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REMARKABLE NEW BIRDLIKE DINOSAUR (THEROPODA: MANIRAPTORA)
FROM THE UPPER CRETACEOUS OF MONTANA

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Abstract.—We describe a small dromaeosaurid dinosaur, *Bambiraptor feinbergi* n. gen. and n. sp., based upon a nearly complete fossil skeleton from the Two Medicine Formation (Upper Cretaceous) of Montana. Widely known as Bambi, this skeleton is a well-preserved subadult that is about 75 percent adult size. Larger bones from the same locality suggest little anatomical change during late ontogeny. While this species fits the dromaeosaurid gestalt, it also shares a number of features with early birds.

INTRODUCTION

In September 1993, Wes Linster discovered the fossil remains of a small theropod in the Two Medicine Formation near Bynum, Montana. Within a few days, Wes and his family excavated the skeleton and began preparing the bones. They also began calling their find Bambi, a nickname that has since become widely used. The family contacted the senior author in November 1995 to conserve and prepare the specimen. The small size and fragile nature of the bones subsequently required thousands of hours of micropreparation.

The discovery of this fossil was announced in a preliminary paper (Burnham, Derstler, and Linster, 1997). Feduccia (1999) figured and briefly discussed the skeleton using information provided by the senior author.

The skeleton is more than 90-percent complete and well preserved. Most of the bones have retained their original shapes and articular surfaces. Some articulation information has been lost, but the excellent preservation allows

us to fit the bones and reconstruct the animal's posture with some confidence.

Scattered bones found within the same deposit apparently came from other individuals of the same species. Most came from animals approximately one third larger than the holotype.

The species is allied with such dromaeosaurid theropods as *Deinonychus* Ostrom (1969a) and *Velociraptor* Osborn (1924). We initially believed it to be conspecific with a dromaeosaurid already reported from the Two Medicine Formation, *Saurornitholestes langstoni* Sues (1978) (Varricchio & Currie, 1991; Burnham, Derstler, and Linster, 1997). We demonstrate herein that it differs from all described theropods including *S. langstoni*. Some of these differences may relate to the subadult nature of the fossil, but there are sufficient differences to erect a new taxon: *Bambiraptor feinbergi* n. gen. and n. sp.

In this paper we describe the new species, offer some initial anatomical observations, and point out some of its more obvious birdlike features.

Institutional abbreviations cited: FIP, Florida Institute of Paleontology, Dania Beach, Florida; KUVF, The University of Kansas Natural History Museum and Biodiversity Research Center, Lawrence, Kansas; SMM, The Science Museum of Minnesota, St. Paul, Minnesota.

SYSTEMATIC PALEONTOLOGY

Terminology follows Weishampel, Dodson, and Osmólska (eds., 1990), except that the semilunate carpal is not referred to as the radiale.

DINOSAURIA Owen, 1842

THEROPODA Marsh, 1881

MANIRAPTORA Gauthier, 1986

DROMAEOSAURIDAE Matthew and Brown, 1922

BAMBIRAPTOR n. gen.

Type species.—*Bambiraptor feinbergi* n. sp.

Diagnosis.—Jugal with row of foramina along ventral margin; scapula with large, medially directed acromion; distinct, short scapulocoracoid suture; coracoid with neck or peduncle forming part of glenoid; coracoid foramen absent; 13 dentary teeth, 9 maxillary teeth; ratio of humerus plus ulna to the femur large ($H+U/F = 1.68$); pubis with distal shaft and boot rotated posterodorsally; ischium with small proximal dorsal process; femur strongly recurved laterally and posteriorly.

Remarks.—Genus presently contains a single species.

BAMBIRAPTOR FEINBERGI n. sp.

Figure 1–8

Velociraptor sp. cf. *V. langstoni* (Sues); Burnham, Derstler, and Linster, 1997, p. 75.

Velociraptor Feduccia, 1999, p. 380.

Diagnosis.—As for genus.

Description.—The holotype skeleton of *Bambiraptor feinbergi* has an estimated length of one meter. It is a lightly built theropod (Table 1), with proportions more similar to those of *Archaeopteryx lithographica* (Table 2) than other known theropods. The holotype is roughly twice the size of the Berlin *Archaeopteryx* (De Beer, 1954), but the head is two and one half times as large (12 cm vs. 4.8 cm).

The skull of the holotype is virtually complete (Fig. 1). It is lightly built with a narrow snout and large, dorsally inflated braincase. Additionally, the skull has large upper temporal openings, T-shaped lacrimal, long narrow frontals with pronounced orbital rim, large antorbital fenestrae, maxilla with 2 accessory fenestrae, and 9 sharply recurved teeth up to 6 mm in length. There are 4.3 denticles per millimeter, but anterior denticles are visible on only a few teeth. They are more closely spaced (6.0 to 6.5 per millimeter) and smaller. The premaxilla contains 4 alveoli, but the tooth crowns are broken and mostly missing. Jugals are long and parallel sided with a row of small, ventrally positioned foramina along the ventral margin. The ascending process of the jugal is inclined posteriorly at nearly 45 degrees.

Table 1. Lengths (in mm) of selected elements of the holotype *Bambiraptor feinbergi* (FIP 001) and *Bambiraptor* adult bones (new).

| | |
|---|------|
| skull | 125* |
| mandible | 121* |
| right scapula | 87 |
| left coracoid | 40 |
| left sternum | 69 |
| five sacral vertebrae | 60 |
| left humerus | 105 |
| left ulna | 95 |
| left metacarpal II | 48 |
| three phalanges of left manual digit II | 85 |
| left ilium | 85 |
| left ischium | 52 |
| left pubis | 105 |
| left femur | 119 |
| left tibia | 168 |
| left metatarsal III | 78 |
| four phalanges of left pedal digit III | 76 |
| adult femur | 170 |
| adult humerus | 145 |
| adult tibia | 225 |
| adult metatarsal III | 105 |

*estimated.

The holotype includes two elements seldom recorded in theropods. The first is a hyoid. This slender rod is 3 cm long and nearly straight. It was preserved in the skull block, below the basicranium and between the mandibular condyles of the two quadrates. The other is the right stapes. A portion of this delicate bone lay in position against the right exoccipital.

A paraquadratic fenestra is framed by a reduced, forwardly deflected bar of bone. This bar is formed by the ascending process of the quadratojugal and the descending process of the squamosal. It is slender and nearly threadlike in *B. feinbergi*. The quadratojugal portion of this bar is curved. The quadrate has rostralateral flanges nearly as long as the quadrate is high.

In lateral view, the mandible is nearly parallel sided. There are 13 dentary teeth, recurved and similar in size to the maxillary teeth with crowns nearly 7 mm in length. The dentary teeth have 5 posterior denticles per millimeter. Anterior denticles are not easily discernable. The coronoid process is low and includes a delicate coronoid bone. The external surface of each dentary has many small foramina, especially abundant on the anterior portion. A mandibular fenestra is present and heavily built. Unfused articulars are present.

The vertebral column consists of 22 presacral vertebrae, including 9 cervicals, a cervicodorsal, and 13 dorsal vertebrae. Large pleurocoels occur on the cervical and dorsal vertebrae. Posterior cervicals, cervicodorsal, and the anterior dorsal vertebrae centra bear a ventral keel, similar to *Deinonychus*. There are 5 fused sacral and 23 preserved caudal vertebrae. The posterior end of the caudal series is missing. Elongated zygapophyseal rods and extensions of the chevrons overlap forward, producing the bony tail typical of dromaeosaurid dinosaurs.

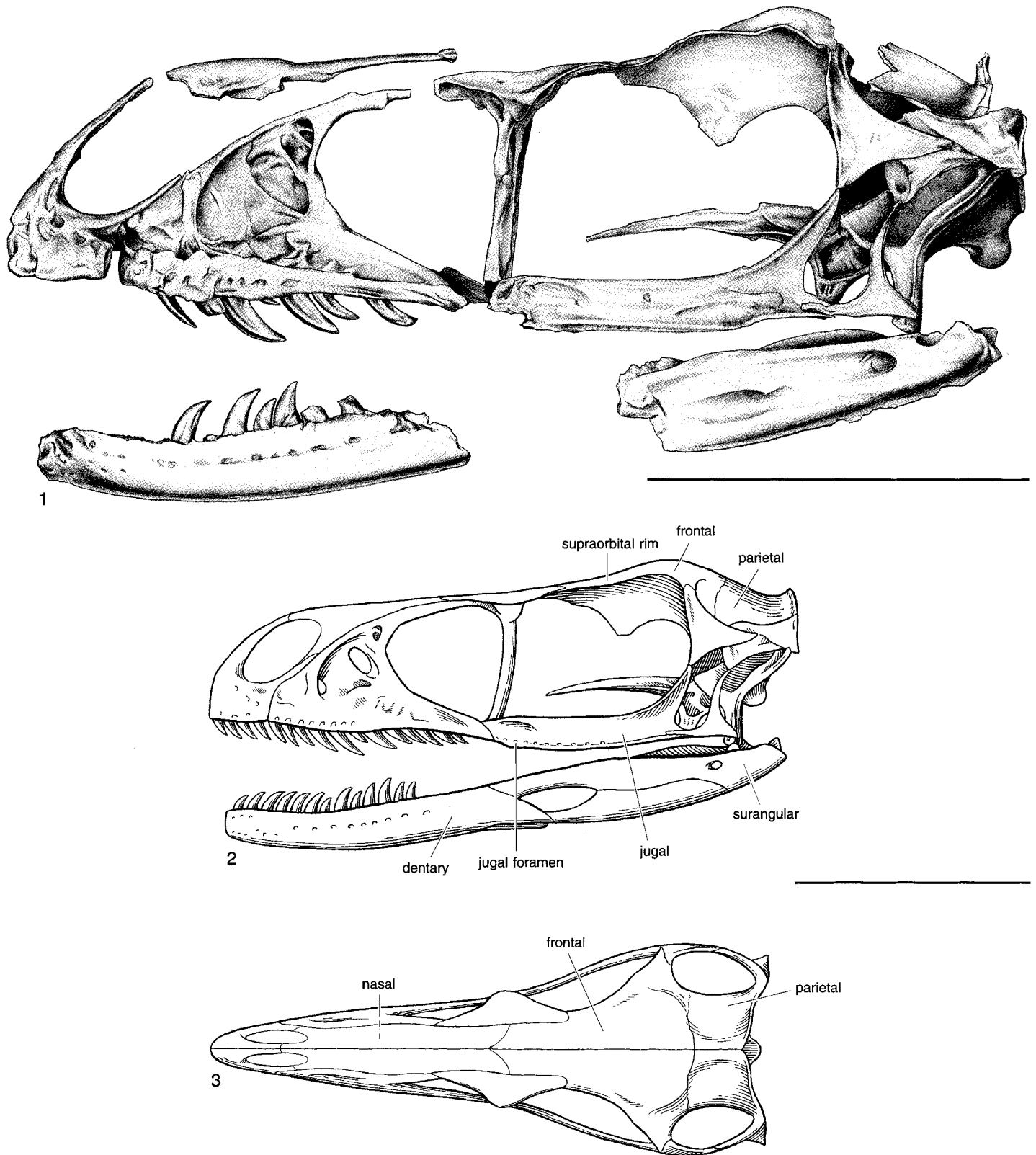


Figure 1. *Bambiraptor feinbergi* n. gen. and n. sp., holotype (FIP 001); 1, skull and mandibular elements in left lateral view; 2, restored skull in left lateral view; 3, restored skull in dorsal view. Scale bar: 5 cm (new).

Most ribs and gastralia are damaged. No single rib or gastralium preserves its full length, although the volume of rib heads and fragments suggests that the ribcage and gastral basket were originally complete. Pending further

restoration, the shape of the ribcage must remain conjectural.

The proximal caudal vertebrae and rod-stiffened portion of the tail have a distinctly upward curve (Fig. 2). It is

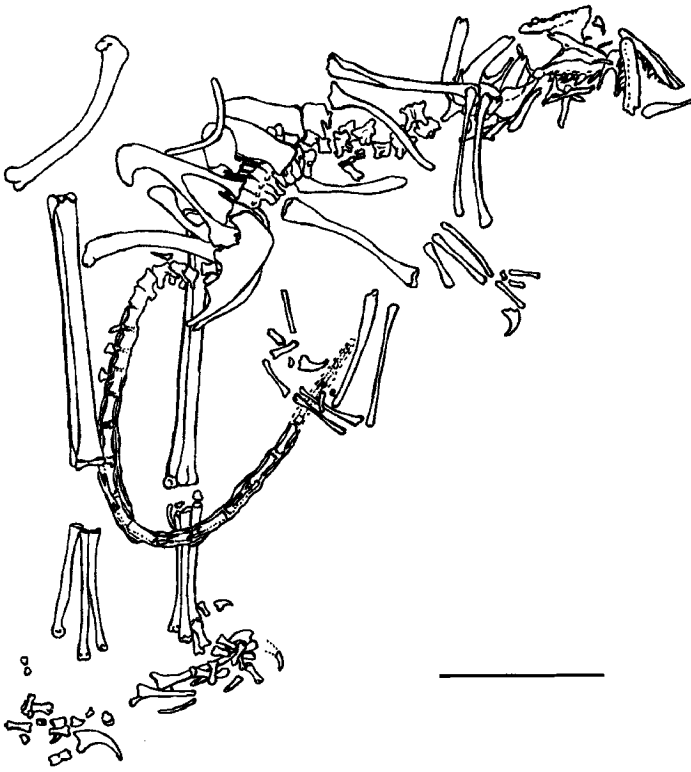


Figure 2. *Bambiraptor feinbergi* n. gen. and n. sp., holotype (FIP 001), bone map of *Bambiraptor feinbergi* showing the skeletal elements that were associated but not articulated. Note the curvature of the tail. Scale bar: 10 cm (new).

difficult to determine if this curve is real or an artifact of preservation.

The pectoral girdle is well preserved three dimensionally and complete (Fig. 3.1) except for the glenoid peduncle (or neck) of the right coracoid. The furcula is craniocaudally compressed, U-shaped, and lacks a hypocleidium (Burnham and Zhou, 1999). The caudal surface of the furcula has a small foramen on each ramus. This furcula (Fig. 3.4–3.5) is reminiscent of those seen in the earliest birds, e.g., *Archaeopteryx* and *Confuciusornis* (Chiappe *et al.*, 1999; Zhou, 1999).

The scapula and coracoid are separate, unfused elements. The suture between them is distinctly shorter than almost all theropods. As a geometric consequence, the acromion is more medially directed, allowing contact with the furcula rather than the coracoid. The glenoid portion of the coracoid forms a distinct neck, anticipating the avian strutlike coracoid. Additionally, the coracoid lacks a foramen and has a prominent biceps (or coracoid) tubercle. The glenoid faces laterally.

Two large, subrectangular sternal plates lie along the posterior edge of the coracoids. Each plate is roughly 18 square centimeters, more than twice the size of the adjacent coracoid. The plates are thin except along the cranial margin, where they are thicker and bear a groove for the insertion of the coracoid. The plates also have articular facets for at least 4 ventral ribs.

The forelimbs are essentially as in *Deinonychus antirrhopus* (Ostrom, 1969b), although they are proportionally longer (Table 2). The wrist contains at least two elements, including a semilunate and a carpal with two saddle-shaped facets and a concave distal face. At least one other small element may also be a carpal. Unfortunately, ambiguities in the bone map leave the original position of these bones unresolved.

The pelvis resembles that of *Deinonychus antirrhopus* and *Velociraptor mongoliensis* (Fig. 4). The postacetabular half of the ilium is compact and tapers posteriorly. The pubis is retroverted, with a heavy, posteriorly projecting pubic boot. The pubic symphyseal suture extends along less than 50 percent of the pubic shaft (Table 2). The distal end of the pubic shaft is deflected posteriorly. The ischium is long (half the length of the pubic shaft) and flat. The obturator process is located near the distal extremity of the ischial shaft. There is a modest proximodorsal process.

The femur has a pronounced curve and lacks a fourth trochanter. The remainder of the hindlimb elements are as those described for *D. antirrhopus* (Ostrom, 1969b, 1976b).

Several features indicate that the holotype is subadult: neural arches unfused to the centra, separate braincase elements (notably the parietals), modest sagittal crest, unfused posterior interdental plates on the dentary and maxilla, large orbits, and skull longer than the femur. Judging from lengths of larger isolated *Bambiraptor* limb elements found at the same locality (Table 1), the holotype has reached 75 percent of its adult size.

Incidentally, the collection of *Bambiraptor* pieces includes almost 40 other bones that are indistinguishable from equivalent elements in the holotype except for the size. These represent at least 2 larger individuals. Among these bones are several articulated, dorsally bent caudal series.

Remarks.—The original preparators removed most of the limb and girdle elements from the matrix, as well as portions of the axial skeleton and skull. When the fossil was turned over to the senior author, only three portions of the skeleton remained in small blocks of rock—most of the skull and anterior cervical series, portions of the anterior torso with the sternals, and the posterior torso with portions of the hips and proximal tail. Articulation within each of these blocks was recorded by photographs, draw-

Table 2. Ratios of lengths of skeletal features; *F*, femur; *H*, humerus; *Pl*, pubic length; *Ps*, pubic symphysis (new).

| | (Tibia:F) | (H+Ulna:F) | (Manus II:F) | (Ps:Pl) |
|-------------------------|-----------|------------|--------------|---------|
| <i>Archaeopteryx</i> | 1.42 | 2.11 | 1.42 | 0.43 |
| <i>Bambiraptor</i> | 1.39 | 1.68 | 1.13 | 0.54 |
| <i>Unenlagia</i> | 1.13 | — | — | 0.63 |
| <i>Sinornithosaurus</i> | — | 1.65 | 1.03 | 0.62 |
| <i>Velociraptor</i> | 1.07 | — | 0.93 | 0.5* |
| <i>Deinonychus</i> | 1.10 | 1.38 | 1.05 | <0.58 |

*estimated.

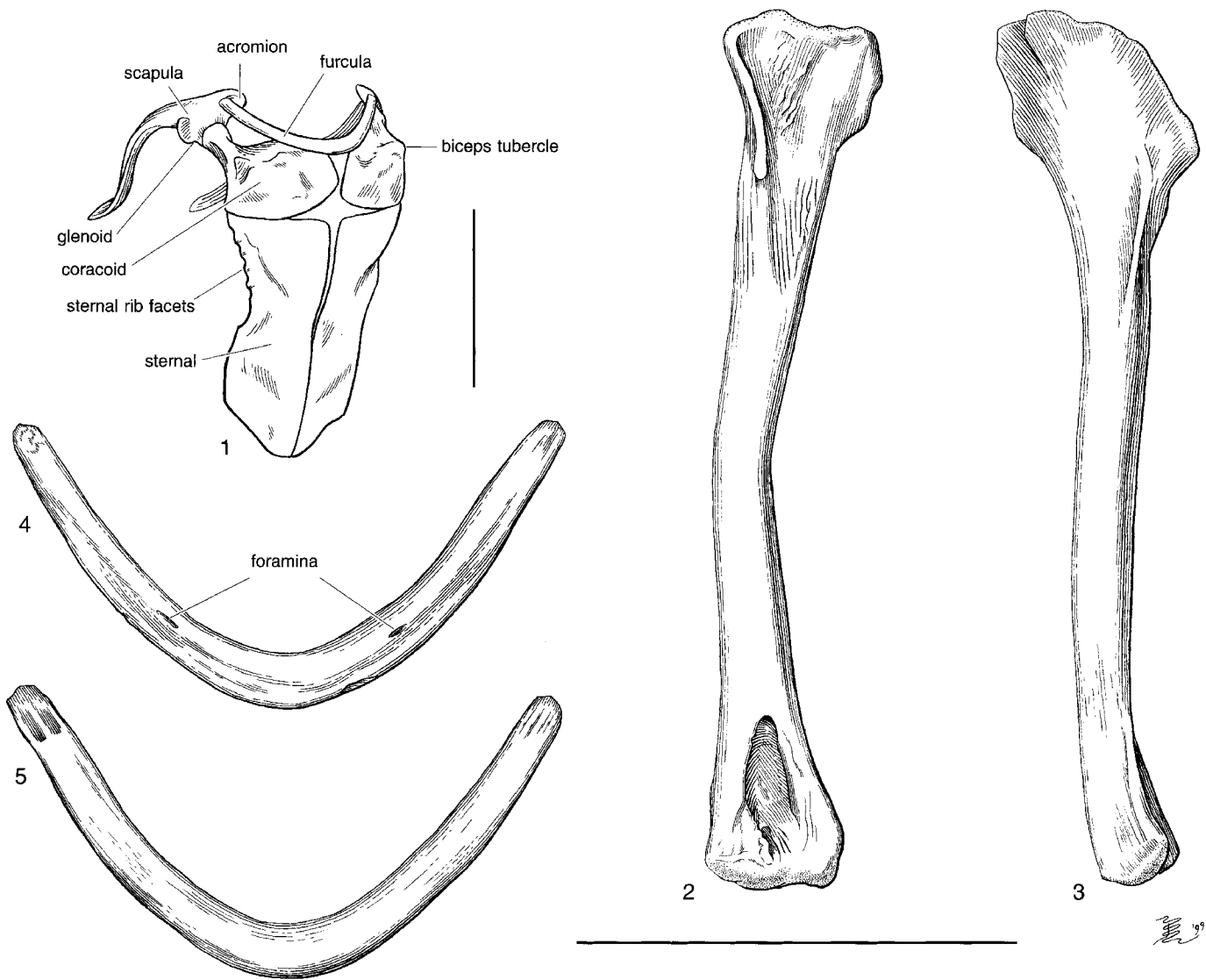


Figure 3. *Bambiraptor feinbergi* n. gen. and n. sp., holotype (FIP 001); 1, pectoral girdle in right oblique anterior view; scale bar: 5 cm; 2, right humerus in external view; 3, right humerus in dorsal view; 4, furcula in cranial view; 5, furcula in caudal view; scale bar: 5 cm (new).

ings, and in some cases, casts. Judging from these blocks, the skeleton was at least partly articulated.

One of the excavators, Robert Linster, skillfully reconstructed a bone map from his family's lab notes. Using this map, it appears that many of the bones shifted position a few centimeters so that much of the skeleton became slightly disarticulated before final burial. Unfortunately, the precise position of some elements, notably the carpals, tarsals, furcula, and anterior presacral vertebrae (including elements of the axis complex) have been lost, so their positions on the bone map are only approximate. Furthermore, almost all rib and gastralia positions are lost and so they have been left off the bone map. At least one bone (a left metatarsal, field number 20) is recorded in two different positions on the bone map and the right femur originally lay beneath the pelvis, rather than the position shown in Figure 3. Finally, as far as we know, the positions of the adult *Bambiraptor* bones are unrecorded.

The individual skull blocks were pieced together before final preparation. Unfortunately, many of the skull elements sustained damage during excavation and initial preparation. Many were split and pieces were missing. The occipital region and skull roof were especially damaged. It is impossible to determine if the two missing skull bones—the right premaxilla and supraoccipital—were present in the outcrop.

The vertebral column suffered damage as well. Some vertebrae were partly disarticulated and crushed by sedimentary compaction. Most presacral vertebrae were removed and further damaged before the senior author received the fossil.

The first 16 caudal vertebrae are articulated and intact. Portions of at least 6 (and probably 8) more exist, all but 1 with fresh breaks indicating that they were originally more complete in the rock. By studying the size of these elements and the size of the zygapophyses, we conclude that

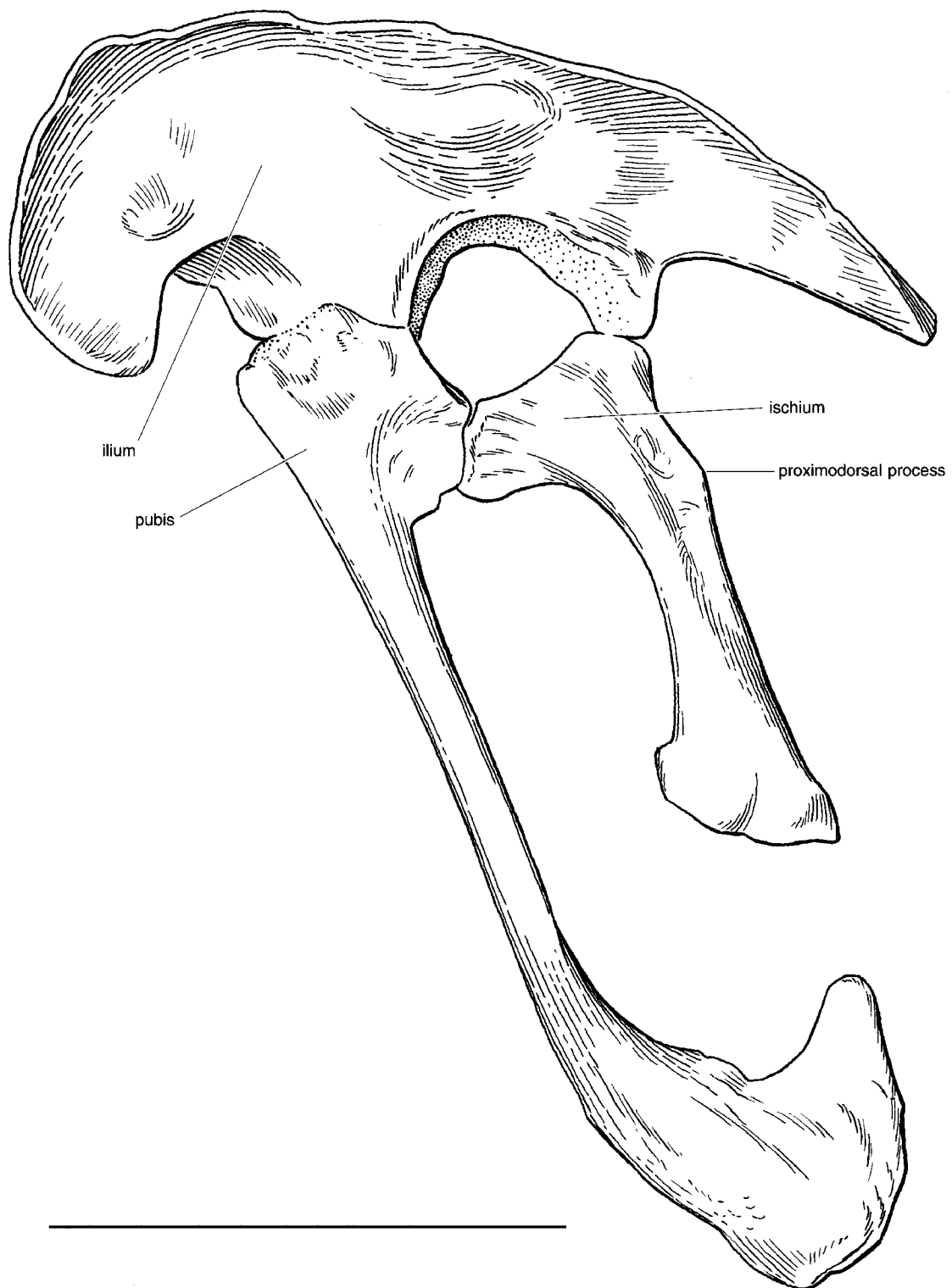


Figure 4. *Bambiraptor feinbergi* n. gen. and n. sp., holotype (FIP 001), pelvic girdle in lateral view. Scale bar: 5 cm (new).

Bambiraptor feinbergi originally had more than 22 caudal vertebrae, some of the additional ones being located between the existing bones and others distal to the preserved end of the series. Unfortunately, we have no way to determine the total number of caudal vertebrae or the length of the complete tail.

Limited information suggests that the holotype may have been a male (P. Larson, personal communication,

February 2000). The first chevron is long, slender, and it reclines against the ventral side of the vertebral column. The distal chevrons are more bladelike and less reclined. This is reminiscent of the condition seen in male crocodylians (Larson, 1995). *Bambiraptor* was possibly a subadult male.

The new species is readily identified as a member of the Dromaeosauridae. It fits the dromaeosaurid gestalt with its

enlarged, retractable second pedal ungual, rod-stiffened tail, and T-shaped lacrimal.

Although nearly contemporaneous with *Sauromitholestes langstoni* (Sues, 1978), the new taxon is distinguished by its relatively long, anteriorly tapering frontal. While this feature may be exaggerated due to the immaturity of the holotype, it is unlikely to be entirely an ontogenetic difference. The frontals in the holotypes of both species are nearly the same length, but the orbital rim of *B. feinbergi* is twice as long as that of *S. langstoni*. There is little basis for further comparison since the holotype of the latter is so incomplete and poorly preserved.

As mentioned above, the limbs and axial skeleton of *B. feinbergi* are similar to those described for *Deinonychus antirrhopus* (Ostrom, 1969b). This may reflect the quality of information available on these two dromaeosaurids, since the forelimbs (and especially the hands) are *proportionally* much longer in the new species. These two species can be distinguished, however, by more teeth in the maxilla (15 vs. 9) and dentary (14 to 15 vs. 13) of *D. antirrhopus*. Additionally, there are numerous differences in the shoulder and pelvic girdles. Most prominent in *D. antirrhopus* are the relatively long scapulocoracoid suture and the less strutlike shape of the coracoid, a less distinct acromion, lack of a glenoid peduncle, higher (and less tapered) postacetabular iliac blade, and the larger size and more proximal position of the obturator process on the ischium.

Bambiraptor feinbergi is different from *Velociraptor mongoliensis* (Osborn, 1924) since the holotype does not have the ventrally depressed nasals or the resulting bulbous snout (Barsbold and Osmólska, 1999). *V. mongoliensis* has several additional maxillary teeth. The furcula is V-shaped with a rounded cross section as well as a small hypocleidium, different from the more *Archaeopteryx*-like condition of *Bambiraptor* (Norell, Mackovicky, and Clark, 1997). The pectoral girdles in the described skeletons of *V. mongoliensis* (Norell and Makovicky, 1999) are imperfect, but they appear to have a longer scapulocoracoid suture (fused in the available specimens) and a smaller acromion. The postacetabular blade of the ilium is higher (as in *Deinonychus*) and less tapered (Norell and Makovicky, 1997). Finally, the femur of *Velociraptor mongoliensis* is reported to have a fourth trochanter, a feature absent in *Bambiraptor* and other dromaeosaurids. Additionally the femur of *V. mongoliensis* is curved in lateral view similar to the holotype of *B. feinbergi*, but in posterior view it is straight. In *B. feinbergi*, the femur is also curved in posterior view (Figure 5).

Two other Mongolian theropods have been described as dromaeosaurids, *Adasaurus mongoliensis* Barsbold (1983) and *Hulsanpes perlei* Osmólska (1982). They may very well belong within the Dromaeosauridae, but each was described from a single fragmentary skeleton. *Adasaurus* was illustrated (Barsbold, 1983, fig. 24) with a pubis that is retroverted, but the distal end is not bent posteriorly and the ischium has a midshaft obturator process. The anterodorsal

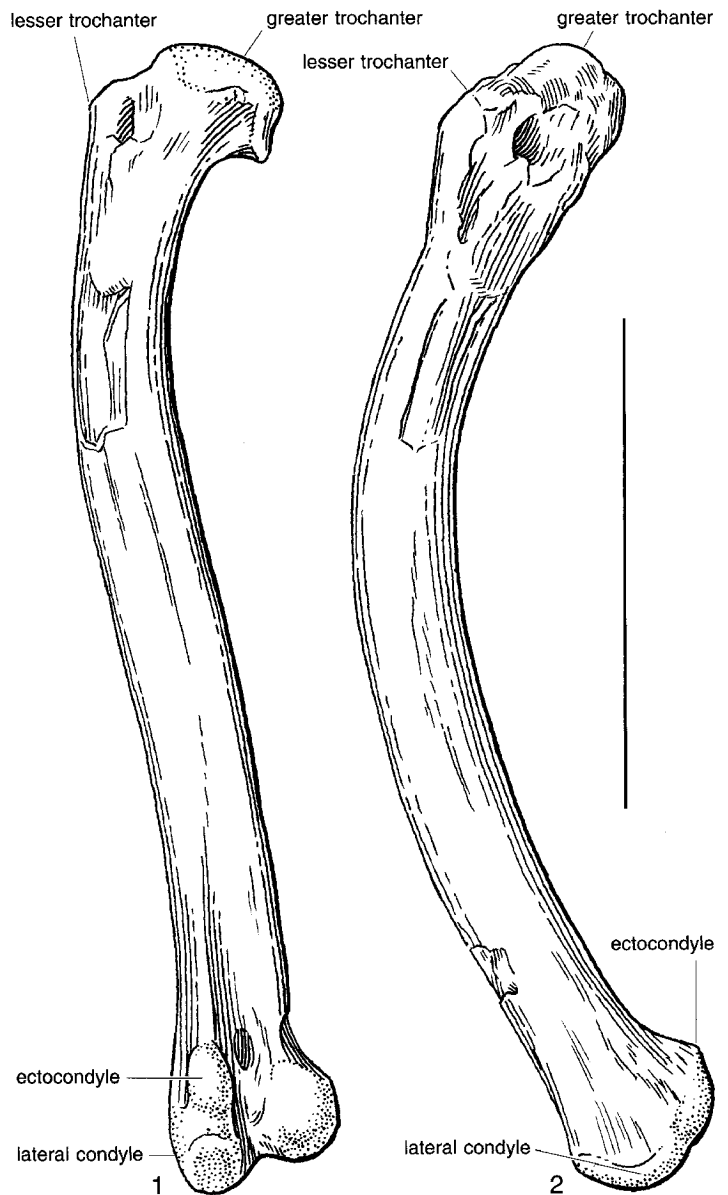


Figure 5. *Bambiraptor feinbergi* n. gen. and n. sp., holotype (FIP 001); 1, left femur in lateral view; 2, left femur in posterior view; scale bar: 5 cm (new).

projection on the ilium is unlike the holotype of *B. feinbergi*. *Hulsanpes* is too incomplete to allow meaningful comparison with other dromaeosaurids (Barsbold and Osmólska, 1999, p. 215).

Achillobator giganticus (Perle, Norell, and Clark, 1999) is described from a single, fragmentary skeleton. The bones present a mix of features, with only a few found in better-established dromaeosaurids. For example, two pedal unguals could come from a dromaeosaurid-type second pedal digit. On the other hand, the ilium, ischium, maxilla, and caudal vertebrae share no unique features with the Dromaeosauridae. It may well be that this taxon is based upon a mixture of bones from two or more actual species. In any event, the femur of *A. giganticus* is relatively straight, there is an anterior projection on the pubic boot, and the ischium has an obturator process that is far larger

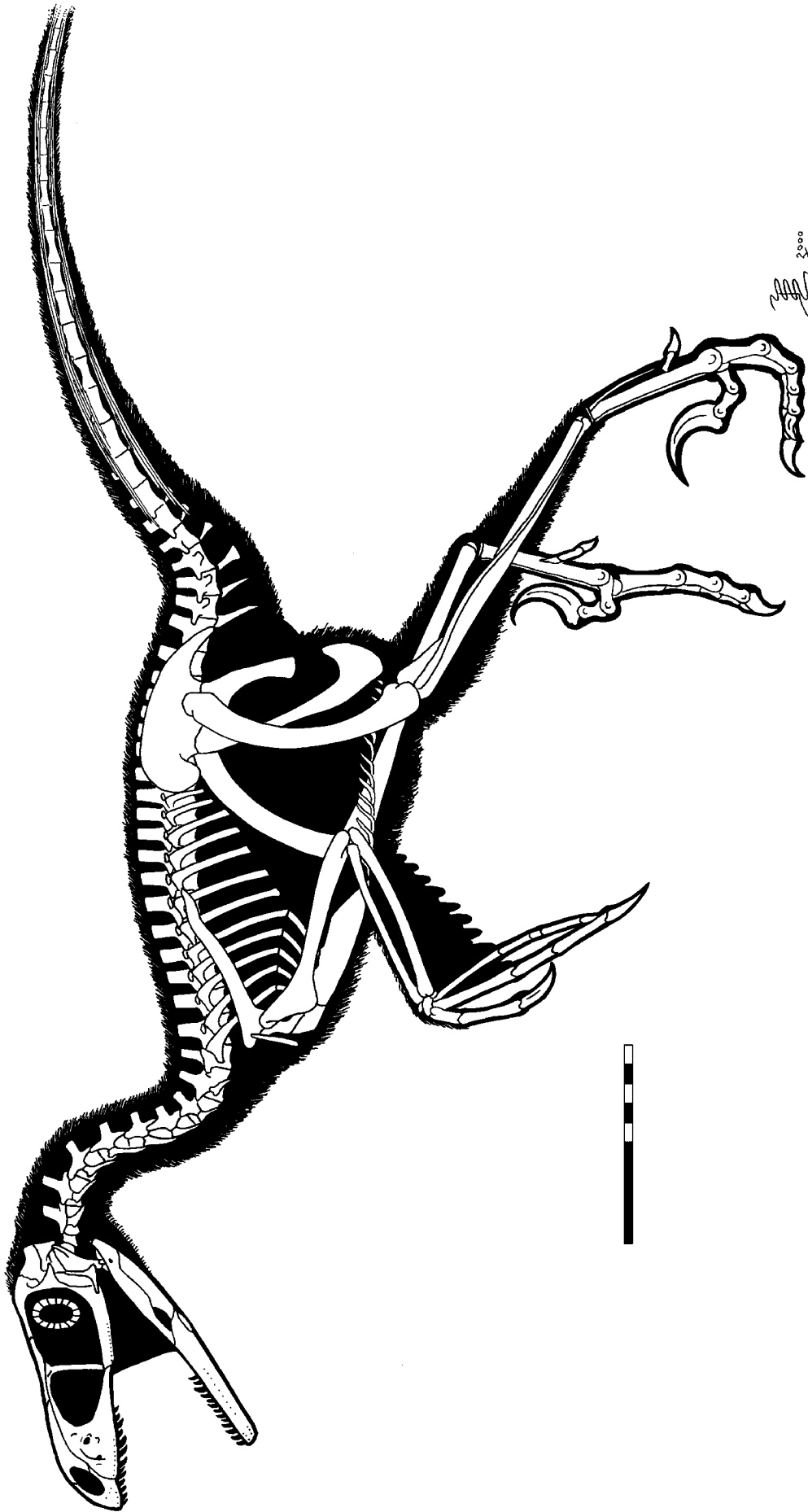


Figure 6. *Bambiraptor feinbergi* n. gen. and n. sp., holotype (FIP 001), reconstruction showing conceptual integumentary structures; scale bar: 10 cm (new).

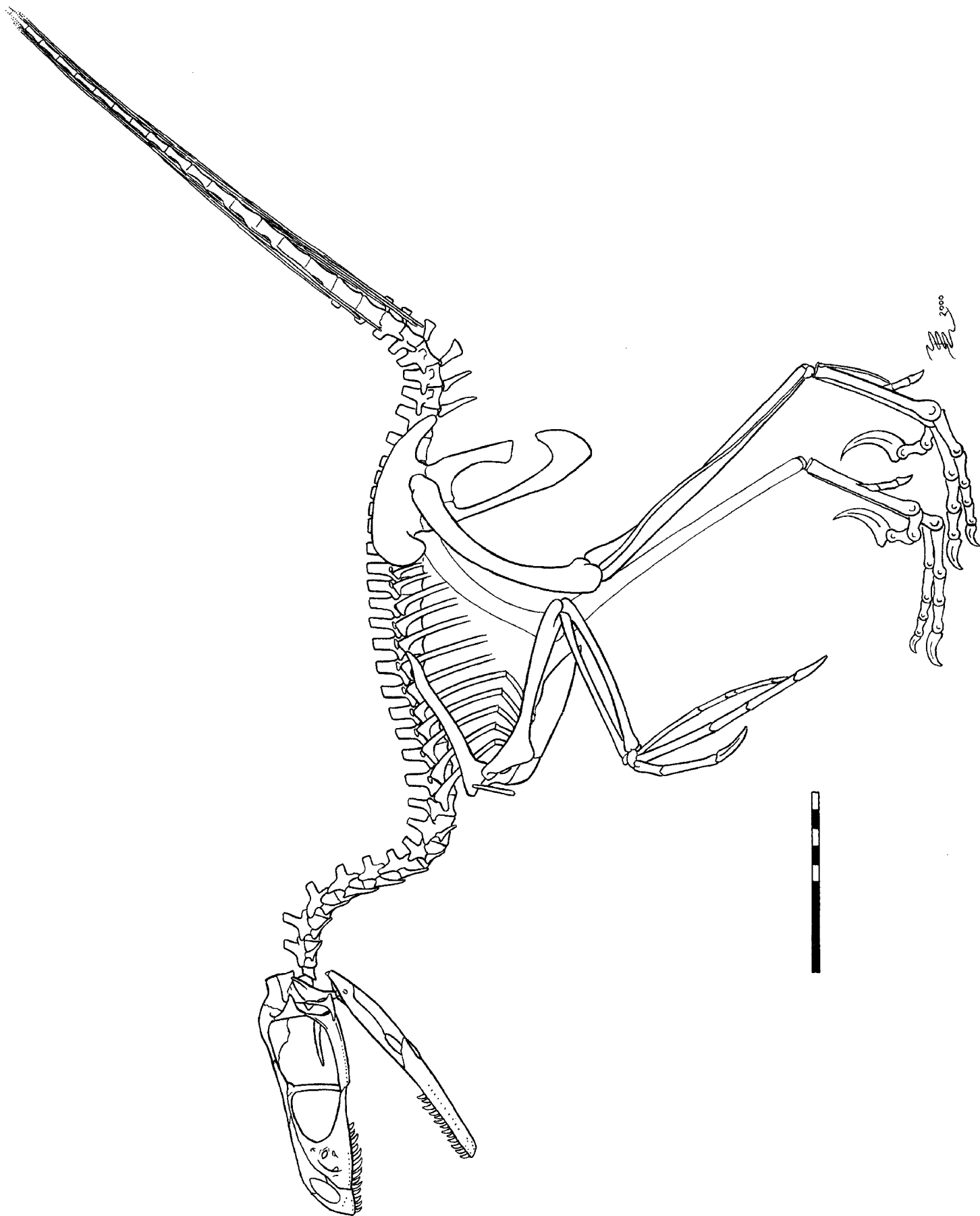


Figure 7. Skeletal reconstruction of the holotype, *Bambiraptor feinbergi* n. gen. and n. sp. (FIP 001); scale bar: 10 cm (new).

and more proximal than analogous features in *B. feinbergi*. Even discounting the size difference, *A. giganticus* cannot be confused with the species described herein.

Comparisons of *Dromaeosaurus albertensis* (Matthew and Brown, 1922; Colbert and Russell, 1969; Currie, 1995) with *B. feinbergi* show the jugal in *D. albertensis* is more robust and lacks a row of ventral foraminae. Furthermore, the bar formed from the descending process of the squamosal and ascending process of the quadratojugal is more robust, straighter, and more nearly vertical. Perhaps most striking are differences in the frontals and tooth crowns. The frontals of *D. albertensis* are relatively short, and the teeth have carinae that follow a nonplanar path along the length of the crown.

The Early Cretaceous *Utahraptor ostrommayi* (Kirkland, Burge, and Gaston, 1993) is described from a small set of scattered theropod bones. We see little reason to believe that these bones come from a single species, let alone a dromaeosaurid. Pending a thorough analysis and redescription of this material, we suggest that *B. feinbergi* can be distinguished from *U. ostrommayi* in its smaller size and the deeper popliteal fossa on its distal femur.

Bambiraptor feinbergi (Fig. 6–7) does share many features with the recently described *Sinornithosaurus milleni* (Xu, Wang, and Wu, 1999). Most noteworthy are the furcula and sternal plates. This Early Cretaceous form, however, lacks a pubic boot and has a long obturator process. Its skull is longer than its femur, and the arms are proportionally shorter, although these may be ontogenetically influenced features. Contrary to the published description, the coracoid and scapula are similar to *Deinonychus* and quite unlike those of *Bambiraptor* described above.

Finally, we compare *Bambiraptor* with *Rahonavis ostromi* (Forster *et al.*, 1998a, 1998b) and *Unenlagia comahuensis* (Novas and Puerta (1997)). Even though neither is a dromaeosaurid, both share features with *Bambiraptor feinbergi*. All three have pectoral and pelvic features otherwise reported only in birds (see Discussion below). Both can be distinguished from *B. feinbergi* by their lack of a ventrally flared preacetabular blade on the ilium. Furthermore, the preacetabular portion of *R. ostromi* is not flared, and the pubic boot projects posteriorly less than twice the thickness of the pubic shaft. Our new species can be differentiated from *U. comahuensis* by pubic shafts, which are joined along more than 50 percent of their length and have posterior dorsals with relatively small pleurocoels.

Etymology.—*Bambi*: from the now widely used nickname for the holotype, originally coined by the Linster family; *raptor*: robber; *Feinberg*: honoring Michael and Ann Feinberg, who recognized the significance of this fossil and have generously encouraged our research and the preservation of this fossil for science.

Holotype.—FIP 001, on exhibit at the Florida Institute of Paleontology, Graves Museum of Archaeology and Natural History, Dania Beach, Florida; casts are available at the University of Kansas Natural History Museum and

Biodiversity Research Center, Lawrence, Kansas (KUPV 129737) and at the Science Museum of Minnesota, St. Paul, Minnesota (SMM P99.3.1c).

Additional material.—FIP 002–036. Elements from the adults (Table 1) discovered within a few meters of the holotype. These are available in the collections of the Florida Institute of Paleontology at the Graves Museum of Archaeology and Natural History, Dania Beach, Florida.

Stratigraphy.—The holotype came from the Two Medicine Formation approximately two-thirds of the way above the base of the unit, Upper Cretaceous, Campanian (Lorenz, 1981; Lorenz and Gavin, 1984).

Locality.—The site is about 19 km west of the city of Bynum, Teton County, Montana, USA.

The holotype occurred within a 60-cm-thick siltstone layer associated with thousands of bones and a few partial skeletons of hadrosaurs, presumably *Maiasaura peeblesorum* (Horner and Makela, 1979). Also associated were at least three specimens of tyrannosaurids, two types of eggshell fragments, and carbonized wood scraps. Brandvold, Brandvold, and Sweeney (1996) interpreted the site as a low-velocity channel fill within the Two Medicine fluvial complex.

DISCUSSION

The main purpose of this contribution aside from systematics and a preliminary description is to identify some of the more obvious avian features of *Bambiraptor feinbergi*. This subject has become relevant since the dinosaurian origin of birds was re-examined by Ostrom (1973).

Furcula.—Many theropods have a furcula (Chure and Madsen, 1996), one of the traditional hallmarks of a bird. Among these wishbone-bearing animals, *Bambiraptor* is unusual in having a furcula that has thick, curved arms, and a rounded interior angle, and lacks a hypocleidium. The authors are aware of only one dinosaur—*Sinornithosaurus*—and a few early birds—*Archaeopteryx* and *Confuciusornis*—that have the same type of wishbone. Other theropods have a furcula with straight arms and a less rounded interior angle, while most other birds have more slender furcular arms and a large, platelike hypocleidium.

Large ossified sternum.—In general, birds have a large sternum produced from two fused ossifications. *Bambiraptor* has two large sternal ossifications although they are not fused. Several other maniraptorans have similar ossified plates including *Velociraptor*, *Sinornithosaurus*, and *Oviraptor* (Barsbold, 1983).

Laterally facing glenoid.—As discussed by Novas and Puerta (1997) in their description of *Unenlagia comahuensis*, a laterally oriented glenoid is a preadaptation for avian flight. In all dromaeosaurids, the glenoid faces laterally to some degree. In *Bambiraptor* the glenoid faces more laterally than in any other theropod.

Elongate coracoid.—Perhaps the most notable feature of *Bambiraptor* is the shape of its coracoid. Loss of the dorsal edge of the coracoid (and resulting loss of the coracoid



Figure 8. Life restoration of *Bambiraptor feinbergi* n. gen. and n. sp. (FIP 001; new).

foramen) shortens the suture with the scapula. The glenoid portion of the coracoid becomes a slender neck. Most modern birds have elongated the coracoid in this direction as well, and all have an extremely long coracoid neck.

Acromion.—Reduction of the dorsal edge of the coracoid, as discussed above, produces a free acromion. In birds, such a free acromion contributes to the construction of the triosseal canal. *Bambiraptor* has a prominent free acromion, as do *Unenlagia*, *Rahonavis*, and modern birds. It is curious that some early birds lack a pronounced free acromion (*Confuciusornis sanctus*, as described by Zhou, 1999), while others have such a structure (e.g., *Ambiortus dementjevi* and *Otogornis genghisi* as redescribed by Kurochkin, 1999).

Biceps tubercle.—*Bambiraptor* has a large biceps tubercle, as do many other smaller theropods. One example among many is *Gallimimus bullatus* Osmólska, Roniewicz, and Barsbold (1972). In birds, an enlarged version of the biceps tubercle is termed an acrocoracoid and forms part of the triosseal canal (Ostrom, 1976a).

Elongated arms and manus.—*Bambiraptor* has proportionally longer arms and hands than any other described theropod, approaching forelimb proportions of *Archaeopteryx* and other early birds.

Large semilunate carpal.—This bone allows the development of a laterally folding wrist. In birds, except *Archaeopteryx*, the semilunate is fused on the proximal ends of the middle metacarpal. The same condition is found in most maniraptoran dinosaurs. Recently, a small semilunate has also been found in an allosaurid (Chure, in press).

Proximodorsal process on the ischium.—Among dinosaurs, this feature is reported only in *Rahonavis*, *Unenlagia*, and *Bambiraptor*. It is also seen in such early birds as *Archaeopteryx*, *Confuciusornis*, and *Cathayornis* (anterior anterodorsal process of Zhou, 1999).

Retroverted pubis.—Widely discussed in the literature and present in all dromaeosaurs including *Bambiraptor*. This condition is easily observed in all modern birds, although the pubic shafts have separated.

Splintlike fibula.—In birds, the fibular shaft is thin and tapers to a point before it reaches the calcaneum. In all dromaeosaurids including *Bambiraptor*, the fibular shaft is thin although it does extend to the calcaneum.

Pneumatic cervical and dorsal vertebrae.—Pulmonary air sacs are an integral part of the unique avian respiratory system. One set of air sacs grows into the vertebrae, entering through pneumatic fossae (pleurocoels) on either side of each centrum. Crocodylians have a modest version of the axial air sac (Britt, 1993) along the most anterior portion of their vertebral column. A more extensive system apparently existed in theropods, associated with pneumatic fossae in the cervical and anterior dorsal centra (see O'Connor, 1999 for a partially contrary claim). The holotype of *B. feinbergi* has large pleurocoels along the entire length of the cervical and dorsal series. They are similar to those found in other dromaeosaurids and birds.

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