COULD YOU HAVE OUTRUN A DINOSAUR?

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Life-size outlines of dinosaur footprints are taped to the hallway floor to simulate a trackway shown in the back of the lab exercise. One sauropod and one theropod trackway is assembled. An explanation is given for the series of calculations and graphical determinations that will be needed. Then, in teams of three, students come out into the hallway to measure the two trackways. Prior to and after making their measurements, students run through the calculations. With all data in hand, students answer the questions at the close of the exercise.

W.I. Ausich – The Ohio State University

Name ____________________

Lab Time ________________

EARTH SCIENCES 110--HISTORY OF LIFE ON EARTH: GLOBAL CHANGE IN THE BIOSPHERE

Exercise IX

COULD YOU HAVE OUTRUN A DINOSAUR?

PURPOSE: Use of trace fossils to determine locomotion behavior of dinosaurs and, from this, to infer aspects of dinosaur biology and ecology.

INTRODUCTION

Trace fossils are unique remnants of ancient life. Unlike body fossils, trace fossils record actions made by organisms which once inhabited the Earth; and therefore, commonly yield information about the behavior of the ancient organisms.

Study of dinosaur trace fossils has taken on new importance in recent years, because the behavior encoded in dinosaur trace fossils may give us insight into the debate as to whether dinosaurs were cold-blooded like living reptiles or warm-blooded like living birds and mammals. It may seem as though dinosaur footprints would have a very low probability of preservation in the rock record, and indeed they did. In order for a footprint or trackway to be preserved, an animal would have to walk along soft ground to leave footprints, and then these would have had to be rapidly buried by a contrasting sediment, so that they could eventually weather out on a sedimentary rock bedding surface. Despite this low probability, numerous well-documented dinosaur trackways are preserved for the simple reason that millions and millions of dinosaurs existed during the Jurassic and Cretaceous (approximately 100 million years). With every step each of these extinct organisms made an impression in wet sediment or a scuff on hard turf which, if buried, could become a fossil footprint.

Two types of dinosaurs need to be considered in the context of fossil trackways -- bipedal and quadrupedal dinosaurs. Each of these types should leave a distinctive trackway. Three trackway types are common (Figure 1). The bipedal gait of a bird or a human leaves a distinctive trackway with which we are familiar (Figure 1b). Alternatively, quadrupedal organisms have two alternative gait styles. A reptile has its legs directed out away from the body and moves its legs by bending or flexing its body laterally (Figure 1a); whereas a mammal has its legs directly beneath its body and swings each leg in an anterior-posterior direction (Figure 1c).

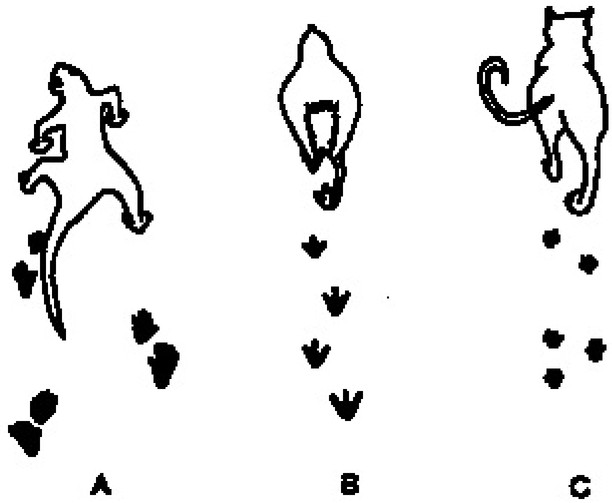

FIGURE 1 -- Trackways of living animals; a, lizard; b, bird; c, mammal (redrawn and modified from Alexander, 1989).

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 (Figure 2).

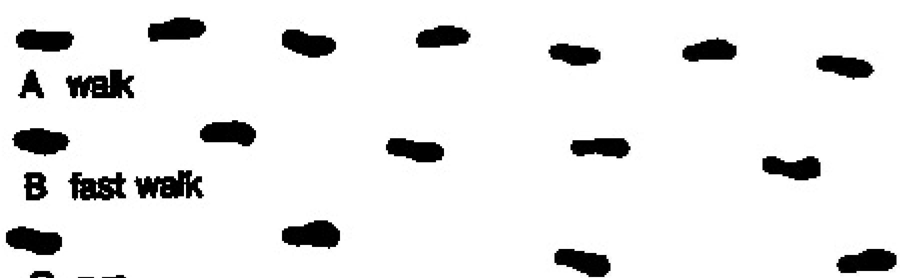

FIGURE 2 -- Changes in stride length and speed in human trackways (redrawn and modified from Alexander, 1989).

Dinosaur feet varied considerably in size and shape. Structurally they had three or five toes. Theropod and many bipedal ornithischians had long toes (Figure 3a,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 (Figure 3c,d).

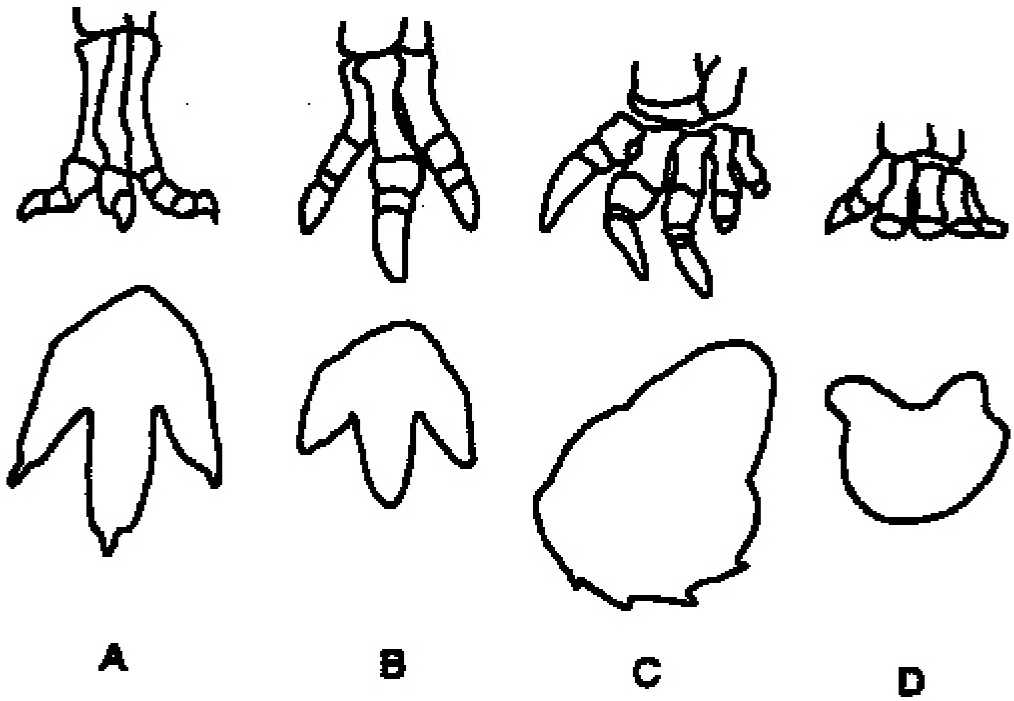

FIGURE 3 -- Foot bone structure and typical footprints in three dinosaurs. a, hind foot of *Tyrannosaurus*; b, hind foot of *Iguanodon*; c, hindfoot of *Apatosaurus*; and d, fore foot of *Apatosaurus* (redrawn and modified from Alexander, 1989).

How fast should a dinosaur have run? This is a question that we cannot measure directly, but we can compare calculated dinosaur speeds with speeds attained by living organisms, which can be directly measured. Table 1 is a list of a few land speeds among living organisms.

TABLE 1 -- Land speeds for various living organisms.

Animal	Speed (m/sec)
Fastest Human	10
Zebras	11-14
Antelopes	11-14
Giraffes	11-14
Greyhounds	16
Racehorse	17

PROCEDURE FOR CALCULATING DINOSAUR LOCOMOTION SPEEDS

Unfortunately we cannot use a stopwatch to determine the speed of a galloping dinosaur, so we must rely upon some indirect calculations. The assumptions that we must make include the relationship between foot length and leg length and the relationship between relative stride length and dimensionless speed. The method that we will use has been demonstrated empirically to be valid for mammals and birds. Therefore, because dinosaurs had a posture with their legs directly beneath their bodies, this method should also generally be applicable to dinosaurs.

To calculate dinosaur walking or running speed, appropriate measurements and calculations must be made in order to compute the speed (see Table 2). Specific steps are given below. Additional discussion of this can also be found at <www.shef.ac.uk/uni/academic/D-H/cs/DINOCO1/dinocal1.html>.

TABLE 2 -- Sample calculations and measurements for dinosaur speed determination. See discussion below. Note that two direct measurements must be made: foot length and stride length.

Track #	Foot Length	Stride Length	Leg Length	Rel. Stride Length	Dim'less Speed	Speed
Sample	0.75m[*]	4.22m[*]	3.00[**]	1.41[**]	0.5[**]	2.7[**]

[*] measured; [**] calculated

1. <u>Measure</u> *foot length* on a trackway (take average if possible).

2. <u>Measure</u> *stride length* along a trackway (take average if possible). Stride length is determined by measuring the distance between the same point on two successive footprints of the same foot.

3. <u>Calculate</u> *leg length* by multiplying "foot length" by 4.

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

4. <u>Calculate</u> *relative stride length* by dividing the *stride length* by the *leg length*.

$$(\textit{Relative stride length}) = \frac{(\textit{Stride length})}{(\textit{Leg length})}$$

5. Using Figure 4 <u>determine</u> 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.

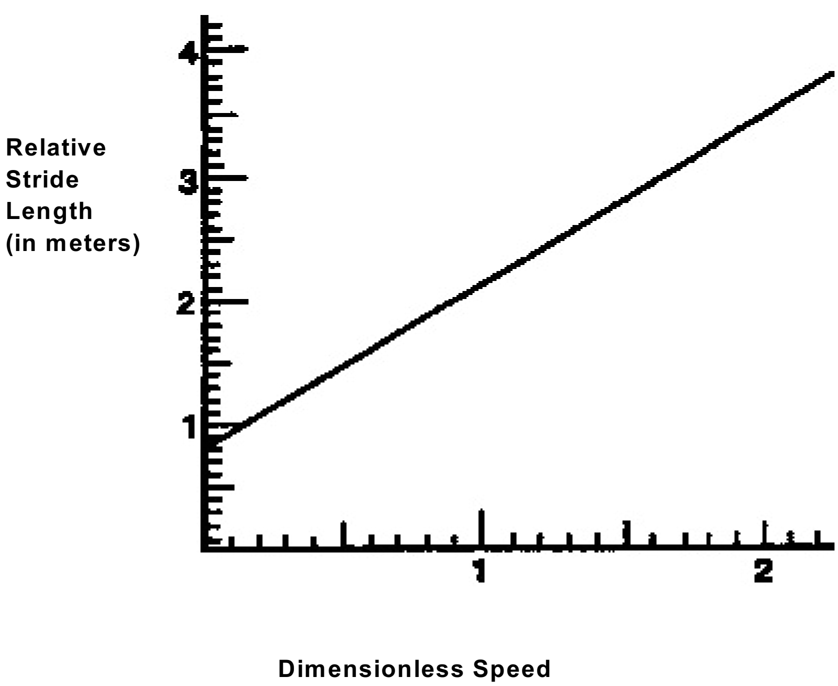

FIGURE 4 -- Graph illustrating the relationship between relative stride length and dimensionless speed among birds and mammals. This diagram will be used in this exercise to determine the dimensionless speed value for dinosaurs (redrawn and modified from Evans, 1990).

6. Using appropriate values determined above, <u>Calculate</u> the dinosaur *speed* using

the following equation, where gravitational acceleration is 10 meters per second - squared ($10\ m/sec^2$) Calculated dinosaur speed will be in meters per second.

$$Speed = (dimensionless\ speed) \times \sqrt{(leg\ length) \times (grav.\ accel.)}$$

An example is given above in Table 2 in which the following measurements were taken: foot length: 0.75m; stride length: 4.22m.

ASSIGNMENT

A. Speed Determinations

Using the procedure outline above, determine the speed of various dinosaurs by making the necessary measurements and calculations to answer the questions at the end of the exercise.

1. Make necessary foot length and stride length measurements on trackway 1 and trackway 2 and record them on Table 3. These trackways are life-size reconstructions from the Lower Cretaceous trackways preserved at Dinosaur Valley State Park along the Paluxy River Valley in Texas. Trackway 1 is the "East Trail" at the Sauropod Section site (Figure 5). It is some type of large sauropod dinosaur. Trackway 2 is from a bipedal theropod dinosaur and is "Trail 1" at the Bluff Overlook site (Figure 6). Enter these measurements on Table 3 as trackway 1 and trackway 2, respectively. From these measurements, calculate dinosaur speed, and fill in all of the columns of Table 3 appropriately.

2. Complete Table 3 by calculating the other dinosaur speeds from the foot length and stride length measurements given.

TABLE 3 -- Sample calculations for dinosaur speed determination. Measurements in meters.

Trackway	Foot Length	Stride Length	Leg Length	Rel. Stride Length	Dim'less Speed	Speed
1						
2						
<u>Other Theropods</u>						
3	.40	3.02				
4	.36	5.36				
5	.25	1.98				
6	.45	7.05				
<u>Other Sauropods</u>						
7	.78	3.98				
8	.62	2.63				
9	.85	3.23				

B. <u>Questions</u>

1. Could you have outrun a dinosaur?

2. Do the speeds calculated for these dinosaurs seem plausible for a warm-blooded organism?

3. Who ran faster, sauropods or theropods?

4. What can you infer about the predator-prey relationships between these theropods and sauropods? How did theropods capture their prey? How did sauropods avoid being captured.

REFERENCES

Alexander, R.M. 1989. Dynamics of Dinosaurs and Other Extinct Giants. Columbia University Press, New York, 167 p.

Evans, R.H. 1990. The physics of dinosaurs. The Physics Teacher 6:364-371.

Farlow, J.O. 1987. Lower Cretaceous dinosaur tracks Paluxy River Valley Texas. Department of Geology, Baylor University, 50 p.

See also <www.shef.ac.uk/uni/academic/D-H/cs/DINOCO1/dinocal1.html>

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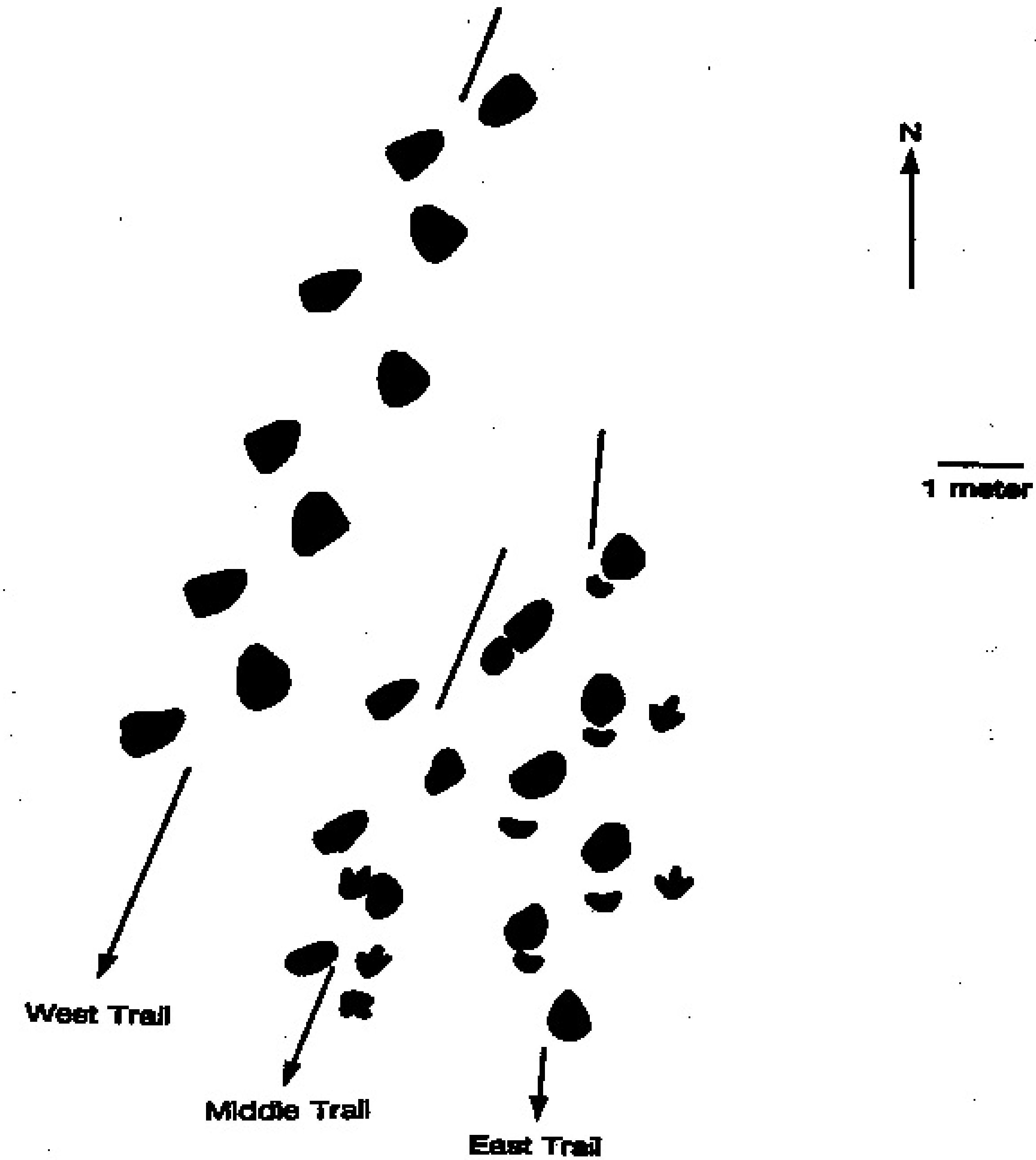

FIGURE 5 -- Lower Cretaceous dinosaur trackways at the Sauropod Section site of Dinosaur Valley State Park along the Paluxy River Valley in Texas. Trackway 1 for this exercise is a replica of the "East Trail". The "East Trail" is some type of large sauropod dinosaur, which has print from both the front and back feet. Note that the "West Trail" has only back foot tracks, which means that its back feet stepped onto the footprints of the front feet. (redrawn and modified from Farlow, 1987).

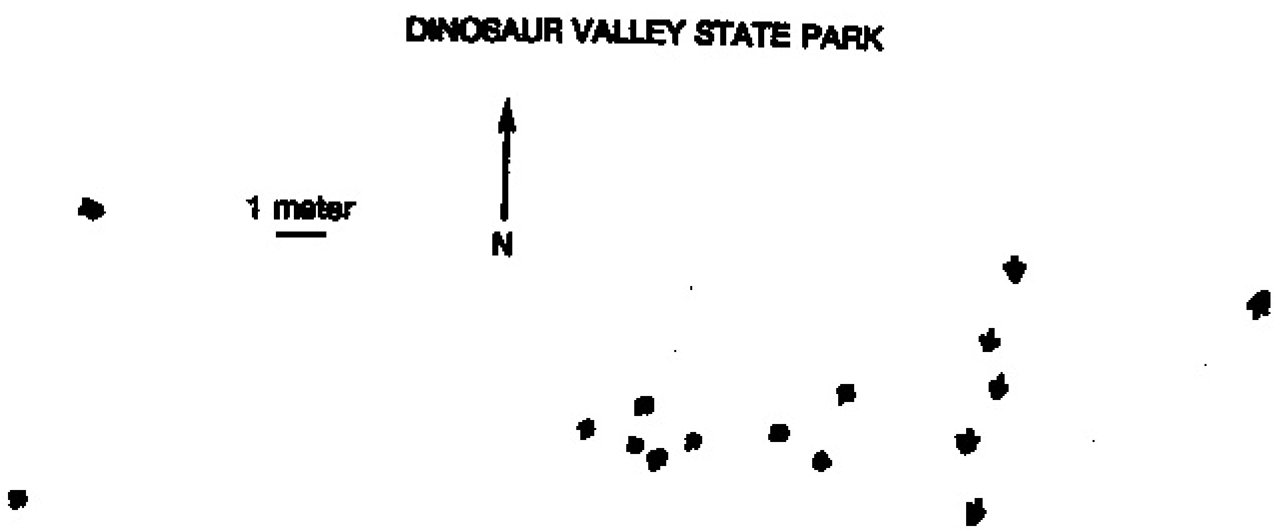

FIGURE 6 -- Lower Cretaceous dinosaur trackways at the Bluff Overlook site of Dinosaur Valley State Park along the Paluxy River Valley in Texas. Trackway 2 for this exercise is a replica of "Trail 1, which is the set of five prints running toward the north. This trackway is from a bipedal hadrosaur dinosaur. (redrawn and modified from Farlow, 1987).