## Lesson 10 - B

# Interdisciplinary Mystery

## Using Dinosaur Tracks to Understand Animals in an Ancient Environment

**Summary**
In this interdisciplinary mystery, students will work with photos and drawings from a dinosaur trackway found in the Hell Creek Formation in South Dakota and try to determine who made the tracks and how fast they were moving. They will compare this site-specific information with other track data.

**Objectives**
Students will be able to:

1. Calculate how fast a dinosaur could move.
2. Explain that different dinosaurs left behind different kinds of tracks.
3. Explain what type of environment is better for preserving tracks.

**Estimated teaching time**
NA

**Groups**
NA

**Materials**

- Worksheets and life-sized photograph of dinosaur tracks

**Teachers Background**
While fossilization has the potential to leave behind only one set of bones per animal, it could result in hundreds to thousands of preserved tracks per animal. Paleontologists refer to such imprints as trace fossils, as opposed to body fossils such as bones or teeth. Not only do they have the potential to be more numerous, trace fossils can also reveal aspects of animal's life not shown by body fossils. For example, tracks can show how fast an animal moves, how it moved, if it traveled with another of its kind, how it hunted, and how it rested.

As you have probably observed, tracks are generally ephemeral and only form in certain environments, thus finding them in the fossil record is rare. Wet sand and mud are good mediums for recording animal movement. Preservation requires new sediments of a different texture or color to fill in, bury, and protect the tracks. Then the tracks have to be buried and changed into rock and finally, that rock has to be exposed at the surface and be discovered.

The Hell Creek site presented here consists of 16 consecutive theropod tracks. They are preserved as three-dimensional casts in ironstone (a hard sandstone). Most of the footprints show a well-developed impression of the hindpart of the foot (normally dinosaurs walked on the front of their feet), which suggests that the track maker was sinking into the mud, either because of the soft sediments or a deliberate stalking behavior.

The goal of this activity is to get students to see what tracks look like in the field, how paleontologists preserve the tracks, and how they incorporate this data into their research.

Note: Although it has been used for many years, there is debate in the paleontological community about the formula used to calculate speed used in this activity. Some claim that the speeds may be too low as the dinosaur's hind limbs were very different than those found in living mammals and birds. Furthermore, dinosaurs often had relatively large muscles in their buttocks, which would have changed how they walked and/or ran. In contrast, some have argued that dinosaurs had very small ankle muscles, which would have made running challenging. And finally, substrate can also influence the measurements of foot length and stride length, leading to additional errors. That being written the formula used in this exercise is the most widely accepted.

**Facilitating the activity**
Pass out worksheet (pp. 2-6) to students. As noted in the introduction to this lesson, teachers should give a broad overview of activity to the students and tell them that each group is contributing to solving the overall issue of the paleoenvironment of the Hell Creek.

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## Using a Dinosaur Tracks to Understand Animals in an Ancient Environment

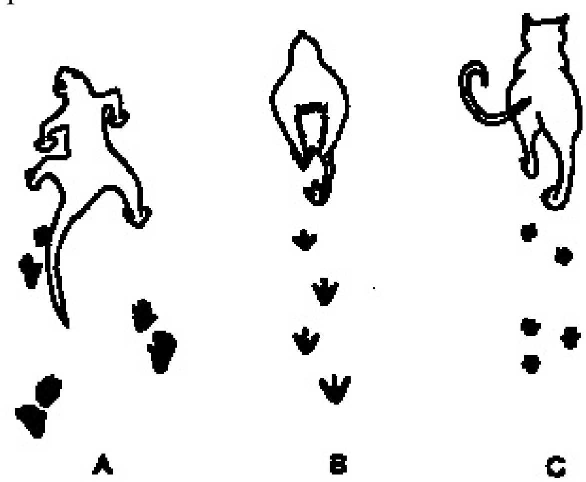
**Summary**
In this activity you will work with photos and drawings from a trackway found in the Hell Creek Formation in South Dakota and try to determine who made the tracks and how fast they were moving. You will also compare the South Dakota data with other track data.

### Question 1

When animals walk they generally produce three different types of tracks.

A. A reptile's legs are directed out away from the body and move by its body laterally bending or flexing (Trackway A)
B. The bipedal gait of a bird or a human leaves a distinctive trackway with which we are familiar (Trackway B).
C. A mammal has its legs directly beneath its body and swings each leg in an anterior-posterior direction (Trackway C).

Because the legs of a dinosaur are beneath the body, bipedal dinosaur footprints would be like a human or a bird, and quadrupedal dinosaurs would be like a cat or an elephant.




Trackways of living animals.
(Redrawn and modified from Alexander, 1989)

**1a. Looking at these two photographs, what type of animal do you think produced these tracks?**
*"Track one" shows the tracks in plaster casts, which the paleontologists used to protect the tracks when they were dug up and removed for further study in a scientific lab.*
*"Track two" shows the tracks in place, in sandstone, after they have been cleaned up a bit.*

a. Lizard
b. Mammal
c. Bird
d. Dinosaur

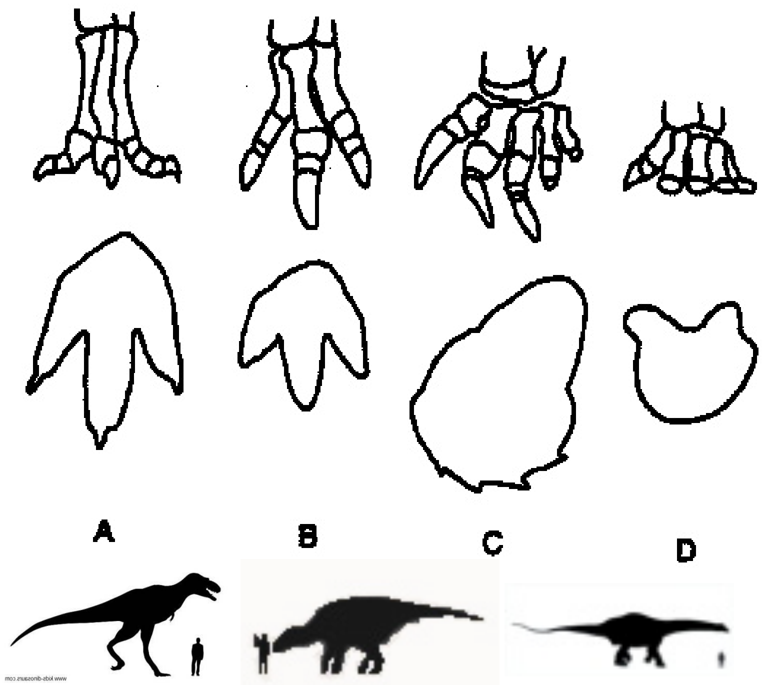
**1b. Why do you think this?**

### Question 2

**2a. Where did this track maker live? (Think about what type of rock the tracks were preserved in, when and where you have seen tracks (human or animal), and what type of environment they were in. Would that have been a good place to preserve them?)**
a. In a sandy desert, where winds blew regularly.
b. Near a fast moving river where water washed away sediments.
c. A river flood plain or muddy beach, where fine-grained sand and silt slowly accumulated.
d. Sandy beach near a sea, where waves constantly washed ashore.

**2b. Why do you think this?**

## Question 3




Foot bone structure and typical footprints of three dinosaurs shown above
*(redrawn and modified from Alexander, 1989 -- scale of dinosaurs relative to a person)*

**A.** Hind foot of *Tyrannosaurus* **B.** Hind foot of *Iguanodon*
**C.** Hind foot of *Apatosaurus* **D.** Fore Foot of *Apatosaurus*

Dinosaur feet had three or five toes. Theropods and many bipedal ornithischians had long toes (Figures A and B), so that a three-toed or triangular footprint was made. Alternatively, the large sauropods probably had massive legs and more rounded, more flat-bottomed feet like those of an elephant with five short toes (Figures c and d).

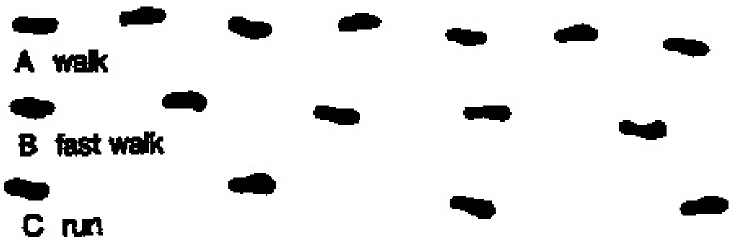
**3a. Looking at single track photograph (Track Three), what type of dinosaur made this track?**

a. Theropod
b. Sauropod

**3b. Use the life sized track photograph (Track Three) to determine how long the animal's foot was.** *Note that the scale in the photo shows centimeters (shorter black bars) and inches (longer black bars). Also, note that you do not want to measure the additional narrow part at the end of the middle toe.*

**How big was it? _________**

## Question 4




Speed can be determined by looking at a trackway because stride length is positively correlated with speed, i.e., as speed increases stride length increase

Notice how human tracks change as speed changes. (Redrawn and modified from Alexander, 1989)

**Step by step process to determine speed of animal at the *Wakangi styxi* site.**

4a. What was the *foot length* of the animal in the trackway (use foot length from question 3)._________

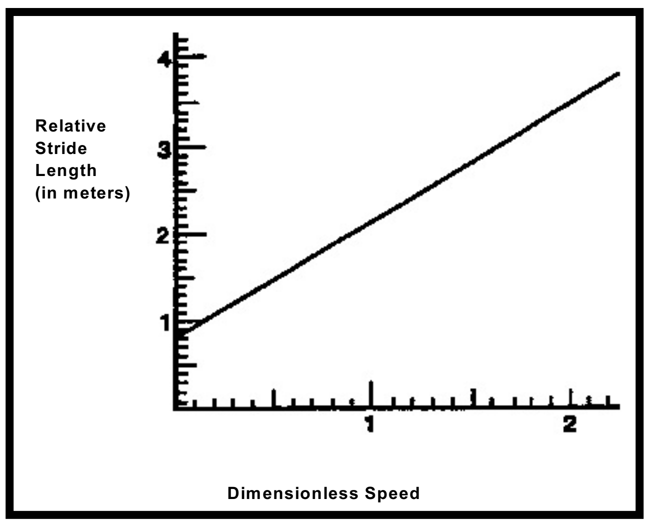
4b. What was the *stride length* of the animal in the trackway. Use average heel-to-heel measurements in CM from drawing of *Wakangi styxi* site to find a stride length. ___________

4c. Calculate the *leg length* by multiplying "foot length" by 4. Leg length gives you an idea of how tall the animal was as it shows the height of the animal at its hip.

(*Foot length*_______) X 4 = *Leg length* ____________

4d. Calculate the *relative stride length* by dividing the *stride length* by the *leg length*.

(*Stride length*________)/(*Leg length*________)
= *Relative stride length* _______________




4e. Use the figure to the right to determine the *dimensionless speed* from the *relative stride length* that you calculated above. If the relative stride length is less than 0.9, use 0.1 for the dimensionless speed.

Dimensionless Speed = ___________

4f. Using appropriate values determined above, calculate the dinosaur *speed* using the following equation, where gravitational acceleration is 10 meters per second-squared (10 m/sec$^2$) The calculated dinosaur speed will be in meters per second.

*Speed* = (*dimensionless speed*) X (square root of (*leg length* X *gravitational acceleration*))

4g. Based on how tall the animal was, describe how fast the animal was moving. Examples might include trotting, running, moseying, walking, galloping, sprinting, or a stealthy and quiet walk.

## Question 5

Determine the speeds of at least two dinosaurs from each category.

| | Stride Length (meter) | Leg Length (meter) | Speed |
|---|---|---|---|
| **Meat Eaters** | | | |
| *Tyrannosaurus* | 3 | 2.1 | |
| *Allosaurus* | 3 | 2 | |
| *Megalosaurus* | 1.3 | 1.1 | |
| *Velociraptor* | 2.7 | 1 | |
| | | | |
| **Plant Eaters** | | | |
| *Apatosaurus* | 2.5 | 3 | |
| *Apatosaurus* | 1.6 | 1.5 | |
| Hadrosaur | 4.2 | 3.4 | |
| *Stegosaurus* | 1.9 | 1.4 | |

5a. Which dinosaurs could you outrun?

5b. Which group ran faster?

5c. What can you infer about the predator-prey relationships between meat and plant eaters?

5d. How did meat eaters capture their prey?

5e. How did plant eaters avoid being captured?