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ON A NEW SPECIMEN OF THE LOWER CRETACEOUS THEROPOD DINOSAUR *DEINONYCHUS ANTIRRHOPUS*

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ABSTRACT. A new specimen of *Deinonychus antirrhopus*, described here, provides morphological and dimensional data on skeletal elements missing in previously known specimens. Included are the femora, pubes, complete ilia and the sacrum. The pubis is normal in its morphology, but unusual in its length (more than twice that of the ischium) and orientation (apparently ventrad). The femur is shorter than the tibia and features an unusual "posterior trochanter" that may have been the attachment site of muscles that powered the offensive leg kick and use of the pedal talon.

INTRODUCTION

My original reports on the unusual theropod dinosaur *Deinonychus antirrhopus* (Ostrom, 1969a, 1969b) necessarily were incomplete because some skeletal elements were not then represented in collections. Specifically, much of the postorbital region of the skull was not known, nor were the femur, pubis or sacrum. These deficiencies now have been partially resolved thanks to the discovery in July, 1974 by a Harvard University expedition to Montana, of another specimen of *Deinonychus antirrhopus*. The purpose of this paper is to provide descriptions of the previously unknown elements that are provided by the new specimen, and to correct certain inaccuracies that were presented in my earlier studies of this remarkable species.

Abbreviations of institutional names cited herein are as follows:

AMNH — American Museum of Natural History, New York City.

MCZ — Museum of Comparative Zoology, Harvard University.

YPM — Peabody Museum of Natural History, Yale University.

Materials: A partial skeleton (MCZ 4371, Field No. 74M #7) including fragments of the snout and mandibles with teeth, a nearly complete but poorly preserved vertebral series including the entire tail, the right forelimb and manus, fragments of the left manus, a complete pelvis and sacrum, both hind limbs and feet, and various rib and gastralia fragments; discovered by Steven Orzack and collected by F. A. Jenkins and party, July 1974.

Geologic and Locality Data: Upper part of Unit V (see Ostrom, 1970), otherwise known (in part) as the Little Sheep Mudstone Member of the Cloverly Formation (Moberly, 1960), Lower Cretaceous. The quarry site is situated 1 km south of

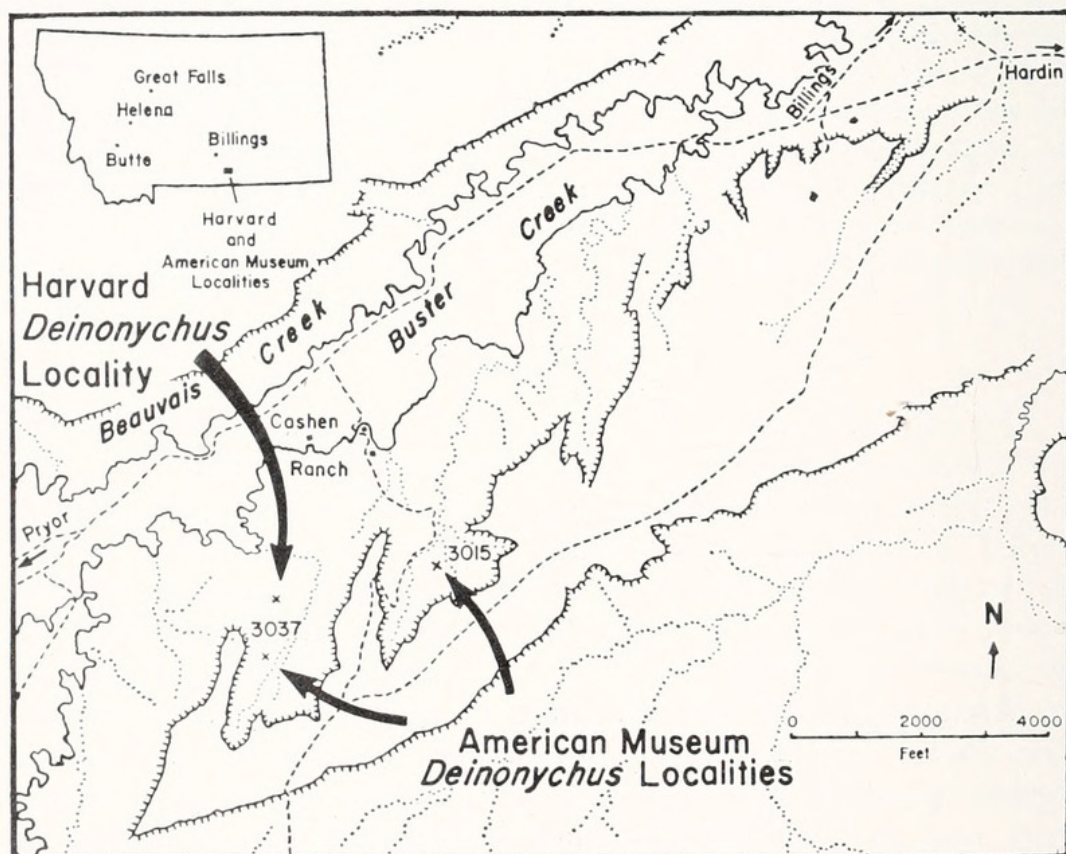


Fig. 1. Locality map showing the Harvard *Deinonychus* site, together with the previously known American Museum sites in southern Montana.

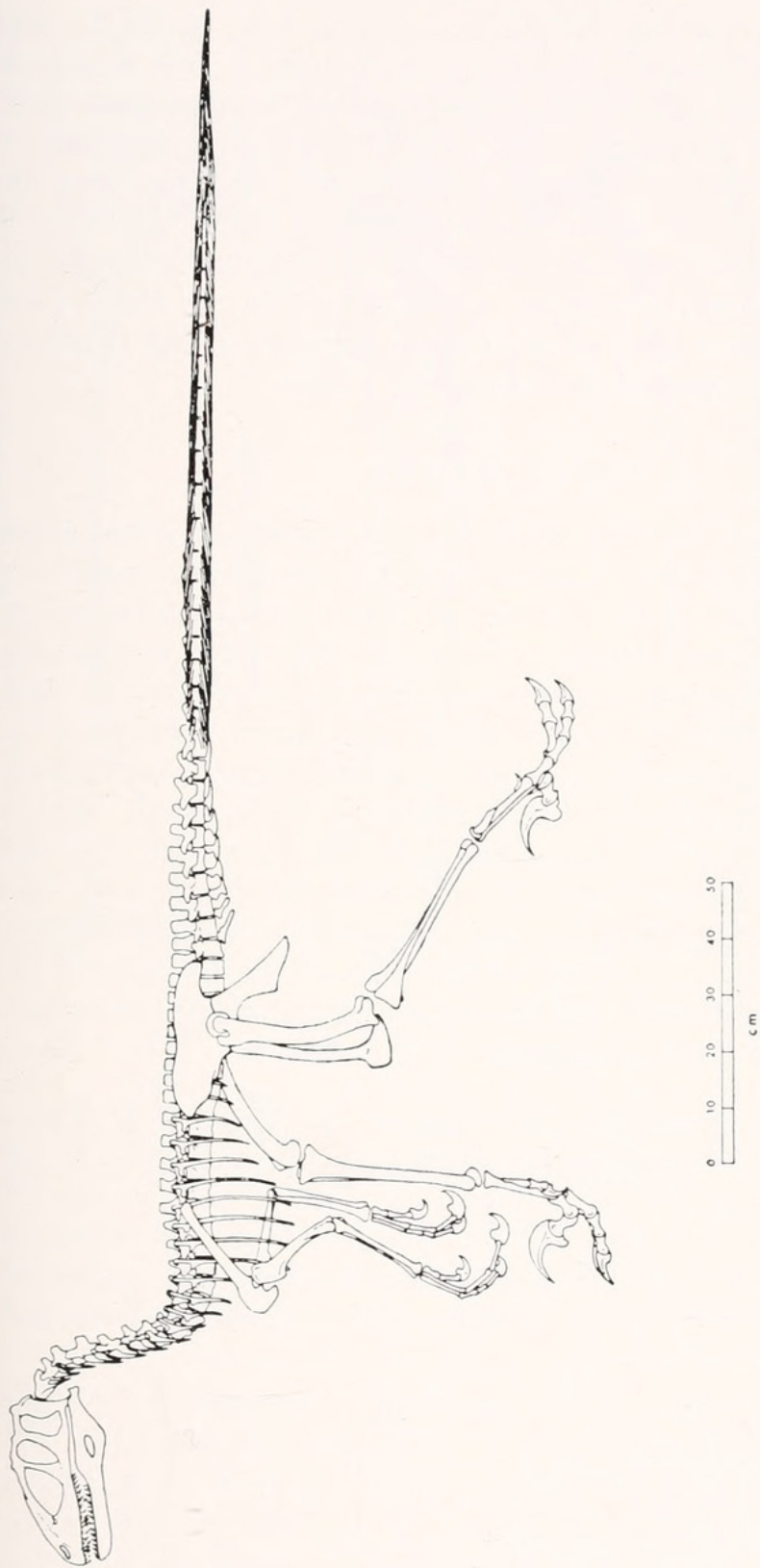


Fig. 2. Revised skeletal reconstruction of *Deinonychus antirrhopus*.

the Cashen Ranch house, NE $\frac{1}{4}$ Sec. 32, T. 4 S., R. 29 E., Big Horn County, Montana. This site is within a few hundred meters of the two American Museum *Deinonychus* sites (see Fig. 1) reported previously (Ostrom, 1969b), and appears to be at approximately the same stratigraphic level as that of AMNH 3037. If my previous correlations (1969b, 1970) are correct, this level is well below that of the Yale *Deinonychus* Quarry near Bridger, Montana, which occurs in the lower part of Unit VII (equals part of the Himes Member of the Cloverly Formation as interpreted by Moberly, 1960).

DESCRIPTION

Excluding many isolated teeth of *Deinonychus* reported from numerous Cloverly sites (Ostrom, 1970), the present specimen brings the total minimum number of *Deinonychus* specimens to six individuals. The collections from the Yale Bridger Quarry, however, consist almost entirely of disarticulated remains that may well include more than the three individuals represented by the three articulated caudal series recovered there. As Table 1 shows, the new specimen is the largest of all presently known specimens, and together with AMNH 3015 provides the first evidence of growth patterns and allometry in this taxon. The following descriptive material deals primarily with those skeletal elements that were not known at the time of the earlier studies. These include the femur, pubis and sacrum, and certain aspects of the ilium, pes and metatarsus.

Femur: Contrary to my earlier guess, the femur of *Deinonychus* is shorter than the tibia by about 10 per cent. This is not an unusual difference, nor is it unusual for the tibia to exceed the femur length in theropods. But this new fact does require a reassessment of my earlier interpretation about the cursorial capacity of *Deinonychus* — a reassessment that will be discussed briefly later.

The femur of *Deinonychus* is moderately robust, with a slight antero-posterior curvature and of hollow construction (Fig. 3). The head is sharply offset medially from the shaft by means of a stout but distinct neck. The axis of the neck projects transversely (parallel to the plane formed by the distal condyles) at about 100 degrees to the femoral shaft. The head is roughly ovoid and broadly convex, but with a slightly flattened area

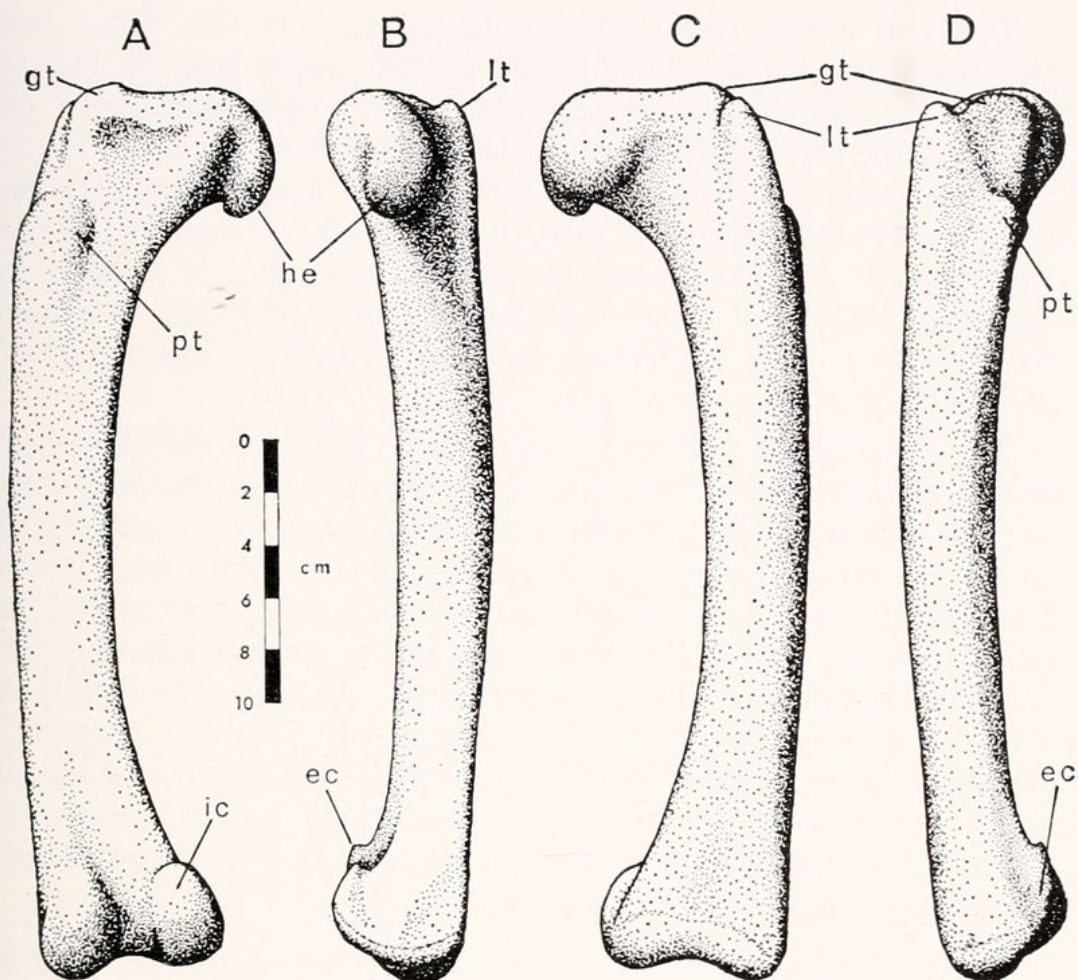


Fig. 3. Left femur (restored) of *Deinonychus antirrhopus* (MCZ 4371) in posterior (A), medial (B), anterior (C), and lateral (D) views. Abbreviations: ec — external condyle; gt — greater trochanter; he — head; ic — internal condyle; lt — lesser trochanter; pt — posterior trochanter.

anterodorsally and with a distinct proximal posteroinferior lip or overhang that sets the head off from the inferior region of the neck. Externally, the neck expands dorsally into a large "greater trochanter," which presumably marks the attachment site of the *M. iliotrochantericus*. External and slightly anterior to this feature is a robust, but not large, "lesser trochanter" (anterior trochanter of some authors). Unlike some theropods (i.e., *Allosaurus*), this last structure is separated from the "greater trochanter" by only a narrow shallow groove rather than by a deep cleft. The "lesser trochanter" of theropods is generally considered as the insertion site of the *M. ilio femoralis*.

Distal to these "trochanters" and posterior to the "lesser trochanter," is a distinct prominence or boss which projects latero-posteriorly. Similar, but much less prominent features occur on many other theropod femora, but it has received little or no attention and has not been given a formal designation. In this paper, for lack of a better term, it is referred to as the "posterior trochanter." Its significance is not known, but it is situated in the general region where we might expect the *M. ischiotrochantericus* (= *M. ischiofemoralis* of birds?) to insert. More will be said of this later.

The uncrushed portions (near midlength) of the shaft are nearly circular in section with a minimum transverse diameter of approximately 38 mm and an anteroposterior diameter of about 32 mm. Dimensions increase slightly toward both ends. Surprisingly, no recognizable fourth trochanter is preserved in either femur, nor is there any discernible scar indicating the insertion site of the *M. caudifemoralis*. Distally, the condyles are well developed and sharply separated in posterior (ventral) aspect by a deep intercondylar groove. The external condyle is nearly twice as large (both proximodistally and in anteroposterior dimension) as the internal condyle. Femoral and other dimensions are given in Table I.

Pubis: Perhaps the most important aspect of the new specimen is the presence of both pubes. In my original study of *Deinonychus* (Ostrom, 1969b), I tentatively but incorrectly identified an isolated bone of curious shape as a right pubis, chiefly because it was found in the quarry immediately adjacent to a right ischium of about the same length. Subsequently I became convinced that it could not possibly be a pubis and after further study concluded that it was a right coracoid of unusually large size (Ostrom, 1974).

The pubes of *Deinonychus* are of normal theropod design (Fig. 4), but of surprising length relative to the short length of the ischium. In fact, the pubis is more than double the length of the ischium, a condition that is unique among theropods. Although crushed in some regions, the major features are all discernible. The proximal end is moderately stout, but the actual articular surfaces for contact with the robust pubic peduncle of the ilium and the thinner peduncle of the ischium are not recognizable. There appears to have been a shallow obturator notch immediately adjacent to the ischial suture, as shown

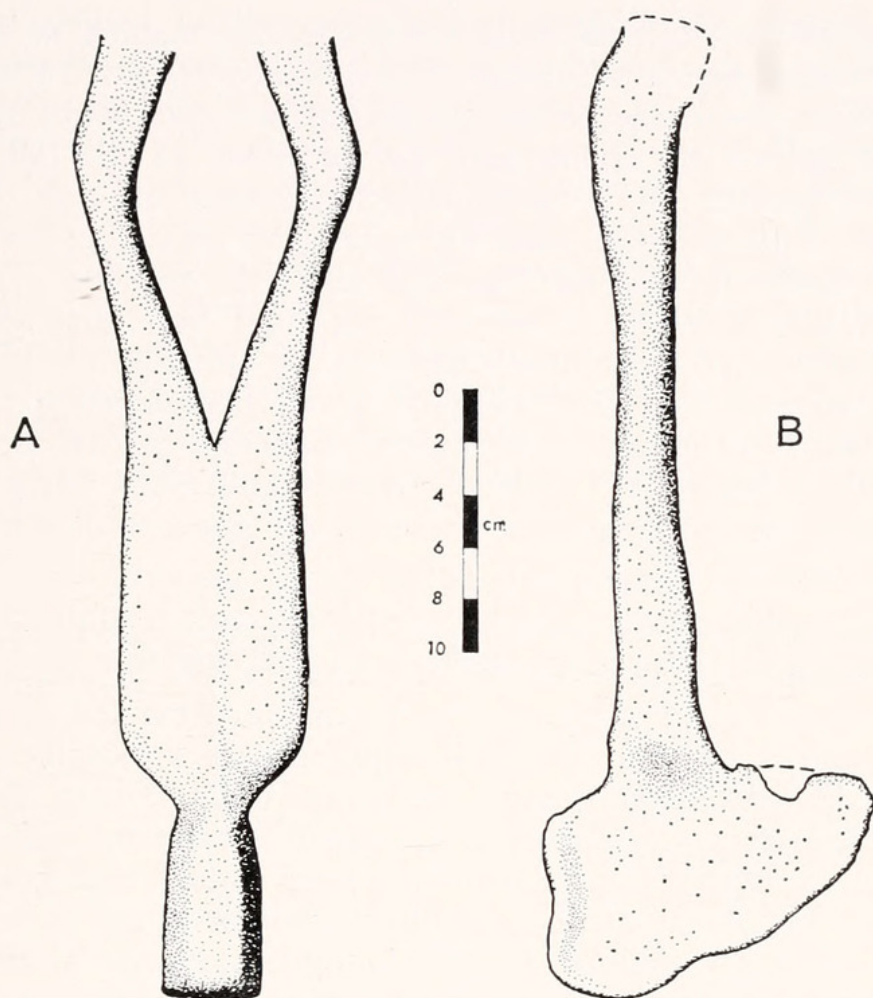


Fig. 4. Pubes (restored) of *Deinonychus antirrhopus* (MCZ 4371) in anterior (A) and left lateral (B) views.

by remnants on the left side. The pubic shafts are oval in section, with the greatest diameter in the transverse direction. Just short of mid-length, the shafts expand medially and the two pubes join in a massive symphysis that measures 210 mm, or more than half the total pubic length. Over most of the symphyseal length, the pubes are quite broad, forming a transverse apron of 60 to 67 mm width. The distal extremity contrarily is narrow transversely, but expanded longitudinally into the typical theropod "footlike" structure. This pubic "foot" is approximately 135 mm long (anteroposteriorly), but only 35 mm in its maximum preserved width.

There is no doubt any longer about the form of the pubis, but doubts still exist about the *in vivo* position of the pubes (and

perhaps of the ischia as well) because of the manner in which the new specimen is preserved. The animal was buried lying on its ventrum, with the pubes pushed up and backward, tightly pressed against the ischia and the underside of the tail, and oriented parallel to the proximal caudals and the axis of the sacrum. The fact that *both* the pubes and the ischia are preserved tightly pressed together and directed *backward* suggests that in life these two bones may not have been arranged as divergently as in most other theropods. It further suggests that the pubes may have been oriented nearly perpendicular to the sacral axis, or perhaps even slightly posterior to that perpendicular. In the revised skeletal reconstruction (Fig. 2), I have so oriented the pubes at right angles to the long axis of the ilium and the sacrum.

Ilium: Prior to the discovery of the Harvard specimen, only one incompletely preserved ilium (AMNH 3015) was known of *Deinonychus*. Fortunately, both ilia are preserved in MCZ 4371, and a more accurate description is now possible. Unexpectedly, the ilium turns out to be much longer than I concluded from the American Museum specimen, with both extremities tapered or triangular, rather than rectangular in outline. In lateral aspect, the iliac blade is long, quite low, and with nearly uniform height throughout, except at the extremities. The anterior process is longer than the posterior process, as measured from the center of the acetabulum. Except for the tapered extremities, the long low profile and the off-

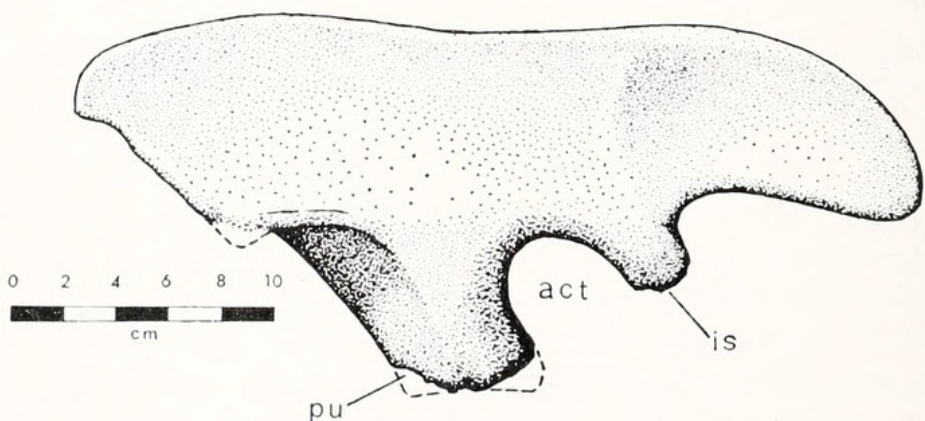


Fig. 5. Left ilium (restored) of *Deinonychus antirrhopus* (MCZ 4371) in lateral view. Abbreviations: act — acetabulum; is — ischiac peduncle; pu — pubic peduncle.

center position of the acetabulum resemble the conditions of coelurosaurs in general, and those of ornithomimids in particular.

As was noted in my earlier description of the American Museum ilium, the pubic peduncle is much more massive and longer than the ischiac peduncle, and, perhaps more important, it is directed downward and *backward*, rather than down and forward. The significance of this unusual orientation was not recognized then, but now in the light of the preserved position of the pubes in MCZ 4371, it seems reasonable to equate this with a possible ventrad or ventroposterior orientation of the pubes. Figure 6 shows my best estimate of the pelvic arrangement in *Deinonychus*, compared with *Struthiomimus* and *Tyrannosaurus*.

Ischium: Although both ischia are present in MCZ 4371, they add little to our knowledge of ischial morphology beyond that which was provided by previous specimens. However, the

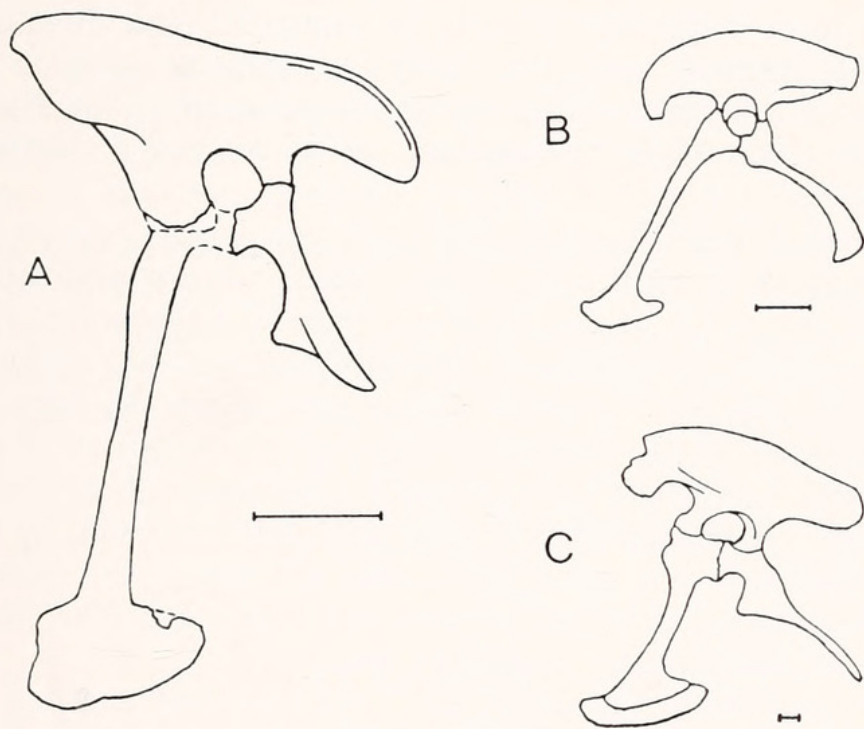


Fig. 6. Comparison of the pelves (lateral views) of *Deinonychus*, MCZ 4371, (A); *Struthiomimus*, AMNH 5339, (B); and *Tyrannosaurus*, AMNH 5027, (C); to show the unusually disproportionate lengths of the pubis and ischium in *Deinonychus*. The scale lines equal 10 cm.

new specimen does establish that the ischia were united at their distal extremities by a well-developed symphysis. Whether the symphysis extended proximally to the level of the obturator flange, as I suggested previously (Ostrom, 1969b) on the basis of the surface texture of that process, cannot be established here. The anterior ischial surfaces are concealed by the broad pubic apron, which has been crushed against the ischia, and the posterior surfaces likewise are covered by the proximal caudal vertebrae that were pressed down against them.

Sacrum: The sacral series, absent in previously known specimens, is difficult to decipher because the anterior portion is incomplete and the full dorsal vertebral count is not known in MCZ 4371. On the basis of the degree of co-ossification and the form of the sacral ribs, I conclude that the sacrum consisted of five segments in which the centra and neural spines were fused together. A sixth centrum, presumably representing the last dorsal, seems to be fused to the first sacral. This segment, and the one behind it, has relatively weakly developed sacral ribs or transverse processes as compared with those of the following segments, but these anterior segments seem to have had firm articulation with the anterior processes of the ilia. On that basis, both might be considered as dorsal, rather than sacral vertebrae.

Pes: Both feet and metatarsi are well preserved and apparently complete in the new specimen, offering verification of most of my original interpretations, but also providing a few new details. The new specimen suggests that the first metatarsal probably consisted of a distal portion only, rather than separated distal and proximal moieties. There is no evidence in either foot (both of which are otherwise complete) of a proximal portion of metatarsal I, as I suggested earlier (1969b, fig. 72). Since both feet and metatarsi in this specimen were preserved fully articulated, it seems unlikely that this particular element should be accidentally missing in both.

Also, as preserved in MCZ 4371, the first digit may not have been reverted to the rear as far as I originally restored it (1969b, Fig. 74). However, since the first metatarsal was not fused to the second, and appears to have been ligamentously joined to the metatarsus, its preserved position (in the absence of any clear appositional scar) may or may not approximate the natural position in life.

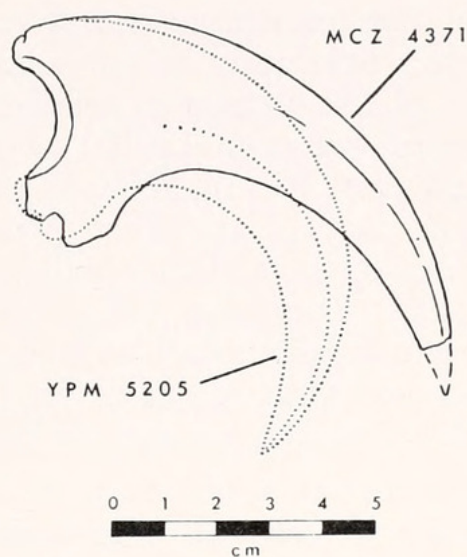


Fig. 7. Contrasting morphology of the second pedal ungual in the type specimen of *Deinonychus* (YPM 5205) and the new Harvard specimen.

One final observation that pertains to the distinctive "*Deinonychus*" character preserved in the new specimen: that is the very different geometry of the foot talon. As Figure 7 shows, the claw in the type specimen (YPM 5205) is much more strongly curved than is that of MCZ 4371. Preservation of the type ungual is virtually perfect with no distortion or crushing and only a few small fragments missing. That is not true of the new specimen, but what distortion is apparent here does not seem to account for the conspicuous difference in shape. Barring preservational distortion, the difference could be due to individual, ontogenetic, or sexual variation. At this point, I have no opinion on the correct explanation, but simply report the difference.

DISCUSSION

In my original study (1969b) of *Deinonychus*, I assumed equal lengths for the femur and tibia, in the absence of any knowledge about the femur. The new specimen shows that the femur is shorter (approximately 90 per cent of tibia length) than I had thought and thus is similar to *Struthiomimus*. This might indicate higher running speeds than I suggested in that

study ("moderately, but not unusually fast"). However, more important than femur/tibia ratio as an index of cursorial velocity, is the length of the metatarsus relative to the tibia. In the American Museum specimen (3015) of *Deinonychus*, this ratio is a surprisingly low .48. In MCZ 4371, it is .45. These values are well below those of any other theropod now known, and when compared with those of such well-known fast-running birds as *Struthio* (.95), *Dromaius* (.96) and *Casuaris* (.85) (where the femur is only about half as long as the tibia) and the presumed fleet-footed *Struthiomimus* (.68), the only reasonable conclusion is that *Deinonychus* was not the most fleet-footed of theropods.

This conclusion is reinforced by other data revealed by the new specimen. MCZ 4371 is a larger individual than AMNH 3015, but not uniformly so. The forelimb is 20 per cent longer in MCZ 4371 and the tibia 18 per cent longer, but the metatarsus is only 12 per cent longer than in AMNH 3015. If the above similar tibia and forelimb values represent an overall average difference in size between these two individuals, then metatarsal growth did not keep pace during ontogeny with the growth of other long bones. The metatarsal fraction of total hind limb length diminished with age, suggesting a corresponding decline in cursorial ability. At the time of my earlier study, I was puzzled by the relative brevity of the metatarsus, but suggested that its unusually short length may have been correlated with the specialized offensive claw of the second toe. I am still of that opinion, especially in view of the apparent ontogenetic decline in relative metatarsal length revealed by the Harvard and American Museum specimens.

The design and orientation of the sicklelike claw on digit II show that the offensive or damaging stroke of this weapon was flexion — a strong backward thrust of the claw and toe. This probably was coordinated with a powerful backward kick of the entire hind leg. This means that the combined power of all the hind limb retractor muscles (those that are usually involved in the locomotory power stroke) may have contributed to the action of this unusual and presumably lethal device. Considering the size and shape of the pedal talon, it is very likely that the toe and the metatarsus were subjected to considerable extensional and shear stresses when this weapon was employed — possibly much higher stresses than usual during normal loco-

motory action of the foot and leg¹. If so, what were the principal muscles available to counteract such stresses in these regions? Presumably, they were the equivalents of the M. gastrocnemius and the digital flexors (particularly the M. flexor perforans et perforatus digiti II and M. flexor perforatus digiti II) of modern birds. As the primary flexor of the ankle, the gastrocnemius is the chief muscle available to oppose extensional stresses applied to the metatarsus and the foot. But as the chief ankle flexor, the mechanical requirements of the gastrocnemius dictate a proximal insertion on the posterior surfaces of the metatarsus. This arrangement, with its extremely short lever arm, provides little or no added strength to the metatarsal shafts against hyperextension or fracture. However, a shortened metatarsus would reduce the length of the resistant (hyperextensional) lever arm and thus can be considered as an adaptation to minimize the possibility of metatarsal hyperextension or fracture. This explanation is further supported by the fact that there is no positive evidence of an enlarged or particularly powerful "gastrocnemius." There are no tubercles evident on the femur distal extremity that might be the origin sites of such a muscle, and there is no hypotarsus-like structure, or any other evidence of muscle scars, on the proximal posterior surfaces of the metatarsals.

Speculative though the above interpretations may be, they are further supported by a comparison of hind limb proportions in *Deinonychus* with those of both cursorial (*Struthiomimus*) and graviportal (*Tyrannosaurus*) theropods (see Fig. 8). The propodial — epipodial proportions of *Deinonychus* resemble those of *Struthiomimus*, but the metapodial — pes proportions resemble those of *Tyrannosaurus* (although not as massive). In the latter, the short metatarsus can be viewed as related to the great weight-bearing (and shear stress) problems in *Tyrannosaurus* (estimated live weight, 7,000 kg). In *Deinonychus*, however, any excessive shear stresses across the metatarsus must have

¹It is interesting that the Yale *Deinonychus* collection includes a damaged second phalanx of digit II which was fractured and healed during the animal's lifetime. The broken extremities were displaced transversely and mended in this position, but perfectly aligned longitudinally. The longitudinal alignment apparently allowed the claw to function normally after healing, with only a sideways displacement of the arc of claw flexion. This specimen clearly indicates that the talon-bearing toe of *Deinonychus* was subject to intense stress.

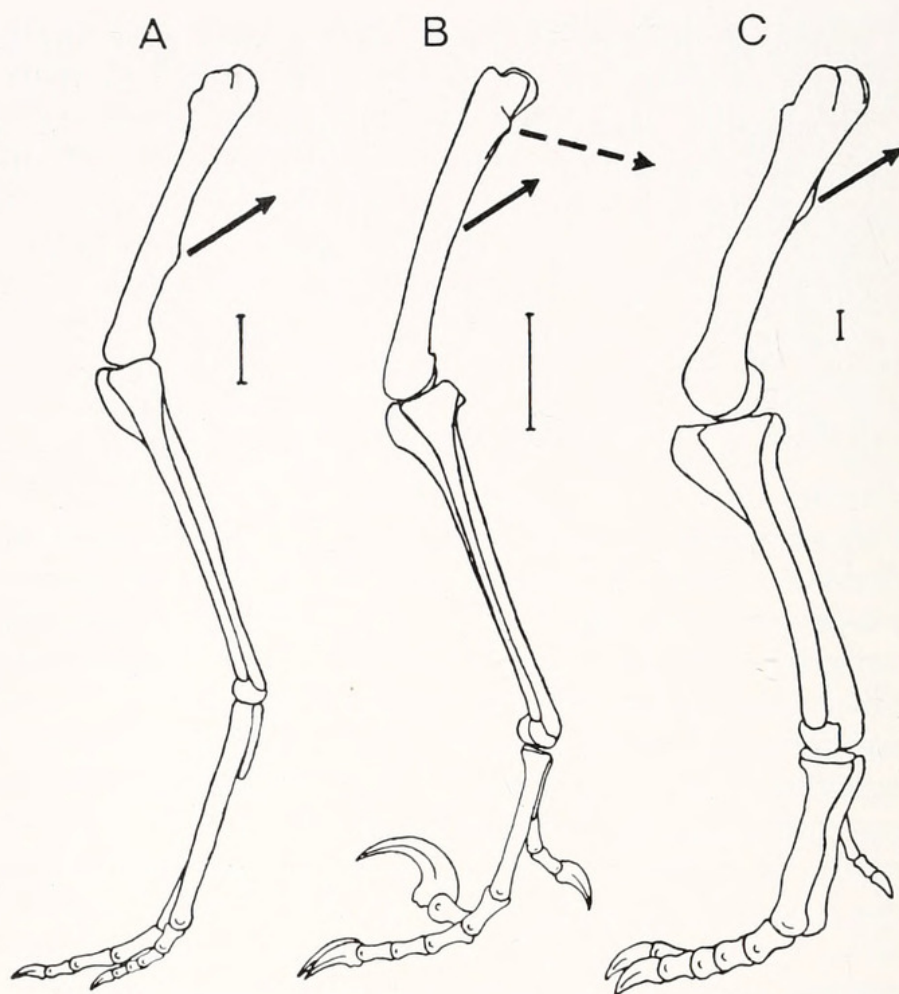


Fig. 8. Comparison of hind limb proportions in *Struthiomimus*, AMNH 5339, (A); *Deinonychus*, MCZ 4371, (B); and *Tyrannosaurus*, AMNH 5027, (C). Notice that the proximal elements of *Deinonychus* resemble those of cursorial *Struthiomimus*, but the distal proportions are more like those of graviportal *Tyrannosaurus*. The solid arrows indicate the location and approximate orientation of the chief locomotory muscle, the *M. caudi-femoralis*. The dashed arrow (B) indicates the possible position of the *M. ischio-trochantericus*, a secondary femoral retractor which may have powered the offensive leg stroke. Scale lines equal 10 cm.

been derived from sources other than weight (which is estimated at less than 75 kg). Use of the foot talon against a larger prey animal might well have resulted in high stresses across the metatarsus, thereby favoring a shortened metapodial component. That could account for the peculiar distal proportions combined with the otherwise "cursorial" design of the tibia and femur.

The above observations lead to one further speculation about the hind limb of *Deinonychus* and its probable actions. As noted in the descriptive section, there is a well-developed prominence (referred to here as the posterior trochanter) on the outer posterior proximal surface of the femur just distal to the "greater trochanter." This feature is present in many other theropods, where it is far less prominent, but as far as I am aware, it has not received any particular attention or interpretation. Even though any analogy here with modern birds may be questionable, it is interesting to note that a bony prominence also occurs in this same region in many modern birds. This avian feature is the site of insertion of the M. ischio-femoralis (= the M. ischio-trochantericus of reptiles), one of the major retractors of the hind leg. Traditionally, the M. caudi-femoralis is considered the principal femoral retractor in modern reptiles (and especially in the extinct bipedal theropods and ornithopods), providing most of the stride power. The M. caudi-femoralis inserts on the fourth trochanter, or on a conspicuous scar near mid-shaft of the femur. This insertion site is well developed in virtually all reptiles, and particularly so in all theropods. The absence of a fourth trochanter in *Deinonychus*, or of any recognizable scar that can be equated with the caudi-femoralis, is a curious anomaly that I am unable to explain.

I am not suggesting that the M. caudi-femoralis was absent, or even reduced, or that the M. ischio-trochantericus (with its lesser leverage) had assumed part or all of the locomotory function of that muscle. Rather, I wonder if the unusual prominence of the "posterior trochanter" here may not be related to the special predatory foot adaptations in *Deinonychus* which obviously were designed for application in a backward "killing" stroke — a motion quite separate and (perhaps necessarily) independent of limb movements concerned with locomotion. Turning our attention to another unusual feature of *Deinonychus*, recall the extraordinary brevity of the ischium and the proximal placement of the obturator flange — a possible origin site of the M. ischio-trochantericus. I cannot help wondering

about the possible connection between these three unusual features of *Deinonychus*: the offensive foot talon; the abbreviated ischium with a proximally situated obturator flange; and the prominent posterior trochanter of the femur. The last two features could well have been the origin and insertion sites of the ischio-trochantericus, which could have powered the *offensive* backward stroke of the hind leg, as opposed to the backward *locomotory* power stroke of the leg. The locomotory power stroke almost certainly was produced by contraction of the caudi-femoralis, despite the apparent absence of an insertion scar or a fourth trochanter.

Why should the offensive backward stroke of the femur be powered by a different set of muscles from the more usual locomotory stroke? Perhaps the answer lies in the fact that the most important locomotory muscle of the reptilian hind leg is the M. caudi-femoralis, which originates on the proximal caudal vertebrae — an origin site which is *not* immovably fixed, and which also is the power base of the tail. The tail obviously is the critical balancing appendage, especially in bipedal reptiles (both obligate and facultative). Bipedal progression and dynamic balance must be coordinated, so it is not surprising that it is the locomotory musculature (M. caudi-femoralis) that is involved with both the propulsive leg stroke and the balancing actions of the tail. On the other hand, the same kind of linkage between the mobile balancing appendage and an *offensive* stroke of the hind leg might be counterproductive. Precise equilibration during any offensive leg stroke would be absolutely essential for an accurate and effective killing stroke, but if the same muscles contributed both to movements of the balancing tail and the offensive leg kick during an aggressive encounter, then the two actions could not be produced independently. Precision of both movements would be seriously impaired. If muscle contractions powering the offensive leg stroke also produced deflection of the balancing tail, or vice versa, one could well be detrimental to the other. Thus it seems logical to conclude that the musculature that powered one action must have been freed as much as possible from producing or contributing to the other action. The M. caudi-femoralis, as it is organized in modern reptiles, cannot meet this requirement. A femoral retractor that does satisfy this constraint, though, is the M. ischio-trochantericus with its *immobile* origin on the ischium, rather than the tail.

SUMMARY

There are no absolute explanations of fossil evidence. The preceding discussion has been offered only as possible reasons for the combination of unusual osteological characters that are peculiar to *Deinonychus* and other dromaeosaurid theropods (*Dromaeosaurus*, *Velociraptor*, *Saurornithoides*, *Stenonychosaurus*). These features are: 1) the sicklelike claw of the second toe; 2) the short metatarsus; 3) a prominent posterior trochanter; 4) a long pubis and an unusually short ischium with a proximally placed obturator flange; and 5) an unusual caudal series with extensive ossified tendons. The foot clearly functioned both for locomotion and as a predatory weapon. In that light, the hind limb proportions seem best explained as a compromise between high cursorial requirements (femur/tibia ratio) of a predator and the need for a strong metatarsal foundation for the foot weapon. The short ischium and prominent posterior trochanter are interpreted as the probable attachment sites of the offensive leg musculature (M. ischio-trochantericus), and the unusual caudal tendons (absent in non-dromaeosaurid theropods) reflect the extreme equilibration requirements of *Deinonychus* and its allies.

ACKNOWLEDGEMENTS

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LITERATURE CITED

- MOBERLY, R. 1960. Morrison, Cloverly and Sykes Mountain formations, northern Bighorn Basin, Wyoming and Montana. Bull. Geol. Soc. Amer. 71: 1137-1176.
- OSTROM, J. H. 1969a. A new theropod dinosaur from the Lower Cretaceous of Montana. Postilla, Peabody Mus. Nat. Hist. 128: 1-17.
- 1969b. Osteology of *Deinonychus antirrhopus*, an unusual theropod from the Lower Cretaceous of Montana. Bull. Peabody Mus. Nat. Hist. 30: 1-165.
- 1970. Stratigraphy and paleontology of the Cloverly Formation (Lower Cretaceous) of the Bighorn Basin area, Wyoming and Montana. Bull. Peabody Mus. Nat. Hist. 35: 1-234.
- 1974. The pectoral girdle and forelimb function of *Deinonychus* (Reptilia: Saurischia): A correction. Postilla, Peabody Mus. Nat. Hist. 165: 1-11.

Table I
Comparative Measurements of *Deinonychus* Specimens

	MCZ 4371	AMNH 3015	YPM 5235
Ilium			
Length	325 mm	245* mm	
Length anterior to acetabulum	165 mm	100* mm	
Length posterior to acetabulum	110 mm	80* mm	
Height above acetabulum	80 mm	72 mm	
Ischium			
Length	175 mm	161* mm	161 mm
Pubis			
Length	380 + mm	—	
Maximum transverse width of apron	67 mm	—	
Symphysis length	210 mm	—	
Length of distal "foot"	134 mm	—	
Width of distal "foot"	35 mm	—	
Femur			
Length	336 mm	—	
Distal width	70 mm	—	
Proximal width	85 + mm	—	
Least shaft diameter	31.6 mm	—	

Tibia				
Length	368 mm	312 mm		
Length with astragalus	382 mm	324 mm		
Distal width	72.7 mm	63.3 mm		
Proximal width	59 mm	44.8 mm		
Least shaft diameter	28.5 mm	18 mm		
Maximum proximal dimension	83.5 mm	74 mm		
	MCZ 4371	AMNH 3015	YPM 5240	YPM 5205
Metatarsal I length	45.6 mm	—	45.5 mm	
Metatarsal II length	144.3 mm	129 mm		134 mm
Metatarsal III length	164.4 mm	151* mm	—	150* mm
Metatarsal IV length	150.4 mm	134 mm	—	141 mm
Metatarsal V length	78 mm	>34 mm	—	53.3? mm
Phalanges (Pes)				
I ¹ Length	34.8 mm	—	—	32.9 mm
I ² Length along outer curve	48 mm	—	—	>47 mm
II ¹ Length	47 mm	37.7 mm	—	43.5 mm
II ² Length	49.9 mm	42.2 mm	—	49.6 mm
II ³ Length along outer curve	>118 mm	>85 mm	—	>122 mm
III ¹ Length	64.4 mm	52.5 mm	—	59.4 mm
III ² Length	44 mm	33 mm	—	39.9 mm
III ³ Length	41.3 mm	28 mm	—	37.6 mm
III ⁴ Length along outer curve	>75 mm	>50 mm	—	>67 mm

Table I — *Continued*

	MCZ 4371	AMNH 3015	YPM 5240	YPM 5205
<i>Phalanges (Pes) — Continued</i>				
IV ¹ Length	55.5 mm	44.7 mm	—	50 mm
IV ² Length	41.8 mm	35.9 mm	—	36 mm
IV ³ Length	35.2 mm	32.2 mm	—	30.6 mm
IV ⁴ Length	32.6 mm	26.3 mm	—	28.7 mm
IV ⁵ Length along outer curve	>60 mm	>42 mm	—	>55 mm
<i>Humerus</i>				
Length	254 mm	237* mm		
Distal transverse width	51 mm	42.1 mm		
Proximal transverse width	53.8 mm	41* mm		
Width across deltopectoral crest	—	43.5 mm		
Least diameter of shaft	21 mm	18.2 mm		
<i>Ulna</i>				
Length	208 mm	186 mm	180 mm	
Distal transverse width	35.8 mm	32 mm	30 mm	
Proximal transverse width	34.4 mm	31.2 mm	29 mm	
Least diameter of shaft	13.7 mm	11.8 mm	10.9 mm	
	MCZ 4371	AMNH 3015	YPM 5220	YPM 5206

Radius	192 mm	172* mm	172 mm
Length	26.8 mm	23.8 mm	21.4 mm
Distal transverse width	18.1 mm	20.6 mm	20.2 mm
Proximal transverse width	10.3 mm	10 mm	9 mm
Least diameter of shaft	—	35.5 mm	45.8 mm
Metacarpal I length	>90 mm	—	93.7 mm
Metacarpal II length	90* mm	73.4 mm	82 mm
Metacarpal III length	—	—	—
Phalanges (Manus)	—	—	—
I ¹ Length	77.3 mm	—	74.1 mm
I ² Length along outer curve	>100 mm	80* mm	>95 mm
II ¹ Length	64.2 mm	62.2 mm	54 mm
II ² Length	83.4 mm	70.7 mm	76.5 mm
II ³ Length along outer curve	>105 mm	—	>80 mm
III ¹ Length	35 mm	21.7 mm	29.9 mm
III ² Length	23.2 mm	15.5* mm	20.5 mm
III ³ Length	—	47.3 mm	—
III ⁴ Length along outer curve	—	—	>54 mm

* = approximate dimension



Ostrom, John H. 1976. "On a new specimen of the lower Cretaceous theropod dinosaur *Deinonychus antirrhopus*." *Breviora* 439, 1–21.

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