1. Discovery of MPC-D 100/127 and 100/128

MPC-D 100/127 and 100/128 were discovered in the Nemegt Formation by members of the Korea-Mongolia International Dinosaur Expedition (KID). The latter was found at Altan Uul IV (N43°36.091', E100°27.066') in 2006, but had been badly damaged by poachers. When MPC-D 100/127 was found at Bugiin Tsav (N43°54.025', E99°58.359') in 2009, many isolated bones and broken blocks containing bones were exposed in a large excavation. This specimen had been excavated by poachers an unknown number of years earlier (probably after 2002, based on money found in the quarry); damaged surfaces of the axis, metacarpals and an isolated pedal phalanx showed that they had collected the skull, hands and feet. In 2011, the sixth author informed the first, third, and fourth authors of the existence of a skull, a left hand and the feet of *Deinocheirus* in a private collection in Europe. The specimen had been collected in Mongolia and sold to an unknown buyer in Japan. It was subsequently sold to another party in Germany and made available to the sixth author. On May 1st, 2014, these poached materials were repatriated to Mongolia. It is clear that they belong to MPC-D 100/127 because the isolated right pedal phalanx II-2 (and associated matrix) that was collected by the Korea-Mongolia International Dinosaur Expedition fits perfectly into an impression in the matrix attached to phalanx II-1 of the poached specimen (Extended Data Fig. 5a-b). The same white colour of the bone and the gray matrix, the fact that they come from an individual of the same size, and the absence of any overlapping elements are further confirmation that they come from the same skeleton.

Newly recognized autapomorphies from MPC-D 100/127 -- including a dome-like tubercle on the anterior edge and a pronounced vertical hook on the posterior edge of the femoral head -- led to the recognition of another *Deinocheirus* (MPC-D 100/128) in the 2006 KID collection. These new specimens suggest that *Deinocheirus* was widely distributed in the Nemegt Formation (Bugiin Tsav is 50 km from the holotype locality at Altan Uul III,

N43°33.987', E100°28.959').

2. Additional description of *Deinocheirus mirificus*

Theropoda Marsh, 1881

Ornithomimosauria Barsbold, 1983

Deinocheiridae Osmólska and Roniewicz, 1970

(=Garudimimidae Barsbold, 1981)

Deinocheiridae = *Deinocheirus mirificus* and all taxa sharing a more recent common ancestor with it than with *Ornithomimus velox*.

Ornithomimidae = *Ornithomimus velox* and all taxa sharing a more recent common ancestor with it than with *Deinocheirus mirificus*.

Ornithomimosauria = *Ornithomimus velox* and all taxa sharing a more recent common ancestor with it than with *Allosaurus fragilis*, *Tyrannosaurus rex*, *Compsognathus longipes*, *Alvarezsaurus calvoi*, *Therizinosaurus cheloniformis*, *Deinonychus antirrhopus*, *Troodon formosus*, and *Passer domesticus*.

Deinocheirus mirificus Osmólska and Roniewicz, 1970

Emended diagnosis. Gigantic ornithomimosaur (approximate body length 11 m) characterized by the following autapomorphies: snout seven times longer than orbit; external nares oriented dorsally; anterior part of premaxilla transversely expanded and spatulate (wider than skull roof); wide sulcus from the anterolateral corner of the external naris extends

to the posterolateral corner of the ventral margin of the premaxilla; antorbital fossa sharply demarcated by keel-like horizontal ridge on the lateral side of maxilla; jugal (antorbital) ramus of lacrimal strongly sloping anteroventrally; maxillary palatal shelf extends ventromedially; extensive ventral flange below infratemporal fenestra formed by jugal and quadratojugal; large quadratic fenestra, about 30% the height of the quadrate; posterolaterally-facing supratemporal fenestra; reduced infratemporal fenestra less than half the height of the orbit; vomerine process of palatine longer than antorbital fenestra; deep mandible (maximum height of mandible/quadrate height = 1.08); pneumatic, tall, anterodorsally oriented posterior dorsal neural spines (maximum 8.5 times taller than centrum height) with anteroposteriorly expanded distal ends, and basal webbing; pronounced hypapophyses and no ventral keels in anterior dorsal vertebrae; anterolaterally projecting parapophyses of posterior dorsal vertebrae; pneumatopores in all dorsal vertebrae; fused 2nd to 6th sacral neural spines form a pneumatic midline plate of bone that extends dorsally up to 170% of the height of the ilium; keeled ventral surfaces of posterior sacral centra; pygostyle formed of at least two distal caudals; U-shaped furcula with a hypocleidium; fused scapulocoracoid; subquadrangular coracoid with ventrally extended blade and unexpanded subglenoid fossa; manual digit I has larger ungual than other manual digits; flexor tubercle of ungual 1/3 taller than articular facet height; preacetabular ala of ilium significantly higher but shorter than postacetabular ala; well-developed and ventrally rounded iliotibialis flange; steep anterodorsal margin of the ilium; posterodorsally projecting posterior iliac blade with a concave dorsal margin; anteroventrally inclined brevis shelf; iliac blades well-separated above sacrum; long pubic boot (ratio more than 0.44 to length of pubic shaft) is triangular in distal view; completely enclosed pubic obturator foramen; femur longer than tibia in mature animals; femoral head has pronounced vertical hook on posterior edge and dome-like tubercle on anterior edge; femoral head directed anteromedially to femur shaft; long fibular crest

extends to midshaft of tibia; posterior portion of proximal fibula mediolaterally wider than anterior portion in proximal view; astragalus and calcaneum fused to each other and to tibia in late ontogeny; ascending process of astragalus slightly offset from astragalar body; wide, blunt tips of pedal unguals.

Additional Description. The skull of the new *Deinocheirus* is complete, but has been crushed lateromedially, and rolled so that the right side has been pushed dorsal to the left side. The total skull length of MPC-D 100/127 is 1060 mm (right side; 1064 on left) from the tip of the snout to the ventrolateral tip of the paroccipital process. The basal skull length (premaxilla to occipital condyle) is 1024 mm. In comparison with occipital condyle width or femur length, this is comparable with tyrannosaurid skull lengths (Extended Data Fig. 2a; Extended Data Table 1) rather than ornithomimosaurs. However, the *Deinocheirus* skull is narrower and lower than the same dimensions in a tyrannosaurid of the same body size. At its widest point behind the orbits, the skull roof is only 230 mm across. The height and width measurements fall within the expectations of these dimensions of other ornithomimosaurs if extrapolated to the large size of the *Deinocheirus* specimen (Extended Data Fig. 2b). The cranial bones are all extremely thin considering the overall size of the skull, and most of the large expanses are formed by thin plates of bone that are less than 6 mm thick. Consequently, when these thin sheets of bone are squashed into a single plane, it is often difficult to discern sutures, edges and even openings. The snout of *Deinocheirus* is more than seven times longer than the orbit. The elongate snout of *Deinocheirus* could be considered the result of a positive allometric trend of the preorbital length that is seen in an ontogenetic series of *Gallimimus*[5]. However, a bivariate comparison of preorbital length versus femoral length in ornithomimids shows that the preorbital length of *Deinocheirus* falls well above the trajectory of the ornithomimid growth series, and falls instead on the growth trajectory of tyrannosaurids and other theropods (Extended Data Fig. 2c).

The external nares are teardrop-shaped (tapering posteriorly) and open dorsally, whereas they are oriented laterally in other known ornithomimosaurs. The antorbital fossa and fenestra are long and low, the orbit is large (116 mm anteroposteriorly at the level of the lacrimal duct), the supratemporal fenestra is short and narrow (approximately 5 x 3 cm), and the infratemporal fenestra is short and low (approximately 3 x 5 cm).

The anterior parts of the paired premaxillae expand transversely to a maximum width of 25 cm (which is broader than the skull roof), and are spatulate in dorsal view. A centimeter-wide sulcus extends from the anterolateral corner of the external naris to the anterolateral corner of the ventral margin of the premaxilla. The nasal process is particularly short, forming about one third of the internarial bar. As is usual in ornithomimosaurs, the elongate posterodorsal maxillary process excludes the maxilla from the ventral margin of the external naris; however, it ends in front of the antorbital fossa. The ventral surfaces of the premaxillae form the anterior part of the secondary palate and the floors of the external nares. A large rounded incisive foramen perforates the anterior margin of the external naris, close to the internarial bar.

The maxilla is also elongate but low. A keel-like horizontal ridge forms the ventral margin of the antorbital fossa on the lateral side of the maxilla. Below the horizontal keel, the maxillary palatal shelf is not horizontal as in other ornithomimosaurs, but extends obliquely medioventrally. This portion of the hard palate is consequently strongly convex. The dorsal process of the maxilla reaches about the mid-length of the antorbital fossa; it does not contact the anterior process of the lacrimal but is close enough to suggest that it did in the living animal. Both the antorbital fossa and fenestra are anteroposteriorly elongate (the respective lengths are 442 and 256 mm). The 12 mm long maxillary fenestra is small and rounded. The promaxillary fenestra cannot be seen. Overall, the maxilla is very thin in spite of its length, with most of the sheetlike external surface being no more than 6 mm thick.

In spite of the elongation of the snout from the condition seen in other ornithomimosaurs, the nasal is probably excluded from the antorbital fossa by the maxilla and the lacrimal[3]. Posteriorly the nasals are separated from each other by the anteromedial processes of the frontals. There is a distinct gap at the junction of the nasal, lacrimal and prefrontal that is 33 mm long and 10 mm wide; presumably this was the result of post-mortem separation of the bones.

As it is usual in ornithomimosaurs, the lacrimal is roughly an inverted L-shape. The antorbital bar of the lacrimal slopes anteroventrally. The anteriorly tapering anterior process extends for at least 180 mm from the posterodorsal corner of the antorbital fenestra, and probably met the maxilla to exclude the nasal from the margin of the antorbital fossa. A short and narrow posterior process covers the dorsal side of the prefrontal and forms part of the rugose anterodorsal rim of the orbit. The ventral process (antorbital bar) is shorter than the anterior process, and is robust and triangular in lateral view; its concave posterior surface is pierced in the upper region by a small lacrimal foramen. As the antorbital bar tapers ventrally in lateral view, it becomes lateromedially wider for its contacts with the jugal externally and maxilla internally.

The prefrontal inserts between the frontal, nasal and the lacrimal, but is not widely exposed in dorsal view. As in *Gallimimus*[5] and other ornithomimids, in dorsal view it clasps a posterodorsal process of the lacrimal, and forms most of the anterior region of the dorsal orbital rim. Its elongate ventral process forms two-thirds of the medial edge of the antorbital bar.

The paired frontals are 105 mm wide across at the narrowest point between the dorsal margins of the orbits, and expand to almost double that measurement where they are in contact with the two postorbitals. Their dorsal surface is slightly concave, but a gentle doming on the posteromedial part marks the emplacement of the cerebrum. Long, tapering

anteromedial processes insert between the paired nasals. The posterolateral portion of each frontal meets the anterodorsal ramus of the postorbital to separate the orbit from the upper temporal fenestra. The posterolateral surface of the frontal forms a relatively deep, concave surface in the anteromedial region of the supratemporal fenestra. The adductor musculature would have originated in this concavity and on the adjacent surfaces of the postorbital, laterosphenoid and parietal.

The nuchal crest of the unfused parietals was destroyed by erosion but was evidently rather weakly developed, as in other ornithomimosaurs. At the narrowest point between the supratemporal fenestrae, the paired bones are 96 mm across. Posterolaterally, each parietal expands laterally and curves posteroventrally onto the occipital surface.

The postorbital is a stout pillar-like bone that forms the posterior border of the orbit, the anterolateral boundary of the supratemporal fenestra, and the anterior margin of the infratemporal fenestra. A short intertemporal process meets the squamosal posteriorly. Ventrally, the postorbital forms an extended oblique sutural surface for the jugal. Its dorsal end is highly modified; it is formed by an anteroposteriorly flattened and mediolaterally extended anterodorsal ramus, which contacts the frontal and laterosphenoid. There is a mediolaterally flattened posterior ramus, which meets the anterior process of the squamosal. Between these rami, the dorsal part of the postorbital forms a wide posterolaterally-facing basin, in continuity with the depressed posterior side of the frontal, for the adductor musculature (*M. adductor mandibulae externus superficialis*).

The jugal, quadratojugal, and quadrate are closely sutured together. The suborbital (anterior) process of the jugal is about 120 mm long, forms the ventral margin of the orbit, and contacts the posterior end of the jugal process of the maxilla and the antorbital process of the lacrimal. The postorbital process is stout (56 mm anteroposteriorly) and short (70 mm high), terminating well below the middle of the orbit as in other ornithomimosaurs. Together

with the quadratojugal, the jugal forms an extensive ventral plate that extends well below the ventral margin of the maxilla. A similar pronounced ventral lobe is also characteristic for jugals of Hadrosauridae. This lobe possibly served as the site of origin of the *M. levator anguli oris*, the fibers of which reached anteroventrally to the dorsal edge of the mandible[29]. If such superficial fibers existed, their attachment to the jugal lobe must have been by a tendinous sheet, because no scars can be observed. Therefore, the huge size of the mandible might explain the development of the jugal-quadratojugal lobe in *Deinocheirus*. However, it should be noted that the extensive contact between the jugal and quadratojugal below the orbital margin is also characteristic of the much smaller *Gallimimus*. The contact with the quadratojugal is more than 125 mm high, and together the two bones form the anteroposteriorly short (22 mm) ventral border of the infratemporal fenestra. The quadratojugal is tall and narrow; it forms the posterior margin of the infratemporal fenestra, meeting the squamosal dorsally. It extends ventrally to the edge of the cranium where the quadrate articulates with the surangular/articular glenoid.

The relatively small squamosal is a triradiate bone that forms the lateral and posterior margins of the supratemporal fenestra and with the quadratojugal forms the posterior margin of the infratemporal fenestra. The short anterior process covers the dorsoposterior ramus of the postorbital and contacts the posterolateral ramus of the parietal. The medial ramus is in close contact with the posterior surface of the parietal.

The quadrate is dorsoventrally elongate with a gently concave posterior surface in lateral view. Regardless of whether it is compared to the basal skull length or femoral length (Extended Data Fig. 2b), it is relatively short as in other ornithomimosaurs. Quadrate height clearly shows that the skull is lower than the skulls of tyrannosaurids and other theropods, and gives the illusion that the skull is elongate (whereas in fact it has a normal theropod skull length but is lower and narrower). Dorsally, the anterior border of the quadrate is exposed on

the left side because of the anterior displacement of the ventral ramus of squamosal. The quadrate intimately contacts the quadratojugal for most of its height. CT data suggests that the ventral articulation is divided into two subequal condyles separated by a deep sulcus. As is usual in ornithomimosaurs, there is a small knob-like accessory condyle anterolateral to the lateral condyle.

The paroccipital processes are broken distally, but extend moderately lateroventrally, reaching the ventral level of the foramen magnum. The width across the paroccipital processes (from posteroventral tip of one to the other) would have been approximately 17 cm if complete. The articular surface of the globular occipital condyle (diameter 52.9 mm) is slightly inclined ventrally. The basal tubera of the basioccipital extend 39 mm below the occipital condyle and together are 66 mm across. The basipterygoid processes are oriented ventrally and slightly anteriorly. The parasphenoid bulla of the basisphenoid-parasphenoid complex can be seen through the orbit, and it appears much less bulbous than in ornithomimosaurs. However, it is possible that this character reflects postmortem transverse compression of the skull. Posteroventral to the pituitary fossa, the incompletely preserved ala basisphenoidalis appears particularly well developed, and the CT-scans suggest they bound a deep basisphenoidal recess.

Twelve articulated scleral plates are preserved on the right side of the skull (Extended Data Fig. 1). The diameter of the ring is 52 mm inside and 84 mm outside. The internal/external diameter ratio of the sclerotic ring (0.62) is therefore similar to those of *Garudimimus* (0.65) and *Ornithomimus* (0.63). However, the sclerotic ring is proportionally smaller in *Deinocheirus* (orbital length/external diameter of the ring = 1.93) than in *Garudimimus* (1.50) and *Ornithomimus* (1.35), suggesting that the eyeball may not have occupied as much of the orbit as the smaller genera. *Garudimimus* and *Ornithomimus* respectively were regarded as mesotopic and mesotopic to scototopic dinosaurs[6].

The lower jaw is strikingly massive in lateral view in comparison with the low height (132 mm in the antorbital region) of the skull. The left mandible is 975 mm long and has a maximum depth (through the surangular and dentary) of 200 mm. The internal and external surfaces of the mandible, however, have been crushed into a single plane (the dentary is no more than 4mm thick, whereas the splenial that lines the internal surface of the mandible is even thinner than that) and in the living animal the jaws may have been more circular -- wider but shallower in depth. In lateral view, the tip of the jaw turns slightly ventrally to match the anteroventrally sloped buccal edge of the premaxilla, and maxilla. The anterior portion of the paired dentaries is spatulate in ventral view, forming a 16 cm wide, duck-like bill. The dentary extends posteriorly for 795 mm, and tapers to point that ends at the same level as the tapering posterior extension of the splenial. The external mandibular fenestra looks very long (467 mm) on the left side, possibly because the dentary and surangular separated when the jaw was crushed. It appears more normal (222 mm anteroposteriorly) on the right side (Extended Data Fig. 1). The articular forms a wide glenoid for the quadrate condyles and, together with the surangular, a short retroarticular process that curves posterodorsally as in *Garudimimus* and ornithomimids[3]. As it is usual in ornithomimosaurs, the surangular forms a small flange that extends anterolaterally from the glenoid. The bone extends anteriorly for 540 mm, ending in an anterodorsal process that sits in a notch in the dorsolateral surface of the dentary (as in most theropods). The angular forms the posteroventral margin of the mandible, and extends 414 mm forward. Its tapering front end is sandwiched between the dentary and splenial for a distance of 205 mm. The prearticular can be seen through the external mandibular fenestra on both sides, and appears to have normal theropod contours as it forms the anteroventral margins of the internal mandibular fenestra.

Ten cervical vertebrae (including the atlas-axis complex) are low and long, and are comparable in shape with those of most ornithomimosaurs. The atlantal intercentrum is

preserved with a right neurapophysis, which has an anterior semicircular concave facet (diameter is 52 mm) for the occipital condyle. The postzygagopophyses do not extend beyond the posterior margin of the centrum in the anterior cervicals, and their centra have parallelogram outlines in lateral view. After the seventh cervical, however, the centra become shorter and trapezoidal in outline (Extended Data Fig. 3a-f). There is one pneumatopore on each side of the centrum posterior to the parapophysis, and a few smaller nutrient foramina on the ventrolateral and ventral surfaces. A short, posteriorly directed process on each diaphysis of the posterior cervicals is present as in *Archaeornithomimus* and *Ornithomimus*. Low neural spines centered on the neural arch are anteroposteriorly short, giving the arch an "X" shape in dorsal view. The epipophyses are low and moundlike, and are positioned above the front margins of the articular facets of the postzygagopophyses. The cervical ribs gradually become shorter and thicker towards the last cervical.

The extreme pneumaticity of the axial skeleton is one of the most defining characteristics of *Deinocheirus*. The nomenclature used here for vertebral fossae follows that of sauropods and other saurischian dinosaurs[30]. Especially tall dorsal neural spines have two pairs of accessary fossae (posterior postzygapophyseal spinodorsal fossae (ppsdf) and posterior postzygapophyseal spinoventral fossae (ppsvf)) above a spinopostzygapophyseal fossa (Extended Data Fig. 4). The spinodiapophyseal laminae are also well developed in neural spines, forming basal webbing; two accessary fossae are bordered by an accessary lamina posterior to the spinopostzygapophyseal lamina. The neural arch is deeply invaded by many pneumatic pockets ventral to the transverse processes. The parapophyseal centroprezygapophyseal fossa (pacdf) is divided into three small fossae (parapophyseal centroprezygapophyseal fossa (pacdf), middle centroparapophyseal fossa (mcpaf), and middle centropostdiapophyseal fossa) by two new accessary laminae (parapophyseal posterior centrodiapophyseal lamina (papcdl) and middle centrodiapophyseal lamina (mcdl)).

The mcdl appears from fifth dorsal vertebra to the last dorsal. The transverse processes are steeply inclined anterodorsally in the dorsal vertebrae closest to the sacrum, and the parapophyses project distinctly. The tall and rugose posterior neural spines are oriented anterodorsally; each is compressed lateromedially with the greatest expansion near the distal end. A distinct pneumatopore is present on each side of each dorsal centrum, unlike other ornithomimosaurs, which have them only in the first one or two dorsals. The anterior five dorsal ribs are straight, suggesting that the animal was narrow-chested. The right seventh dorsal rib shows remodeling of a healed trauma in MPC-D 100/127.

Six co-ossified vertebrae form the sacrum. It is slightly arched ventrally in lateral view. The ventral surface of the first sacral is convex, whereas sacrals 2, 3, 4 and 5 are sharply keeled, unlike those of other ornithomimosaurs. The ventral surface of the sixth sacral is broad with a longitudinal midline sulcus. Pneumatopores are also present in all sacral centra except the last one. Three major sacral ribs (3, 4, 5) are firmly fused into a massive bar between the centra and the lower region of the ilium. All six transverse processes extend dorsolaterally to contact the iliac blade. The diapophysis of the first sacral has a diminutive rib, of which the distal end is blunt. The postzygapophyses are vertically fused with the prezygapophyses between the second to fifth sacrals. The distal parts of the sacral neural spines are fused into a midline plate of bone in MPC-D 100/127 except for the first one. However, the last sacral neural spine is additionally not fused in MPC-D 100/128, which indicates that there is ontogenetic variation in neural spine fusion. The spinodiapophyseal lamina is prominently developed from the middle of the neural spine to the diapophysis in each of sacrals 2, 3, 4 and 5. This forms distinct basal webbing that is not present in the first sacral and is not prominent in sacral 6.

The amphiplatyan caudal centra are oval in anterior view, and each has a longitudinal midline sulcus on the ventral surface. The top of the first caudal neural spine is slightly

convex in lateral view, whereas the distal ends of the second to seventh caudal neural spines are concave in their anterior halves. In more posterior vertebrae, the dorsal margins are broadly concave and expand anteroposteriorly; the neural spines eventually become low ridges in the most distal caudals. The centrum becomes longer than high from the sixth caudal to the end of tail. The transverse process (probably composed mostly of a fused caudal rib) is centrally positioned on the centrum, and becomes progressively shorter from the first to sixteenth caudal; there are no transverse processes in the remaining caudals. An incomplete pygostyle consists of one and a half fused vertebrae (Extended Data Fig. 3g-l), but it is unknown how many additional vertebrae were incorporated into the pygostyle. Each Y-shaped haemal arch consists of two proximal rami without anterior processes; the haemal spine is laterally compressed.

The estimated width of the furcula is 280 mm between two flattened articular facets (epicleidea). It curves each way from an apical ridge (hypocleideum) to form a U-shape. The acromial process of the scapulocoracoid projects prominently from the scapular blade and lacks a squared-off profile[2].

The carpus was not found with the holotype, but three carpals are preserved *in situ* in MPC-D 100/127. Looking at the proximal view of the metacarpus, the first small spherical carpal is positioned at the medioposterior corner of the first metacarpal, the second large discoid carpal covers the second metacarpal anteromedially, and the last small triangular carpal is positioned at the anteromedial corner of the third metacarpal.

The ilium is very distinctive in *Deinocheirus*. The broad dorsal expansion of the preacetabular ala is convergently similar in large therizinosaurs. The ventrally rounded iliotibialis flange is large and continues to the anterior margin of the iliac blade, which lacks the long and acute ventral projection that is found in derived ornithomimids[5]. The brevis fossa is mediolaterally wide and is slightly open laterally. Iliac blades are well-separated

dorsally, and do not contact the sacral neural spines medially. The ischial process of the ilium

plugs into a socket in the ischium. However, whereas the suture is obliterated by fusion in

mature ornithomimids, it is open in both *Deinocheirus* specimens. The pubis is long and

straight, pointing anteroventrally. The ratio of the length of the public boot to public shaft

(0.44) is higher than those of other ornithomimosaurs (less than 0.3), but pubic boot length

grows with strong positive allometry and scales well on tyrannosaurid and ornithomimid

regressions for an animal of this magnitude (Extended Data Fig. 2d). The anterior process of

the public boot is short whereas the long posterior process is fused to its neighbor to produce

a triangular outline in distal view. The pubic obturator foramen is completely closed and

dorsoventrally elongate. The ischium is almost the same length as the pubis, whereas in most

ornithomimids it is about 2/3 the length of the pubis. However, the ischium grows with

positive allometry in most theropods (including ornithomimids), whereas pubic growth is

isometric (Extended Data Table 1). Therefore the subequal length of the pubis and ischium in

Deinocheirus is expected and has no taxonomic significance. The ischium expands at the

long puboischial contact and like other ornithomimosaurs expands distally into a knob. The

distal end curves anteriorly in lateral view. Both specimens are damaged in the region where

the obturator processes should be, but this feature appears to have been relatively small as in

other ornithomimosaurs.

  The femoral shaft is massive and straight. An alariform lesser trochanter is robust and

projects proximally, but is slightly lower than the proximal articular surface and the greater

trochanter. It is separated from the greater trochanter by a 12 cm deep cleft, and there is a

large intertrochanteric foramen at the distal end of the cleft on the anterodorsal surface of the

femur. The tibia is shorter than the femur but falls within the projected regressions of

femoral/tibial growth for ornithomimids (and that of *Gallimimus* in particular, Extended Data

Fig. 2e). The massive lateral condyle (fibular condyle) has a distinct ball-like accessory

process proximoanteriorly. The thin rectangular fibular flange (facet) is clearly separated from the proximal articular surface and extends to midlength of the tibia. The fibular head is crescentic in proximal view with its posterior portion mediolaterally wider than the anterior portion. The insertion of *M. iliofibularis* is weak and positioned at midshaft. The astragalus and calcaneum are fused to each other and to the tibia in MPC-D 100/127, but not in MPC-D 100/128. The ascending process of the astragalus is tall, and is at least 29% the length of the tibia. As in other ornithomimosaurs, the calcaneum is a thin disk adhering to the lateral surface of the astragalus. It contacts the fibula, but contributes relatively little to its support.

Both feet are preserved in MPC-D 100/127. The third and fourth distal tarsals are tightly integrated with the proximal surfaces of the second to fourth metatarsals. The metatarsus is not arctometatarsalian in condition; this is considered as one of the synapomorphies for the Ornithomimidae[3, 31], and its absence in *Deinocheirus* suggests that this animal represents a more primitive clade. However, whereas the proximal ends of the third metatarsals of the non-ornithomimid ornithomimosaurs *Garudimimus* and *Harpymimus* are triangular in outline, they are rectilinear in *Deinocheirus* and ornithomimids. The first and fifth metatarsals were not recovered with either specimen, but facets indicate that at least the fifth was present in living specimens of *Deinocheirus*. There is no facet on the second metatarsal for the first metatarsal, which suggests that the first digit was not present in *Deinocheirus*. The ratio of length from the distal end of metatarsal III to the medial expansion of metatarsal III is 0.4, which is similar to primitive ornithomimosaurs (*Harpymimus*, 0.436; *Garudimimus*, 0.354) rather than ornithomimids (*Gallimimus*, 0.288)[15] (Extended Data Fig. 2f). However, given the large size of *Deinocheirus*, this similarity could be size-related, and further analysis is necessary to fully understand the implications of using this ratio.

Phalangeal proportions look superficially more like those of tyrannosaurids than ornithomimids, but this is because of the great weight that this animal had to bear. The

proximal ends of the pedal unguals are triangular in cross section with flat ventral surfaces. However, their distal ends are not pointed, but are distinctively stubby (up to 64 mm across in II-3) and flat, so that they resemble the unguals of large ornithischians (Extended Data Fig. 5).

3. Cladistic analysis

The phylogenetic analysis of *Deinocheirus* within a large context of Theropoda[17] (96 taxa and 568 characters) was analyzed with equally weighted parsimony using TNT v. 1.1[32]. Four hundred and eighty eight characters were identified from *Deinocheirus* and incorporated into the matrix. The dataset was assembled in Winclada v. 1.00.08[33]. New states were recognized in *Deinocheirus* and were added to characters 51, 488 and 524. Trees were rooted on *Herrerasaurus*. Eight multistate characters were ordered (characters: 84, 100, 227, 231, 236, 239, 261, and 471). A heuristic tree search strategy was conducted performing 1000 replicates of Wagner trees (using random addition sequences, RAS) followed by TBR branch swapping (holding 10 trees per replicate). The best trees obtained at the end of the replicates were submitted to an additional round of TBR branch swapping. Bremer Support[34] for nodes was calculated by saving 10000 suboptimal topologies up to 11 steps longer than the MPTs in TNT v. 1.1. The heuristic search resulted in six most parsimonious trees of length 2927, ensemble consistency index 0.22 and retention index 0.59. Relationships within Theropoda were in agreement with recently published analyses of non-coelurosaurian theropodan relationships and coelurosaurian relationships[35, 36] (Extended Data Fig. 6).

Deinocheirus coding

??0000002100100100?01?0101110-0013011?000----0000000201101001100100?0-0--1010110 01120001001-000?0-000000-0010010010001011????????010?0?0???1?1?????????0000001??

000??????????????????10-?001101110-00-000000-1?1??000-0???011------1---------2---------

---??????010-10201210000?11211112000111010010001001011004120100211?00020000000

0000110?10100?????111??200100111000100120010001200000000000000011?00010101011

1110022100211101000000110111000110001100-000000100000010101000010000000-0010

----10000-1020001000110010001000100010111011?010200001010200001000010?????000

00010000?0000010

Character 51: External nares

    0:   facing laterally

    1:   facing anterolaterally

    2:   facing dorsally (new state)

Character 488: Femoral head

    0:   without fovea capitalis

    1:   circular fovea present in center of medial surface of head

    2:   vertical ridges on anterior and posterior edges of medial surface of head (new state)

Character 524: Fibular proximal dimensions in proximal view

    0:   anterior portion subequal to posterior portion in mediolateral width

    1:   anterior portion mediolaterally wider than posterior portion

    2:   posterior portion mediolaterally wider than anterior portion (new state)

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