On the Discovery of the earliest fossil bird in China (*Sinosauropteryx* gen. nov.) and the origin of birds

by

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Introduction

The origin and early evolution of birds is one of the great subjects for speculation in biology that has yet to be resolved. It is a subject that is consistently controversial and intensely followed by scientists globally and particularly by paleontologists. The 1861 discovery and description of *Archaeopteryx lithographica* from the Solnhofen Limestone, of Bavaria, Germany, not only provided paleontological evidence that birds are descendents of reptiles, it is also regarded as the direct ancestor to the class Aves. In the mid 1990's, the discovery of the primitive bird *Confuciusornis sanctus* (Hou et al., 1995), from the Mesozoic sediments of western Liaoning Province, shattered the German leadership in this sphere; but after the study of several dozen specimens and comparisons to *Archaeopteryx*, it was determined that *Confuciusornis* was more derived than *Archaeopteryx*, represented a young geological era, and therefore could not represent a more ancestral morph for Aves. Moreover, underlying the lithologic units that produce *C. sanctus*, is a sedimentary package exceeding a thousand meters in thickness, providing a motivation to find an even earlier genuine ancestor for birds.

With the search for a more primitive bird as the primary motivation, it was fortuitous that in August of 1996, the authors of this text recovered an extremely valuable specimen in the basal limestones of the lower Yixian Fm. at the village of Shangyuanxiang, Beipiao, western Liaoning, representing a horizon stratigraphically lower than the *Confuciusornis* beds. The characters on this specimen indicates that it is the most primitive bird known in the world to date and represents the genuine earliest ancestor of birds. This is one of the great discoveries in paleornithology and is of extreme scientific significance, rivaling the discovery of *Archaeopteryx* in Germany.

Description

Aves Linnaeus, 1758

Sauriurae Haeckel, 1886

Sinosauropterygiformes ord. nov

Sinosauropterygidae fam. nov

***Sinosauropteryx* gen. nov.**

***Sinosauropteryx prima* sp. nov.**

Etymology: Sino- Latin, denoting China, sauro- Greek, referring to reptilian, pteryx- Greek for wing, indicating the specimen has transitional characters between small Theropoda and Aves. Species etymology: prima- Latin for first.

Type: A relatively complete skeleton housed at the Chinese Geological Museum (specimen #GMV2123).

Locality and stratigraphic position: Lower section of the Upper Jurassic Yixian Fm. from the village of Shangyuanxiang, Beipiao Municipality, Liaoning Province.

Diagnosis: A small primitive bird with a relatively high skull, blunt rostrum and a slightly high premaxilla. The antorbital fenestra is elliptical but not enlarged, the dentary is robust, the surangular is narrow and elongated, and the dentition is extremely well developed and acute. There are over 50 extremely elongated caudals, constituting 60% of the body length, and the forelimb is extremely short with a short and thick humerus. The pubis is elongated and extremely inflated at its distal end and the ischium is broad. The hind limb is long and robust, the tibia is only slightly longer than the femur, the tarsals are separated, and the metatarsals are relatively

robust with unfused proximal ends. The feathers are short, small, and uniform; many ornament the top of the skull, cervical, and dorsal regions, in addition to the dorsal and ventral caudal region.

Description: The specimen is preserved in lateral perspective and has a complete length of approximately 65 cm. The skull is nearly triangular in lateral perspective, and is over 6 cm long. It is relatively short and high and has a slightly blunt rostrum; the premaxilla is relatively high and bears sharp anterior teeth, but the maxillary dentition is rather poorly preserved. The nasals are thin, elongated, and extend extremely posteriorly. The frontals are large and form the dorsal margin of the orbit. The jugal is narrow and elongated, the antorbital fenestra is elliptical but not enlarged, and is surrounded by the anteriorly narrow and posteriorly rather broadened orbital. The diameter of the orbit is approximately 11 mm. Cranial elements posterior to the orbit are scattered within the matrix.

The thickest point of the mandible is at its midsection, where it is 8 mm thick and there is an elliptical mandibular foramen on the same vertical plane as the orbit. The dentary is long and robust, and the surangular is narrow and elongate; the dentition is not completely preserved but two anterior teeth are extremely well developed and in contact. The crown height of the second tooth is 2.5 mm; the crown is acute and slightly posteriorly curved; the lower half of the tooth is relatively large and thickened, and the posterior mandibular dentition is relatively low and small.

There are an estimated nine cervical vertebrae with slender and short ribs, composing a complete length of 70 mm. There are 12-13 dorsal vertebrae composing a total length of nearly 90 mm; at least 12 of these preserve single or paired ribs. Paired dorsal ribs 3-6 are relatively long, measuring approximately 50 mm with diameters of 1.5 mm. Posteriorly along the column the ribs gradually shorten. The rib articular region is relatively broad and slightly curved. Approximately 20 extremely slender gastralia with acute termini are visible. They have approximate lengths of 20 mm and are curved and oriented like the dorsal ribs. Caudal vertebrae are basically complete and are represented as a column of 54 centra with a length of 38 cm. In lateral perspective the anterior half of the series has rectangular centra; their lengths slightly exceed their heights. Among the posterior half of the series, vertebral height distinctly diminishes and centra gradually become smaller. Neural arches are relatively low and elongated. Haemal arches are elongated, perpendicular to the centra, and gradually become smaller posteriorly, although their morphology remains consistent.

Only an extremely small portion of the posterior scapula is preserved. There is also an 8 mm rounded element in this region that may represent the coracoid. The forelimb is extremely short, or approximately two-fifths the length of the hind limb. The humerus is short and thick and approximately 20 mm long; each end has a breadth of 7-8 mm, is very slightly convex, and its midshaft diameter is constricted to 3 mm. The radius and ulna are damaged but are estimated to have lengths slightly exceeding 20 mm. Both the length and morphology of these two elements are consistent. Carpals, metacarpals, and digits are rather poorly preserved. Compared to *Archaeopteryx* and *Confuciusornis* the forelimb is exceptionally small.

The ilium length is 35 mm, its outline resembles those of small theropod ilia but the postacetabular process does not taper. The proximal pubis is vague, but its length would exceed 45 mm, the midsection is constricted, and the distal end is extremely inflated with a relatively distinct posterior process. Only 18 mm of the ischium is preserved, the distal end being lost, but what is represented is a relatively broadened plate.

The hind limb is long and robust. The femur is a stout 53 mm long element that is slightly curved posteriorly; the midshaft is only 6-7 mm in diameter, and termini are inflated to a breadth of nearly 10 mm. The tibia is thick, large, not pneumaticized, and nearly 60 mm long. It has a slightly convex proximal articular facet and its distal end is flat and relatively broad. The proximal fibula is 6.5 mm wide, is in tight contact with the proximal tibia, and rapidly attenuates distally.

At least four tarsals preserved, the majority of which are elliptical and aligned in two series, the proximal of which has three. The metatarsals are extremely well developed, but only three are visible; they have unfused proximal ends, they are 36 mm long and are relatively thick with 2-3 mm diameter shafts. Phalanges are relatively short and bear talons.

Feathers are present only on the posterior apex of the skull, on the cervical and dorsal region, and on the dorsal and ventral caudal region. They are not preserved on any other portions of the body. The feathers are short, small, and uniform, resembling down feathers and unlike later avian feathers which maintain pinnate veins and barbs.

Comparison: Because *Sinosauropteryx* has extremely short and primitive feathers, it is undoubtedly a member of the class Aves. It is also hereby recognized as an independent order, the Sinosauropterygiformes. It is distinct from *Archaeopteryx* (Wellnhofer, 1992) and *Confuciusornis* by its numerous plesiomorphic characters

The principle characters of *Sinosauropteryx,* including its forelimb/hind limb index, approach the condition of several small theropods. However it differs in its presence of feathers, the relatively short and high skull, and the relatively robust hind limb.

Sinosauropteryx shares plesiomorphic characters with *Archaeopteryx* and *Confuciusornis* in its body size, presence of forelimb talons, and undeveloped sternum. It is distinct from the latter two in its skull outline, its more acute and robust dentition, its extremely elongated and unfused caudal series, its extremely short forelimb, its long and robust hindlimb, its unfused proximal metatarsals, and its uniform feathers (Table 1.).

Discussion: *Sinosauropteryx prima* was either carnivorous or omnivorous and could not fly, but it relied on the ability to run rapidly like an ostrich. This primitive bird is in a transitional phase between small theropod dinosaurs and true birds and represents the authentic ancestor to Aves. It is also an extremely significant discovery for the following reasons:

1. *Sinosauropteryx* upsets and supercedes the over 100 year standing of *Archaeopteryx* as the ancestor to birds.

2. *Sinosauropteryx* unequivocally proves that the phylogeny of the class Aves progressed from a small theropod as proposed by Ostrom (1976) and supported by numerous workers in the field, although previously there had been no empirical evidence such as a transitional form. *Sinosauropteryx* hereby provides the most convincing evidence supporting Ostrom's theory.

3. *Sinosauropteryx* is an indication that the western Liaoning region of China is the site of origin of the class Aves and a center for bird evolution. Western Liaoning (including neighboring Hebei Province and Inner Mongolia) produces distinct avian faunas at different stratigraphic levels from the Late Jurassic to Early Cretaceous (Hou et al., 1995), thereby filling numerous gaps in the early evolutionary history of birds.

4. *Sinosauropteryx* establishes the early evolutionary prototype for birds. There are still three to four undescribed genera and species of fossil birds from the *Confuciusornis* sediments of western Liaoning which that preserve an avian fauna. Generally speaking, these faunas reflect periods of radiation, not origin. As such, *Confuciusornis* should represent an intermediate form between *Archaeopteryx* and true birds, or a relatively derived primitive bird. This analysis and comparison of primitive bird characters, leads to the conclusion that early avian evolution (from Late Jurassic to Early Cretaceous) occurred in four phases represented by *Sinosauropteryx, Archaeopteryx, Confuciusornis,* and true birds.

5. *Sinosauropteryx* provides significant paleontological evidence for resolving the long standing controversy of the Jurassic-Cretaceous boundary problem. *Sinosauropteryx*, *Archaeopteryx*, and *Confuciusornis* lie in the early evolutionary transitional phase of avian evolution, whereas true birds including *Sinornis santensis* and *Cathayornis yandica* possess numerous extremely derived characters, and represent a new phase of avian evolution. One may then recognize the occurrence of true birds as the Lower Cretaceous boundary.

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Table 1. Character comparisons among *Sinosauropteryx*, *Archaeopteryx*, and *Confuciusornis*.

	Sinosauropteryx prima gen. et sp. nov.	*Archaeopteryx lithographica* von Meyer, 1861	*Confuciusornis sanctus* Hou et al., 1995
Skull	Relatively short, high, thick, and heavy with high and blunt rostrum, high premaxilla, antorbital fenestra not enlarged, robust nearly linear dentary with anterior end.	Skull relatively thin and long with a low and acute rostrum, premaxilla small, antorbital fenestra enlarged, dentary slender and long.	Skull relatively thick with relatively low rostrum, premaxilla extremely large and anteroposteriorly elongated, antorbital fenestra reduced, dentary robust and slightly acute anteriorly, surangular extremely long.
Dentition	Acute and robust	Conical, acute, and relatively high crowned	Extremely reduced with only extremely weak dentition anteriorly
Hind and forelimb	Forelimb short and small, hind limb long and thick, proximal metatarsals unfused	Forelimb relatively long, carpals and metacarpals unfused, proximal metatarsals fused	Resembles *Archaeopteryx*, proximal humerus expanded with a pneumatic fenestra
Caudal vertebrae	Extremely numerous, over 50, approximately four times the length of the dorsal series, and unfused	Long series, nearly 25 or twice the length of the dorsal series, and unfused	Shorter than the dorsal series and most terminal centra have begun fusion
Feathers and ability for flight	Dorsal and caudal feathers are all extremely short primitive, uniform morphology, and incapable of sustaining flight	Forelimb and caudal region with relatively long feathers, and capable of short distance gliding	Forelimb wings with completely well developed flight feathers, indicating a distinct ability for flight