Confuciusornis sanctus, a new Late Jurassic sauriurine bird from China*

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In this note we report a new sauriurine bird from the Late Jurassic of Liaoning, China: *Confuciusornis sanctus*. This bird can be morphologically distinguished from the two infraclasses in Sauriurae by significant features, such as the presence of horny bill, a pneumatic foramen at the proximal end of the humerus and extraordinary long ungual phalange of the first manual digit. It is referred to a new order: Confuciusornithiformes ord. nov., under the subclass of Sauriurae.

1 Description

Class Aves Linnaeus 1758
Subclass Sauriurae Haeckel 1886
Order Confuciusornithiformes Ord. nov.
Family Confuciusornithidae Fam. nov.
Genus *Confuciusornis* Gen. nov.
Species *Confuciusornis sanctus* sp. nov.

Holotype An incomplete articulated skeleton with skull, forelimb elements. Institute of Vertebrate Paleontology and Paleoanthropology Collection V10918.

Paratype One with a nearly complete pelvis and an articulated hindlimb, another with an incomplete hindlimb, six separate feather impressions. Institute of Vertebrate Paleontology and Paleoanthropology Collection V 10895, V 10919—10925.

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Locality Shangyuan, Beipiao, Liaoning, China.

Horizon Yixian Formation (Tithonian, Late Jurassic).

Etymology The genus name is dedicated to Confucius, the greatest thinker and educator in Chinese history.

Diagnosis Size of Eichstatt *Archaeopteryx* specimen[1,8]. Teeth absent on either upper or lower jaw. Grooves with regular pattern present on jaws, indicating the presence of horny beak. Orbital large. Antorbital fenestra small. Proximal end of humerus expanded with a pneumatic foramen. Ungual phalange of digit I long and robust. Manual phalanges slender and unreduced. Carpals unfused with metacarpals. Ischium robust with an slightly expanded distal end and a dorsal process near its proximal end. Fifth metatarsal present. Foot claws large and curved.

Skull Nearly laterally preserved. Premaxilla is relatively well developed. The nasal process of the premaxilla is long, with no teeth on its ventral margin. On the surface of the nasal process are some grooves and a few pits, which are believed to be the trace of attachment of the horny beak. The narial opening is large, and elliptical in shape. The antorbital fenestra is probably small. The lachrymal is large. The nasal forms the upper posterior margin of the narial opening. The maxilla is overlapped by the maxillar process of the premaxilla; it has a dorsal process that forms the lower posterior margin of the narial opening. The frontal is large and unfused with the parietal. The parietal is positioned dorso-posteriorly. The quadrate is large, with a wide articular surface with the lower jaw. The palatine is slender relative to the short and stout pterygoid. The dentary is also well developed, with no teeth on it. There is a V-shaped depression of the lateral surface of the dentary. The dentary is divided into two branches posteriorly. The grooves and pits on the anterior lateral surface of the dentary also indicate the presence of a horny bill in the lower jaw. The surangular is long and robust and extends anteriorly at least to the position of the narial opening. The angular is also preserved and slender in appearance. The prearticular is between the angular and the dentary. The articular is well developed and round posteriorly. The paraoccipital process is probably dislocated and very long as compared to other birds (fig. 1).

Humerus Shaft of the humerus is strong. Th head is big. There is a large pneumatic foramen at the proximal end. The deltoid crest is very well developed. The internal tuberosity appears to be yet developed. The distal end of the humerus is unfortunately missing.

Ulan and radius The ulna is obviously wider than the radius and slightly bowed, with its proximal end missing.

Carpals and metacarpals Three free carpals are observed, probably including an

ulna, a radiale and a semilunate bone. The first metacarpal is relatively long. The second one and the third one are subequal in length, similar to that of *Archaeopteryx*[2]. No fusion between these metacarpals is recognized. The third metacarpal is slightly bowed.

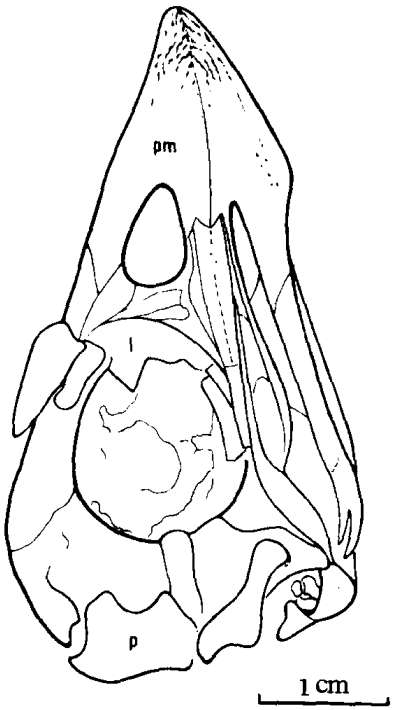


Fig. 1. Skull of *Confuciusornis sanctus* gen. et sp. nov. lateral view, V10918.

Phalanges and claws The first phalange of the first manual digit is long and slender; the manual claw of the first manual digit is slightly longer than the first phalange and is curved. The second manual digit includes two phalanges that are slender and unreduced. The third digit includes three phalanges among which the first is short, the second and the third are slender.

Hindlimbs The femur is complete and bowed. The tibia is long, slender and bears feathers attached on both sides. The distal end of the tibia is not well preserved, probably due to juvenile age. The tarsometatarsus is basically formed as there seems to be a proximal fusion among the three main metatarsals and the tarsals. The fifth metatarsal is slender, splint-shaped, and separated from the tarsometatarsus along most of its length. The third metatarsal is the longest among the five. All the claws are long and strongly curved.

Pelvis The ilium posterior to the acetabulum is very reduced and much shorter than that anterior to the acetabulum. The ischium is robust and thick. There appears a strut-shaped dorsal process near the proximal end of the ischium. The ischium forms most of the posterior margin of the acetabulum. The distal end of the ischium is thickened and slightly expanded. The pubis is probably retroverted and slender. Whether or not it has a pubic cup is unknown. The three bones of the pelvis are not well fused.

Feathers Feathers are attached to both sides of the tibia in specimen V10895. Several separate feathers represent various types, probably including both body and down feathers.

2 Comparison and discussion

The subclass of Sauriurae is diagnosed by the following synapomorphies[8]: (i) fusion of the tarsometatarsus proximally to distally; (ii) presence of a peculiar ridge on the lateral side of the distal posterior femoral surface; (iii) a unique median ridge from the proximal end of the scapula; (iv) presence of an anterior dorsal process on the proximal ischium;

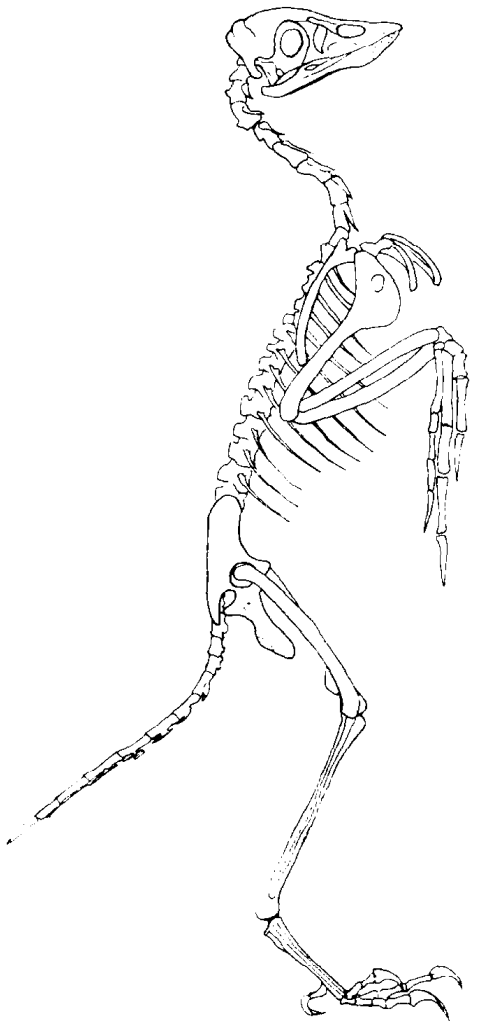


Fig. 2. Reconstruction of *Confuciusornis sanctus* gen. et sp. nov.

(v) presence of a groove that divides the head of the humerus antero-posteriorly. The present subclass includes two infraclasses: Archaeornithes and Enantiornithes. The former contains only one genus, *Archaeopteryx*. The latter is restricted to the Cretaceous Period.

Confuciusornis can be referred to the subciass of Sauriurae as at least two of its synapomorphies are found in this bird: a proximally fused tarsometatarsus and the proximal ischium with a peculiar anterior dorsal ischiadic process. On the other hand, *Confuciusornis* is also distinguishable from the known two infraclasses in Sauriurae. It is here referred to a new order, Confuciusornithiformes. This new order is diagnosed by the following characters: presence of a horny beak, absence of teeth, presence of a unique pneumatic foramen in the head of the humerus, and an extraordinary long first manual claw (figs. 2, 3).

Morphologically, *Confuciusornis* shows certain resemblances to *Archaeopteryx*, such as the basic structure of the skull, the unfused skull bones, large orbital, humerus longer than the ulna and radius, unfused carpals and metacarpals, a long first manual digit, unreduced manual digits II and III. These indicate that this bird probably had not yet possessed a strong power of flight. In addition, the bones of the pelvic girdle are not fused with each other and the fifth metatarsal is still retained. All these characters are more primitive than in Enantiornithes.

On the other hand, *Confuciusornis* also possesses some characters that are more advanced than in *Archaeopteryx*, such as the presence of the oldest known beak and the peculiar pneumatic foramina, the more posterior position of the dorsal ischiadic process on the ischium. All these indicate that this bird has already shown the reduction of weight, though this does not seem to be a quite efficient way in light of the bone structure of modern birds.

The members of the infraclass of Enantiornithes which includes *Cathayornis*[4] and *Sinornis*[3] are much more advanced than the new Jurassic bird in many respects: skull bones

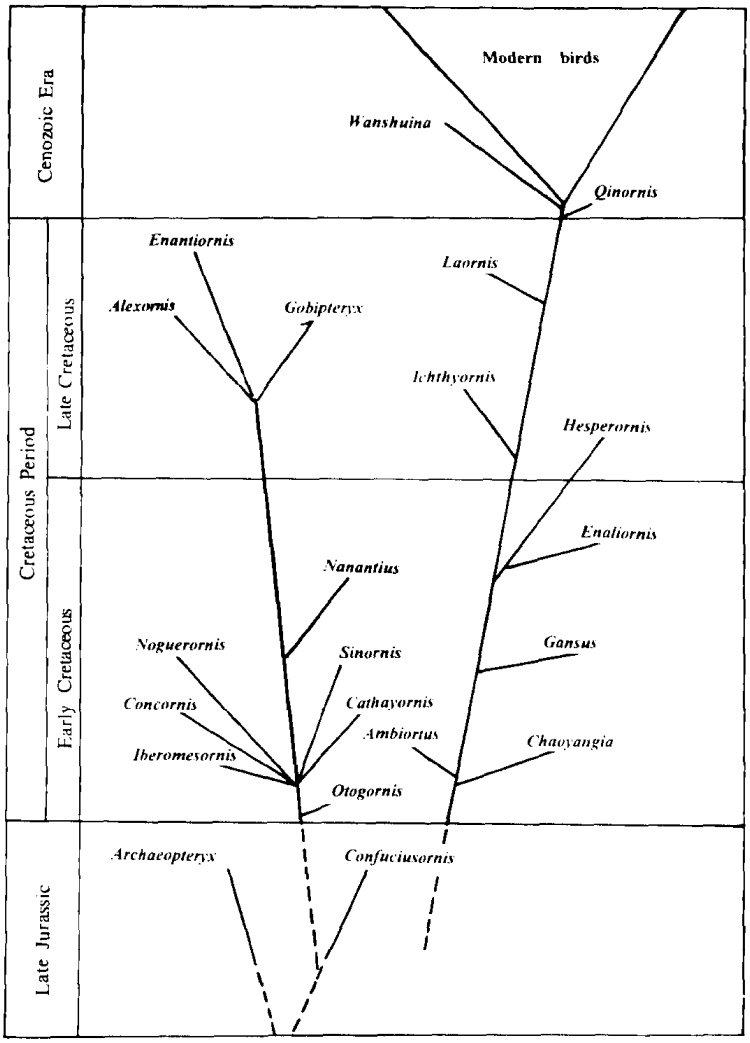


Fig. 3. Proposed phylogeny of early birds[5].

becoming thin and light, the enlarged brain, the forelimb modified into a wing with basically modern structure, the ulna longer than the humerus and further wider than the radius, presence of carpometacarpals reduced manual phalanges, the small manual claws, the pelvic bones beginning to co-ossify, and entire disappearance of the fifth metatarsal totally.

From the above comparisons, it is suggested that the new Jurassic bird from China occupies a very important position in the evolutionary line between *Archaeopteryx* and Enantiornithes. The side branch position of the oldest bird from Germany is further confirmed.

More significantly, its discovery indicates that the diversification of birds began no later than the Late Jurassic. The abundant Early Cretaceous birds from China[5] were further

developed from the earlier ancestor. The members of the both subclasses from the same site and the same horizon provide further evidence of the diversification of early birds.

Since the known earliest birds (Jurassic birds) are all members of the extinct subclass of Sauriurae, it is reasonable to assume that the ancestor of birds must have appeared much earlier, probably in Middle Jurassic or earlier.



Fig. 4. *Confuciusornis sanctus* gen. et sp. nov. Skull and forelimb, V10918×0.75.

The feather impressions attached to the tibiotarsus of *Confuciusornis* provide additional evidence that the Jurassic birds had been covered by feathers. Besides it is interesting to note the preservational bias of feather in Jurassic birds. In *Archaeopteryx*, except the wing and tail feather, the feathers attached to the tibia are most commonly preserved. In Chinese Jurassic birds, the tibiotarsal feather is well preserved. This fact probably indicates that the attachment of feather to the tibiotarsus is much stouter than the other hindlimb element (figs. 4, 5).



Fig. 5. *Confuciusornis sanctus* gen. et sp. nov. a, Skull in lateral view, V109185, ×1; b. Pelvis and hindilimb, V10895, ×1.

Finally, as regards the age of the lacustrine Yixian Formation[6,7], there has been a long history of disputes. The recovery of the early birds makes it possible to compare it directly with the marine deposits bearing the Jurassic bird *Archaeopteryx*. The age of *Archaeopteryx* has been dated as Early Tithonian. Previously in this note we have made a detailed comparison between the new Chinese bird and *Archaeopteryx*. They are basically similar in all important aspects of the structures. Although the new Chinese Jurassic birds may be slightly more advanced than *Archaeopteryx* for the presence of a horny beak and the pneumatic foramen on the head of the humerus, most of them are significantly more primitive than the Early Cretaceous birds in many respects. With all these factors considered, we support the suggestion that the Yixian Formation is of a Late Jurassic age.

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