Classifying Dinosaurs Based on Fossils

Imagine that you are a vertebrate paleontologist studying dinosaurs, and your dream comes true—you are invited to join an AMNH expedition to the Gobi Desert in Mongolia.

Over the course of three months, your team has found some spectacular dinosaur fossils that date from the late Cretaceous period. Some of the fossils are complete or nearly complete skeletons, and some are single bones. After the fossils are brought back to the lab and prepared for study, your first task is to identify the dinosaurs that you have found. Having complete skeletons allows scientists to use a wide variety of different characters to identify the dinosaur, but paleontologists can often identify the species based on a single bone.

In this assignment you will examine the characteristics of two different fossils in order to construct evidence-based hypotheses regarding their taxonomic identity. You will first work on identifying a single femur (leg bone) and then shift your focus to a headless skeleton that was found sitting on a nest. Follow the steps in this handout to examine selected characters that will help you make an identification. You may not be able to identify the exact species, but you should be able to narrow it down to a specific set of branches on the dinosaur phylogenetic tree. As you work, please record your observations and respond to reflection questions on the answer sheet provided.

PART I: IDENTIFYING THE FEMUR

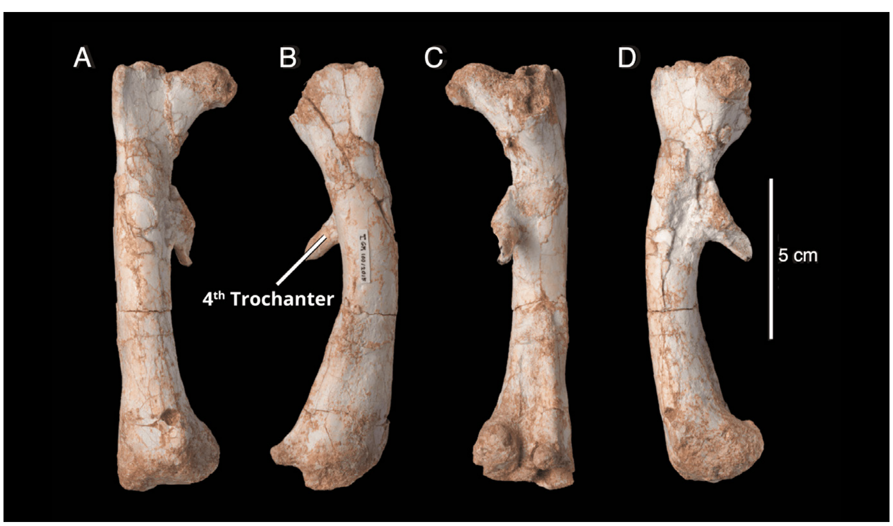


Figure 1. Right femur found in the Gobi Desert in (a), anterior, (b), lateral, (c), posterior, and (d), medial views.

Your instinct as a paleontologist is to ask: What type of dinosaur does this bone belong to? Can it be placed in one of the clades of the dinosaur tree of life? How far can we go in the identification? Immediately, you notice the protrusion on the side of the femur (**Fig. 1**), which is called the fourth trochanter. This structure is the site for the attachment of the caudofemoralis muscle, responsible for the movement of the hindlimbs.

The interesting thing about this structure is that it is highly variable across dinosaurs and other archosaurs (crocs, pterosaurs, and dinosaurs, including birds (**Fig. 2**). That makes it helpful for identifying, or at least getting close to identifying, the species the bone belongs to.

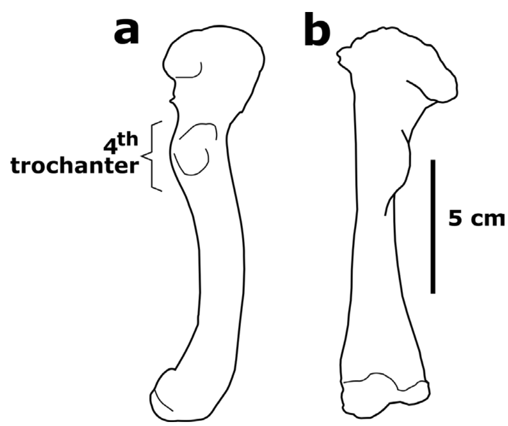


Figure 2. Left femur of an American alligator, *Alligator mississippiensis*, in (a) medial and (b) posterior views.

OBJECTIVE

Your task is to examine the characteristics of the fossil and construct an evidence-based hypothesis regarding the taxonomic identity of the mystery dinosaur femur.

INSTRUCTIONS

- Review the different types of fourth trochanters described for dinosaurs (**Table 1**).
- Examine your fossil specimen (**Fig. 1**).
- Identify the species or clades in the dinosaur phylogeny (**Fig. 3**) that present the same type of fourth trochanter as your fossil.

Record Your Answers on Your Answer Sheet.

TYPE A  *Allosaurus fragillis*	**TYPE B**  *Iguanodon bernissartensis*	**TYPE C**  *Protoceratops andrewesi*	**TYPE D**  *Hypsilophodon foxii*
The fourth trochanter has the shape of a **symmetrical crest.**	The fourth trochanter is strongly **asymmetrical without a finger-like process.**	The fourth trochanter is **asymmetrical with a small finger-like process.**	The fourth trochanter is **asymmetrical with a strong finger-like process.**
This condition is observed in **non-dinosaur archosaurs** such as *Lagosuchus talampayensis*. This condition is observed in some **ornithischian dinosaurs** showing secondary reduction of the fourth trochanter, such as species of the hadrosaur lineage. Among **saurischian dinosaurs**, the condition is observed in sauropodomorphs and some theropods, such as *Allosaurus*.	This condition is observed in **ornithischian dinosaurs** showing secondary reduction of the fourth trochanter, such as *Iguanodon*. It is also observed In **basal theropod dinosaurs**, such as in *Herrerasaurus*. In some groups, the fourth trochanter is further reduced to a large ridge or rugosity. This is observed in **more derived groups**, such as coelurosaurian theropods. In the cladogram, these groups are identified with a star symbol.	This condition is also observed in **ornithischian dinosaurs** in which the fourth trochanter (which originally was Type D) was secondarily lost or reduced. This occurred in *Protoceratops*.	This condition is considered a shared derived character state for the **Ornithischia** clade.

Table 1. Variation of the femoral fourth trochanter across dinosaurs

The general trend in the shape variation of the fourth trochanter is from a symmetrical “bump” or “crest” to a strongly asymmetrical process with a finger-like protrusion. This range of variation can be narrowed down to four types, A–D, which are briefly described in the table. The star added to the line drawings indicates the highest point of the trochanter and serves as a reference for assessing symmetry of the trochanter.

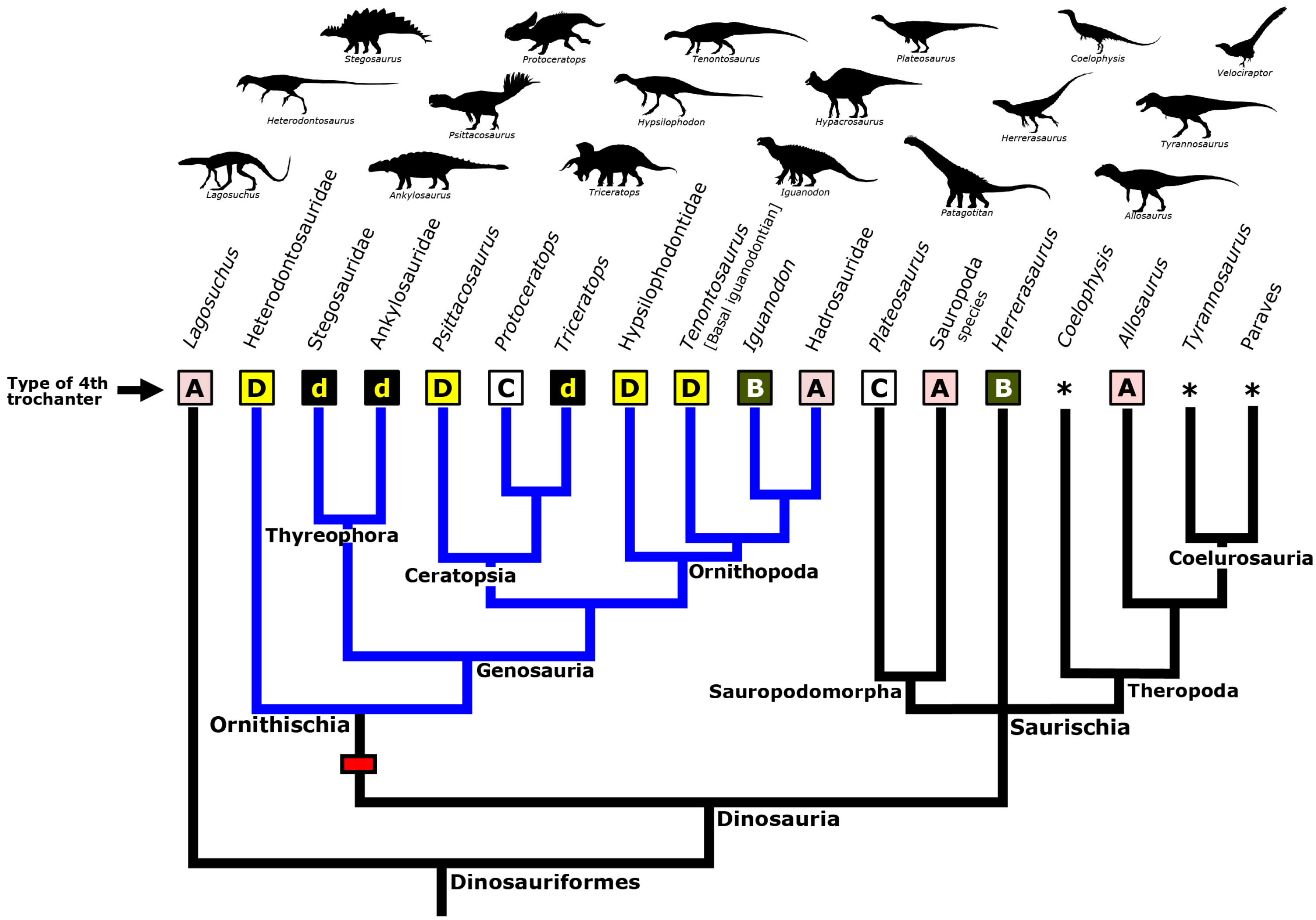


Figure 3. Phylogeny of dinosaurs showing the distribution of the four different types of fourth trochanter, A, B, C, and D. Lower case 'd' identifies secondary reduction of the type-D fourth trochanter. The symbol ' * ' denotes the fourth trochanter reduced to a rugosity or low ridge.

Write Answers to Questions 1-3 on Your Answer Sheet.

PART II: FURTHER IDENTIFYING THE FEMUR

To narrow down your identification, examine the drawings of the femur in *Heterodontosaurus*, *Psittacosaurus*, *Hypsilophodon*, and *Tenontosaurus* and compare them against the mystery femur (**Fig. 4**). First determine whether the fourth trochanter is **entirely** above the midline. Then use the shape to zero in on your final classification.

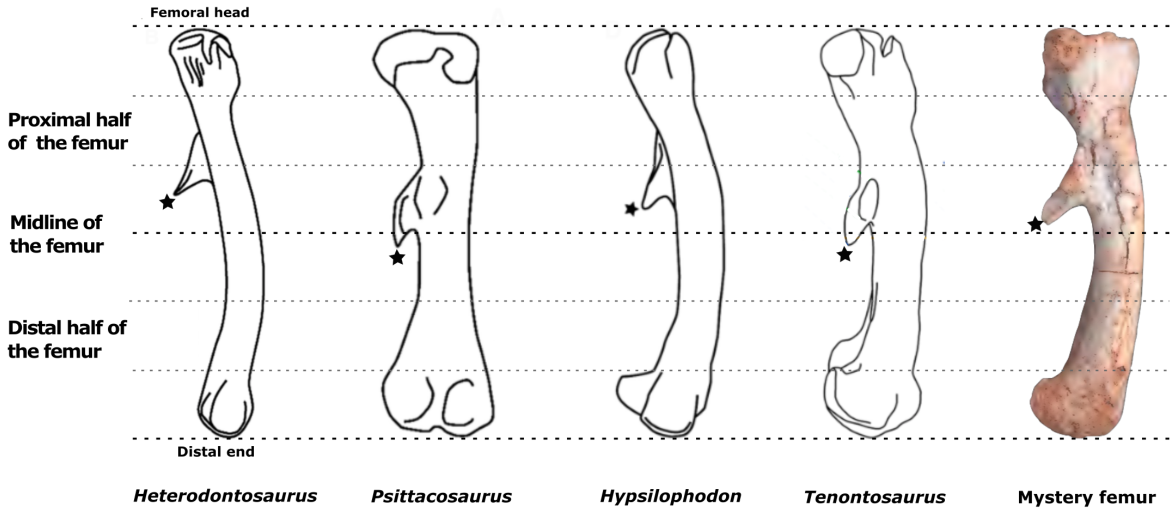


Figure 4. Comparison of the shape and position of the fourth trochanter among species with Type D.

Write Answers to Questions 4-5 on Your Answer Sheet.

PART III: IDENTIFYING A SKELETON

Another find that your team made on the expedition is a fantastic fossil of an adult dinosaur preserved in a brooding position in a nest with eggs. This is a rare and important fossil because it preserves not only the dinosaur's anatomy but evidence of its behavior. Back in the lab, a preparator cleaned the fossil, and the bones were exposed as much as possible. The fossil is nearly complete. It is just missing the head, which isn't unusual in fossil finds. Unfortunately, the head is distinctive and provides characters that would help us identify the species very accurately. But having the rest of the skeleton should allow us to get close.

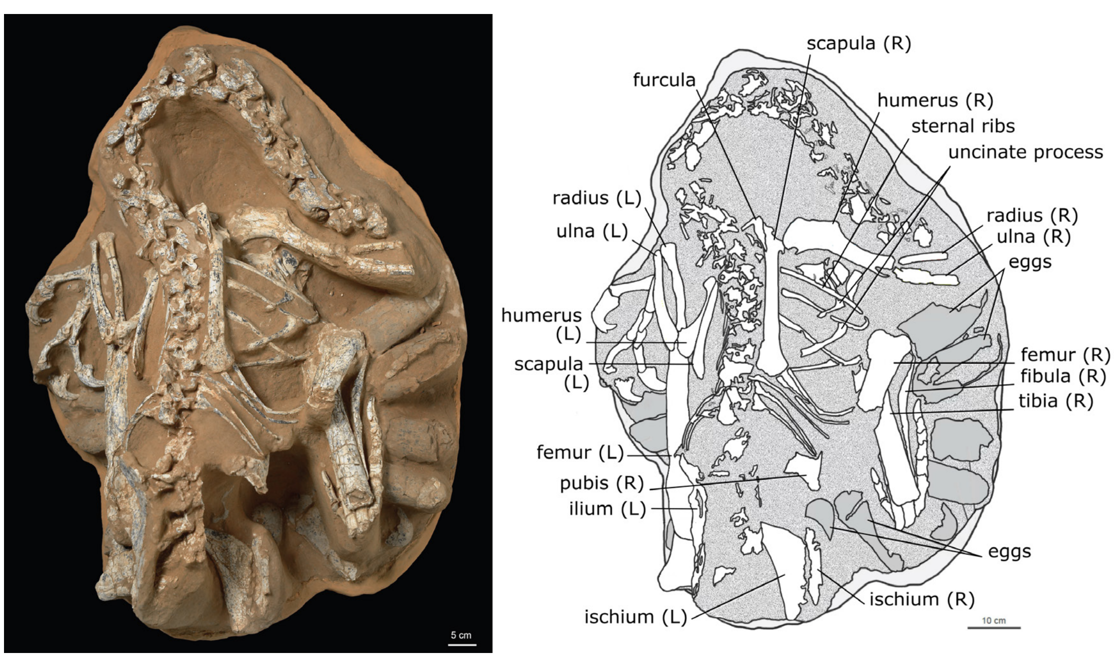


Figure 5. (Left) This picture shows the fossil after it was cleaned and prepared for study. (Right) Labeled drawing of the fossil.

OBJECTIVE

The goal of this investigation is to assess the available evidence to infer the most likely place of the fossil in the phylogeny of dinosaurs. Without any head bones, we may not be able to pinpoint the species, but just figuring out which dinosaurs the fossil is close to can be significant.

INSTRUCTIONS

You will carry out the investigation using the phylogeny of dinosaurs and descriptions of some of the characters that provide the evidence to determine which clade a dinosaur belongs in. Where do these characters come from? When paleontologists publish a new phylogeny, they also include a detailed description of each character that supports each of the clades. (When we use a character to assign a dinosaur to a clade, we say that the character “supports” the clade.) We can use those descriptions as clues to determine where the fossil fits. Each character has a derived state and an ancestral state. Only the derived states can be used to support the monophyly of a clade (See the essay **Reconstructing Dinosaur Phylogenetic Trees** from this week).

Let’s look at an example. The claim that dinosaurs are a group of species that share a more recent common ancestor is supported by, among other characteristics, the presence of the hole in the hip socket. The absence of this trait is proposed as the ancestral condition. We can check what the hip looks like in the new fossil, and if it has a hole in the hip socket, we can use this as evidence to infer that this fossil is also a dinosaur.

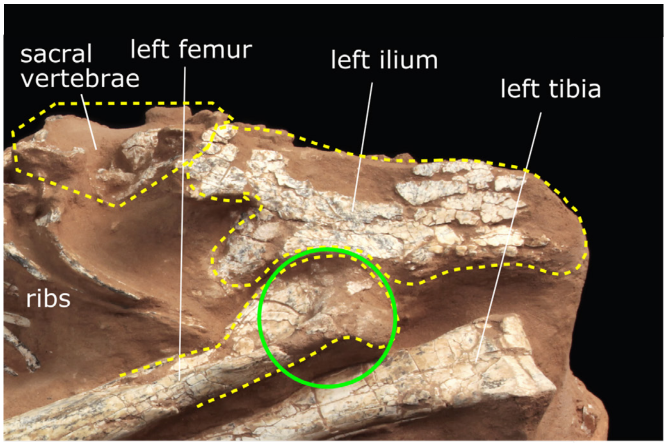
Fill in the table and cladogram on the answer sheet (Questions 1 and 2 from Part III) using the information below to guide your investigation.

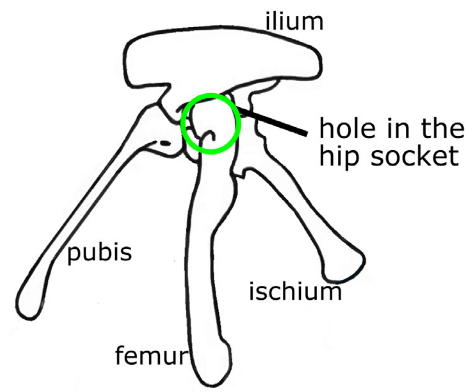
Record Your Answers on Your Answer Sheet.

CHARACTER DESCRIPTIONS

1. Hole in the hip socket: The presence of hole in the hip socket is a *derived state* for the clade Dinosauria.

Ancestral condition: The hole in the hip socket is not developed.

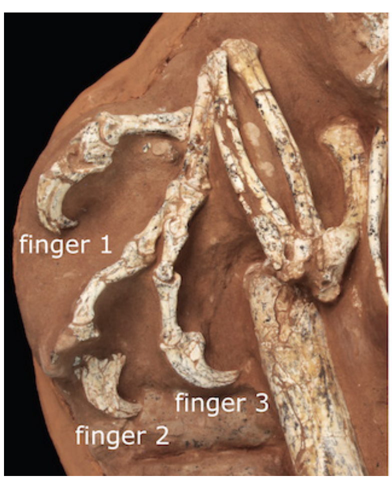


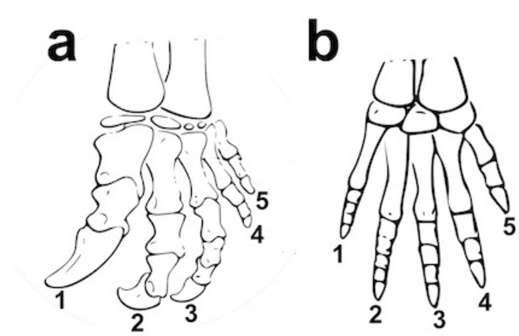


Partial view of the left hip bones showing the head of the femur fitting in the hole of the hip socket (called acetabulum).

2. Grasping hand: The presence of a grasping hand (a) is a shared derived character state of the Saurischia clade within Dinosauria. This trait involves a combination of unique characteristics: The fingers differ in size and shape; the thumb is strong and offset from the hand plane; and the second finger is the longest.

Ancestral condition: hands with fingers similar in length and shape (b)





Dorsal view of the left hand and drawing of the shared derived condition (a) and the ancestral condition (b).

CHARACTER DESCRIPTIONS CONT.

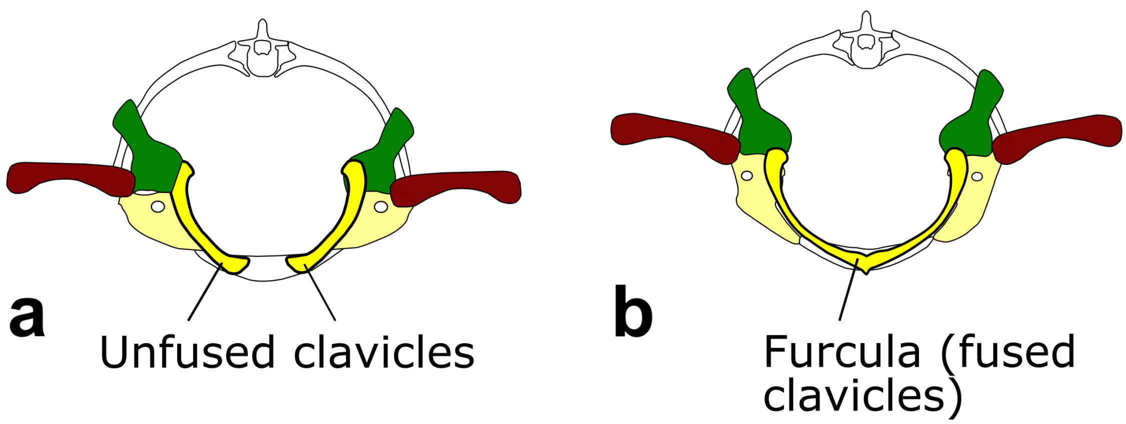
3. Femoral fourth trochanter: The presence of a well-developed fourth trochanter—the site for the attachment of leg muscles—is a shared derived character state of the Ornithischia clade within Dinosauria.

Ancestral condition: absence of a well developed fourth trochanter

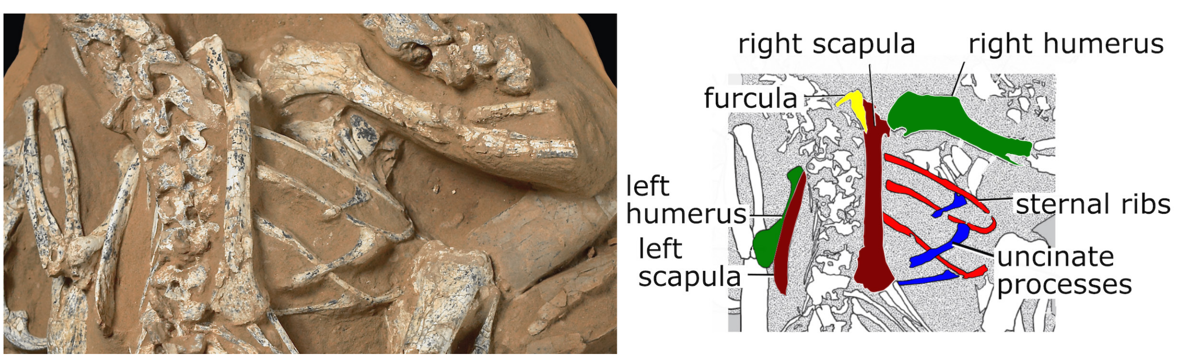
You can check for the presence of the fourth trochanter on the femur in the image for Character 1.

4. Coracoids fused along the midline forming the furcula: The presence of a wishbone (furcula) is a shared derived condition for the Theropoda clade within Saurischia.

Ancestral condition: absence of a furcula



Comparative diagrams of shoulders with unfused clavicles (a) and clavicles fused in the midline forming a furcula (b).



Dorsal view of the fossil showing the shoulder bones and ribs.

CHARACTER DESCRIPTIONS CONT.

5. Length of the leg bones: Having the tibia shorter than the femur is a shared derived condition for the Saurapodomorpha clade within Saurischia.

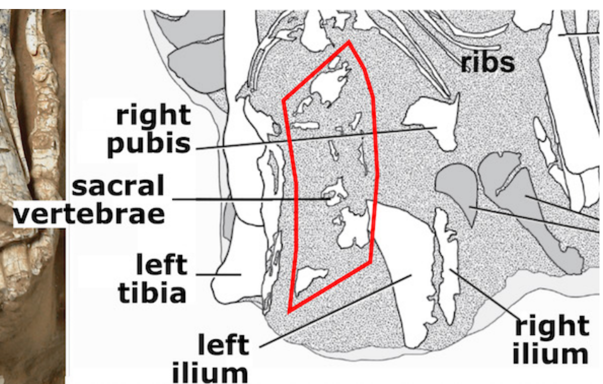
Ancestral condition: Tibia longer than the femur

You can compare the lengths of the left femur and left tibia in the image for Character 1.

Additional information: All the bones of the fossil were carefully measured in the lab. The left tibia was completely preserved although broken in two pieces, 183 mm and 270 mm long, each. The femur is approximately 402.4 mm. Which is the longer bone?

6. Sacral ribs fused to the ilia (plural of ilium): Among adult ceratosaurs, the sacral vertebrae are extensively fused between each other and with the sacral ribs. The ribs, in turn, are fused to the ilia (hip bones). This is a shared derived condition for the Ceratosauria clade within Theropoda.

Ancestral condition: Sacral ribs are not fused to the ilia.



The relationship between the sacral vertebrae and the ilia can also be seen in the image for Character 1, although there is a partial view of the bones. What would we expect to observe if the bones are fused in any way? What do you observe?

7. Number of fingers: Having three fingers is a shared derived state for the Tetanurae clade within Theropoda.

Ancestral condition: having five fingers

Go back to the image of the hand included in the description of Character 2 to check on this character.

CHARACTER DESCRIPTIONS CONT.

8. Uncinate process connecting the ribs: The presence of a bony uncinate process is a shared derived state for the Pennaraptora clade within the Maniraptora.

Ancestral condition: bony uncinate process not present

You can check for the presence of the uncinate process in the image for Character 4.

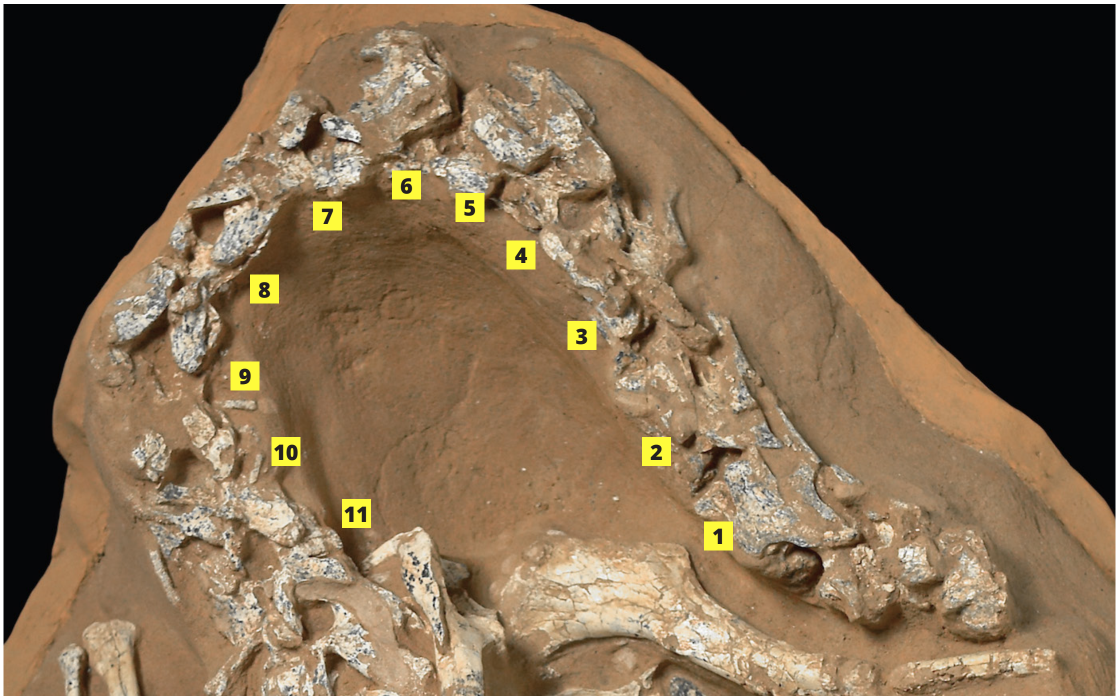
9. Scapula/humerus length: Having the humerus longer than the scapula is a shared derived state for the Paraves clade within the Pennaraptora.

Ancestral condition: scapula longer than humerus

You can observe the scapulae and humeri in the image for Character 4.

10. Neck length: Having a long neck, with 11 to 13 cervical vertebrae, is a shared derived state for the Oviraptorosauria clade within Pennaraptora.

Ancestral condition: neck short, with fewer than 11 cervical vertebrae

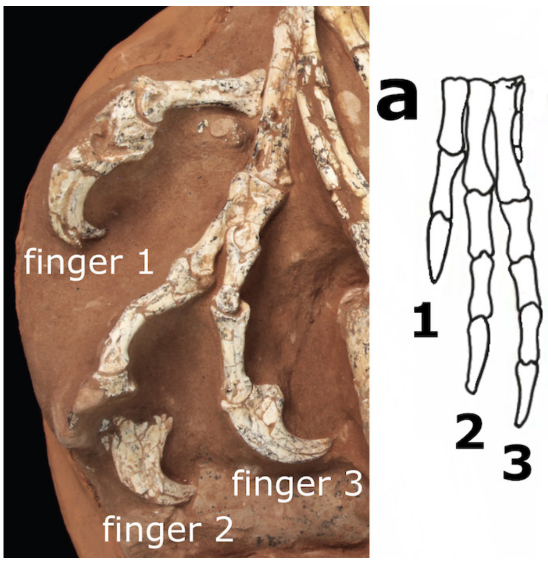


Dorsal view of the fossil with close-up of the cervical vertebrae.

CHARACTER DESCRIPTIONS CONT.

11. Relative length of the fingers: An evolutionary trend toward a shorter finger 3 can be observed in Oviraptorosauria. Having finger 3 slightly shorter than finger 2 is a shared derived state for the Oviraptoridae clade (b). Having finger 3 much shorter than finger 2 is a shared derived state for the Caegnathidae clade (c).

Ancestral condition: Finger 3 visibly longer than finger 2 (see hand a)



Dorsal view of the left hand.

Summarize your finding by responding to Question 3 in Part III of your answer sheet.

CREDITS
Parts 1 and 2:
Figure 1: M. Ellison/© AMNH

Figure 2: © AMNH adapted from Persons and Currie 2019, The Anatomical and Functional Evolution of the Femoral Fourth Trochanter in Ornithischian Dinosaurs. *The Anatomical Record*

Table 1: © Persons and Currie 2019 (4)

Figure 3: *Stegosaurus* by artrociraptor; *Protoceratops* by Emily Willoughby; *Tenontosaurus* by Matt Dempsey; *Plateosaurus* by Jack Mayer Wood; *Coelophysis* by Tasman Dixon; *Velociraptor* by Tasman Dixon; *Heterodontosaurus* by Jaime Headden; *Psittacosaurus* by Tasman Dixon; *Hypsilophodon* by Scott Hartman; *Hypacrosaurus* adapted from Slate Weasel; *Herrerasaurus* by Tasman Dixon; *Tyrannosaurus* by Matt Dempsey; *Lagosuchus* by Steven Traver; *Ankylosaurus* adapted from Slate Weasel; *Triceratops* by Jagged Fang Designs; *Iguanodon* by Tasman Dixon; *Patagotitan* by artrociraptor; *Allosaurus* by Jagged Fang Designs

Figure 4: © Persons and Currie 2019 (4); M. Ellison/© AMNH

Part 3:
All figures © AMNH

Answer Sheet:
Ceratosaurus by Tasman Dixon; *Spinosaurus* by Tasman Dixon; *Deinocheirus* by T. Michael Keesey; *Falcarius* by Scott Hartman; *Anzu* by Brad McFeeters (vectorized by T. Michael Keesey); *Khaan* adapted from Scott Hartman; *Talos* by FunkMonk; *Cardinalis* by Stacy Farina; *Archaeopteryx* by Scott Hartman; *Microraptor* by Brad McFeeters (vectorized by T. Michael Keesey)

