group. Caudipteryx, show this animal had advanced feathers on the arms These hair-like filaments seem to have been hollow. The fibers have branched at the ends and seem to corand tail. These are just like the feathers of a bird, except that they lack the asymrespond to either Stage 1 or Stage 2 of the "evo-devo" model of feather evolution. Large patches of filament have been preserved on both the forearms and the legs. By implication, all therizinosauroids had feath metry that defines modern flight feathers. They correspond well to Stage 4 of the "evo-devo" model of feather evolution. There is evidence that the entire body may have had a down-like covering of small plumulaceous feathers of up to 14 mm (about 1/2 inch) long, that presumably served as thermal insulation. Oviraptor philoceratops Falcarius utahenis Means: "Egg Robber" Means: "Sickle maker" Erlikosaurus andrewsi Pronounced: OH-vi-RAP-tor Pronounced: Fal-care-e-us Means: "Erlik's (King of the Dead's) lizard" Age: Late Cretaceous - 80-84 MYA Age: Early Cretaceous - 125 MY Pronounced: ER-lik-oh-SAWR-us Place: Omnogov, Mongolia Length: 8 ft. / 2.5 m. Weight: 72 lbs / 33 kgs Place: Utah, USA Age: Late Cretaceous - 90 MYA Place: Omnogov, Mongolia Caudipteryx zoui Length: 13 ft. / 4 m Weight: 850 lbs. / 295 kg. Length: 17-20 ft. / 5 - 6 m. Weight: 1,500-2,500 lbs / 750 - 1200 kgs The first Oviraptor skeleton was found in on Pronounced: caw-DIP-ter-iks In 2005, Utah scientists announced the Erlikosaurus is so far known from a well-preserved skull. It is significant top of a nest of fossil eggs and that the animal Age: Early Cretaceous -125 MYA; Place: Liaoning, China scovery of this small new dinoaur. They because the jaws are toothless and covered with a horny, bird-like beak. died while stealing them. Seventy years later, Length: 28-36 in. / 70 - 90 cm. Weight: 25 lbs. / 7 kgs ad excavated over 1,700 fossils from a another skeleton and nest was found and, in mass burial ground. Fossil remains indicate animal had advanced feathers. There is a fan of this case, a tiny fossil embryo was found in paired feathers on either side of the end of the tail. Long feathers wereon its one of the eggs, which was clearly an Oviraparms. There is evidence that its entire body may have had a down-like covertor. Rather than being an "Egg Robber," they ing, as the hips and the base of the tail of the original specimen are covered by Incisivosaurus gauthieri were guarding their own nests! small plumulaceous feathers. Pronounced: In-siz-EE-voh-SOREe-us Age: Cretaceous Period - 120 MYA Length: 3 ft / 1 m; Weight: 9 lbs. / 4 kg Therizinosaurus cheloniformis While most other Oviraptorids had no teeth, Incisivosaurus had a Means: "Scythe Lizard" mouth full of them, including enormous gnawing incisors, rs, similar Pronounced: THER-uh-ZEEN-oh-SAWR-us to the "buckteeth" found in mice and beavers. They have given rise to it being called "a cross between Bugs Bunny and the Road Run-Age: Late Cretaceous - 72-68 MYA ner." Incisivosaurus was obviously no carnivore Place: Mongolia Length: 26-40 ft / 8-12 m; Weight: 6.2 tons Not all the feathered dinosaurs were small. T. cheloniformis, the largest of the therizinosauroids, grew up to 40 Feather Length were two and half feet long. It may have been a herbivore Most authorities now agree that some of the small, swift bipedal and used them to pull down branches to eat the leaves. dinosaurs were warm-blooded and that they developed feathers as The fossil record is far from complete, consisting mostly a means of providing body insulation, but this does not explain why of claws and bone fragments. No fossil feathers have yet feathers became so large. Oviraptor philoceratops is known to have protected its eggs, but its clutches were large and could not be totally Nomingia gobiensis. protected. A recent theory is that dinosaurs that mutated to produce shown without feathers large feathers were better able to protect their eggs from heat and cold. This led to feathered dinosaurs having a higher survival rate and far more descendants - a classic case of "survival of the fittest." Flight may have been a byproduct of this new characteristic. Nomingia gobiensis, Avimimus portentosus shown with feathers Pygostyle | Pronounced: A-bee-mee-moos Age: Late Cretaceous - 95 MYA Beipiaosaurus inexpectus Nomingia gobiensis Place: Mongolia, China leans: "Beipiao lizaro Means: Nomingiin" (a part of the Gobi Desert) Length: 5 ft. / 1.5 m; Weight: 45 lbs. / 20 kg. Pronounced: bay-peow-SAWR-us Pronounced: no-MING-ee-uh Avimimus looked so much like a bird that its name literally means that it imitates a Age: Early Cretaceous - 125 MYA; Place: Liaoning, China Age: Late Cretaceous - 68 MYA bird. It looks like a large reptilian roadrunner. Avimimus had a long, lean neck topped ength: 7 ft. / 2.2 m; Weight: 100 lbs / 45 kgs Length: 3 feet / 1 m; Weight: Unknown by a short skull that was equipped with a toothless beak and a relatively large brain-This was the fourth non-avian dinosaur found with feathers in the Chinese depos-This little dinosaur is a good example of the term "missing link". case. It had long, slender back legs built for fast running. But its front limbs had not s. It is important because of the preserved protofeathers. It is the the most primi-Nomingia gobiensis is unique in that the last five vertebrae on its It was developing features of modern birds. The most important yet evolved into wings. They were lightly built and equipped with sharp, curved claws ve known therizinosauroid. It probably used its claws to pull branches from trees tail are fused together, creating what is called a "pygostyle." Pygostyles are used to anchor the tail feathers. It lets them steer while was a short tail that ended in a pygostyle. This is the type of Avimimus had the ability to fold its whole arm against its body, much like the wings of down to its beaked jaws. This behavior, like its appearance, made the creature bone that attaches tail feathers to bodies of birds; it permits a bird. Unlike a bird however, Avimimus had a long bony tail. The deposits in which esemble the Cenozoic giant ground sloth. flying. The presence of this bone in the oviraptorosaurs establishes them to steer wile flying. Nomingia was just about ready to fly! the fossils were found were to coarse to preserve impressions of feathers. that they tail feathers too. **Alvarezsauridae Troodontidae Tyrannosauroidae** The five species in this family had very similar skeletons. All had The discovery of feathers on so many closely related species led many scientists to speculate that the Tyrannosaurs also had feathers. Their prediction proved to be Troodontids resemble early birds in the complex middle ear, associated sinuses and teeth constricted between the root and the crown; long legs, suggesting they were fast runners, long tails and many dromaeosaurs in their stiff tail and sickle-like toe claw; and ornithomimids ("ostrich dinosaurs") in the arrangement of their leg bones, elonbird-like features in the backbone, pelvis and hindlimbs. In one gated neck vertebrae, the general shape of the head and form of the braincase. They were the brainiest of all dinosaurs, with a brain size correct when Dilong paradox was discovered in 2004. looked more birdlike than Archaeopteryx. and presumably intelligence - equal to that of modern birds. The eyes are huge and placed forward, meaning they had excellent binocular Tyrannosaurs were the largest and most powerful of the meat-eating dinosaurs and vision, and the legs are long and sturdy, like the legs of ostrich dinosaurs. There are no known troodontid feather impressions. However, as have long been regarded as the fiercest animals that ever lived. Wouldn't it be a big they were closely related to both dromaeosaurs and archaeopterygids, it is almost certain that they had similarly advanced feathers. surprise to everyone if Tyrannosaur rex turned out to be a really big chicken? But that is probably not the case. as T. rex's powerful jaws and sharp teeth establish that its eating habits wiere considerably different from a bird. However baby tyrannosaurs may have had feathers to provide insulation. Pronounced: my long Age: Early Cretaceous - 130 MYA Place: Liaoning, China This 2004 discovery was quickly dubbed "the Shuvuuia deserti eeping dragon" because of its posture. Its Means: "Desert Bird orlimbs are folded birlike next to the its body and Pronounced: shu-VOO-ee-a its "tucked-in" head position is identical to that of Age: Late Cretaceous - 85-75 MYA birds. This is the first case of such behavior being Place: Mongolia's Gobi Desert shown in the fossil record. Shuvuula deserti may be the best known alvarezsaurid, because it is the only one to have fossils that include complete and well-preserved skulls. It's forelimbs were short and stubby like an Dilong paradoxus ostrich or emu. They were very strong, Means: "Emperor Dragon Paradox" Sinornithoides youngi but certainly unsuitable for flight. If it had Pronounced: Dee-long Means: "Chinese bird forn feathers, then they were not preserved. Age: Early Cretaceous125 MYA Prounounced: sy-NOR-nith-OY-deez Unable to fly, this carnivore was about the Place Liaoning China Age: Middle Cretaceous - 110 MYA size of a turkey. It's long legs indicated This tiny, earlier ancestor of *Tyrannosaur rex* Place: Mongolia, China that it was fast runner. Known theropods vas unique in that it had a partial coat of hair-like Length: 3.6 ft / 1.1 m had three claws, but Shuvuuia had but athers, known as protofeathers. Fossils of four Weight: 12 pounds / 5.5 kg one. at the end of each arm was a single Troodon formosus speciemsn have been found. One had feath-S. youngi was the first dinosaur discovered large, hooked claw, bearing a resemers. Since Dilong predates T. rex by many, many with primitive feathers. This turkey-sized Means: "Wounding Tooth" blance to a scythe. millions of years, scietists now believe that all of dinosaur had very long legs and was a fast runner. It was a very intelligent dinosaur, as it had a relatively big brain. The largely comthe tyrannosaurs could have had feathers, at least Age: Late Cretaceous - 75-70 MYA; Place: Canada, USA Length: 2 - 3.5 m / 6 - 12 ft; Weight: Up to 50 kgs / 110 lbs when young Named in 1856 from a single tooth discovered the previous year, this aniplete skeleton and skull revealed for the first time the arm, back, and neck structure of the mal has the distinction of being the first dinosaur to be named in the western hemisphere. Its arms were very bird-like. Buitreraptor gonzalezorum Means: "Vulture Raptor" **Dromaeosauridae Furcula** Pronounced: Boo-eeh-tre-rap-tor Age: Late Cretaceous - 90 MYA The dromaeosaurids were one of the important groups of Cretaceous meat-eating dinosaurs. Very Place: Patagonia, Argentina Better known as the "wishbone," the furcula closely related to birds, these small to large sized dinosaurs are distinguished by the enormous was also long thought unique to modern This rooster-size predatory dinosaur is different from killing claw on the enlarged second toe, which was held off the ground when the animal walked or northern dromaeosaurs in that it has a slender snout pirds. It was recently found on Microraptor, ran and which was used to bring down large prey. They were popularized as the "raptors" of the with teeth that lack meat-tearing serrations. It probably Suchomimus (110-100 MYA), and even a T. Jurassic Park movies, where they are incorrectly shown as scaly and featherless. Dromaeosaurids Microraptor gui hunted small animals, such as lizards and mammals. It rex named "Sue" now on display at the Field in life were very bird-like, very like their near relatives the archaeopterygid birds. In all likelihood, long bird-like arms confirm such a life of grasping fastthey were warm-blooded with a bird-like metabolism. Pronounced: Mee-cro-RAP-tor moving small prey. It has long legs and must have been Age: Early Cretaceous - 125 MYA in agile runner. It most likely had feathers. Place: Liaoning, China .ength: 17 in. / 48 cm; Weight: 9 oz. / 250 g The Microraptor was a four-winged dinosaur, which not only had front wings, but rear legs, both covered with feathers. Some experts believe that it used its sharp claws to climb trees then glide down to attack unsuspecting prey. Unenlagia comahuensis Pronounced: oon-en-LAHG-ee-ah Age: Late Cretaceous - 93-86 MYA Place: Neuquen, Argentina Length: 6 ft. / 2 m; Weight: 33lbs / 15 kgs A very bird-like theropod that more closely resembles Archaeopteryx than any other theropod. The shoulder joint structure indicates that it could flap its arms/wings although, because of the tiny wing size, it could not fly. Deinonychus antirrhopus Pronounced: Deh-eeh-noh-nee-kus Age: Cretaceous -110-100 MYA Bambiraptor feinbergorum Place: Montana, USA Name Means: "Baby Raider Atrociraptor marshalli Length: 10 ft / 3 m Weight: 175 lbs Pronounced: Bam-bee-Rap-tor Velociraptor mongoliensis Name Means: "Marshall's Cruel Thie / 80 kgs This was a lightly built, Bambiraptor is one of the most important fossils found in North Names Means: "Swift Robber Pronounced fast-moving, agile, bipedal bird-like America. This little bird-like dinosaur was a very quick hunter, Pronounced: vel-Os-ih-Rap-tor Age: Late Cretaceous - 70 MYA dinosaur. The three fingers on each and it may have been an important step in dinosaurs' evolution Age: Late Cretaceous - 67 MYA Place: Alberta, Canada hand had sharp, curved claws. Place: Gobi Desert, Mongolia into birds. Scientists believe that feathers and fuzz covered its Atrocirpator is known only from a partial skull. It is related to the swift velociraptors of Bone for bone, there is very little to body. The fuzz would have been like the downy covering on Jurassic Park fame, but is smaller. It had a relatively short, massive skull with slende Length: 6 ft. / 3 m; Weight 60 lbs. / 25 kg distinguish it from its smaller cousin The movie "Jurassic Park" made Velociraptor famous. The baby birds. Bambiraptor had quite a few features in common lower jaws and long, highly curved teeth. The partial skull was discovered in 1995, Archaeopteryx. with modern birds. It had a wishbone, something all modern real Velociraptor is much smaller than in the film and it has but not fully described until 2004. Raptors like Altrociraptor are considered the closest The scapula evolved into a different shape. This allowed birds have that allow them to flap their wings, and its arms and a longer, thinner snout. It did have a large brain, but was not non-avian relatives of a Archaeopteryx, a feathered fossil with both reptile and bird this ostrich-sized animal to have greater up-and-down mosmart enough to open doors. Still, pound for pound, Velociraphands were very long for its body size. In fact, the length of its features. Although no dinosaur specimens have been found with preserved feathers in The semilunate carpal was a half-moon shaped bone in the bility in its arms. It now appears that other dromaeosaurids tor was a very effective killing machine! It most famous characarms and hands approached the lengths needed for flight. North America, many of the Late Cretaceous species from Alberta and other regions wrist of dromaeosaurids that permitted them to swivel their were able to move their arms this way too. teristic is the "Killing Claw." are closely related to the feathered dinosaurs of China. wrists. This flexibility made flight possible. Family Tree The Puzzlement Aves The feathered dinosaurs show the evolutionary development of one bird-like feature after another - feathers, wings, special bones, behavior, etc. The big problem is the

Archaeopteryx lithographica Means: "Ancient Wing" Pronounced: ark-ee-OP-ter-iks Age: Late Jurassic - 150-148 MYA Place: Bavaria, Germany Length: 18 in. / 45 cm; Weight: 13 oz. / 370 g Archaeopteryx has long been considered the first bird. Eight fossils of it were discovered, all in Germany. It is an intermediate species, one that linked modern birds with the predatory dinosaurs like Deinonychus.

Archaeoptervx Forelimb Long considered the first bird, it had asymmetrical feathers and fully developed wings that it could lift high above its head. It lacked the strong chest muscles and short tail essential for prolonged controlled flight. Flying was limited to short hops

Protarchaeopteryx robusta Pronounced: Pro -tar-key-Op-ter-ix Age: Early Cretaceous - 135 MYA Place: Liaoning Province, China. Length: 3 ft. / 1 m; Weight: 10 lbs. / 4 kg

This animal is considered to be more primitive than Archaeopteryx and it is more like the non-avian theropods. Protarchaeopteryx specimens were found with feather impressions. The best preserved of the newest specimens definitively shows feathers attached to the front leg and tail.

Unlike Archaeopteryx, however, Protarchaeopteryx's feath-

ers are symmetrical, indicating that Protarchaeopteryx may

not have been able to fly. Anatomical it less advanced than

Archaeopteryx, but lived 15 million years later.

The vertebrate class Aves includes the birds. An estimated 9,000 species exist worldwide. They have light yet strong hollow bones, a skeleton in which many bones are fused or lost, powerful flight muscles, and - most importantly - feathers. Today we know that not all dinosaurs became extinct. They survive in the form of the birds that fly around in your back yard.

Eoalulavis hoyasi 125-130 MYA Haliaeetus leucocephalus Pronounced:

In this primitive bird, the thumb has developed into an important structure to support the alula, a tuft of feathers that provided flight controls: the ability to turn and bank while flying.

Names Means: White headed sea eagle Age: Modern Day Place: Native to North America The Bald Eagle is the national bird of the United States. It is found throughout the country. It is a bird of prey and often lives near large bodies of water, where it catches fish. It is an excellent flyer, able to ride thermal convection currents, permitting it travel great distances.



Bald Eagle Forelimb Modern birds have small, lightweight bones, large wing surfaces and short tails. Large sternums (breast bones) allow for large flight muscles. These permit them to be excellent flyers.



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timing. These development should have led to the first modern bird appearing about 60 million years ago, but yet Archaeopteryx lived 150 million years ago, long before any of the bird changes took place in dinosaurs. Each of the feathered dinosaur families developed bird-like features in its own way. Thus there were many several different lines of evolution. Archaeopteryx was the result of another one. The big problem is no fossils have been found of it's ancestors.



220 million years ago, about the same time as the earliest known dinosaurs. It has two series of elongated, scale-like appendages along its back, which have been interpreted as parachuting or gliding devices. According to a new study, these appendages are feathers, making Longisquama the earliest known feathered animal. Many authorities dispute this claim. However, Archaeopteryx evolved from something and it wasn't any of the known feathered dinosaurs

Longisquama insignis is an unusual small diapsid reptile of uncertain affinities that lived