STRIDING THROUGH TIME: ***An Investigation into Dinosaur Tracks***

http://commons.wikimedia.org/wiki/File:Dinosaur_Ridge_tracks.JPG

In the beginning of this semester, we studied different fossil preservation types, including permineralization, carbonization, replacement, casts, and unaltered remains. Trace fossils are included as one of the fossil types, but they are rather unique: Whereas body fossils can provide information about the anatomy of an organism, trace fossils can supply details about an organism's environment and *behavior,* such as its movement and speed. How do scientists determine behaviors from trace fossils? They use the construct of uniformitarianism to investigate extinct life forms, based on observations of living organisms!

Zoologist R. McNeill Alexander (1976) researched modern animals, and derived a general formulaic relationship that related an animal's speed to its hip height (leg length [LL]) and its stride length (SL). This formula has been simplified for classroom use, but it has also been more extensively researched and modified for greater accuracy. We can now apply these formulas to tracks preserved in stone, made by animals that are no longer alive!

This research project will require that you investigate trace fossil tracks—in particular, dinosaur tracks—by first starting with humans' gaits and speeds, and then exploring possible connections between footprints and height. Next, this investigation is extended to *extinct* animals, or those from whom we cannot make direct observations. Finally, you will have an opportunity to *apply* this learning and *construct* your own, accurate trackway display.

Guidelines for the Research: Remember, all measurements should be recorded in METRIC UNITS!

Part I: The Human Gait and Speed Connection

You will begin by examining the connection between human gait and speed. You will need some colleagues for this activity. You will also need a measuring tape, a stopwatch, a recording chart, and a bright ribbon.

1. You will need a minimum of six individuals (two groups of three).
2. Measure out a 20-m path. This can be done on a sidewalk in front of your school or house. You may want to mark the start and finish lines with sidewalk chalk.
3. Each group member will take turns 1) walking and running the path, 2) recording the number of strides of a runner, and 3) recording the time required for a runner to traverse 20 m.
4. For the first runner, tie the bright ribbon around his or her left ankle. The first runner will then WALK the 20-m path at his or her preferred speed.
   a. The stride recorder will count how many times the left foot (with ribbon) touches the ground. Remember, stride length is the measure between *successive* right or left foot steps, NOT the distance between right and left footsteps. Therefore, you must measure from left foot to left foot.
   b. The time recorder will use the stopwatch to measure the number of seconds required for the runner to walk the 20 m path.
5. After the runner walks the path, repeat this experiment, but this time the runner RUNS along the path. Use the same methods as before.
   a. What relationship do you observe with each runner's time and number of strides as he or she completes the path either walking or running?
6. Each group member takes a turn being the runner. At the conclusion of Part I, you should have six data sets per group (or 12 total sets from the two groups; i.e., walking and running data for each runner).
7. **CALCULATIONS**: To determine STRIDE LENGTH (SL), divide the length of the path (20 m) by the number of times the runner's left foot hit the path.
   a. Look at these data: Do you see any relationship between taller runners and their stride lengths?
8. The TIME is the total number of seconds the runner took to walk or run from the beginning of the path to the end.
9. The SPEED (S) of the runner is determined by the distance traveled, divided by the time it took the runner: (20 m, divided by seconds)
10. ***GRAPH IT!*** We need to present these data in a useable form. In order not to reinvent the process, we will rely on the work of Alexander and other scientists.
    a. Runners who are taller tend to have a longer stride length. To factor this into our analysis, we need to determine a RELATIVE STRIDE LENGTH (RS).
    b. First, measure each runner's leg length (LL). This is done by measuring the distance from the ankle bone to the hip bone.
    c. The relative stride length is the stride length, divided by the leg length:
       i. RS = SL / LL

11. We also need to determine a DIMENSIONLESS SPEED (DS). This is the actual speed of the runner (step 9), divided by the square root of (gravitational acceleration [g = 9.8 m/s^2] times the leg length):
    i. $DS = S / (g*LL)^{1/2}$
12. Plot the relative stride length (RS) against the dimensionless speed (DS). The relative stride length should be plotted on the x-axis, and the dimensionless speed should be plotted on the y-axis.
    a. What trend(s), if any, can you determine??

Part II: FOSSIL Footprints—Do Size Connections Exist?
PROBLEM. What happens if a track is found, and we are uncertain what type of organism made the footprints? How can we determine the speed of the animal? We can use our graph to find the dimensionless speed (DS)! However, to do this, we need to be able to determine the relative stride (RS) for our x-axis. We can measure the stride length (SL) from the footprints, but can we measure the leg length (LL) of an organism *without* the actual leg bone?

1. Measure the length of each runner's foot. This is the distance from the heel to the toes. This will probably be easiest to accomplish by measuring each runner's foot with his or her athletic shoe *on.*
2. Divide each person's leg length (LL) by the foot length (FL).
    a. What trend(s), if any, can you determine?

Part III: HERE COME THE PRINTS!
We need to apply our research to extinct dinosaur prints! Typically, the relationship between the foot length (FL) and the leg length (LL) is approximately 4:1, or the LL = 4 * FL. Is this what you discovered in Part II?

1. Let's begin by looking at a theropod trackway that is available on University of California at Berkeley's museum site.
    a. A close-up of one track is available at http://www.ucmp.berkeley.edu/education/dynamic/session3/images_sess3/student2.pdf
    b. A trackway and a single series of prints is available at http://www.ucmp.berkeley.edu/education/dynamic/session3/images_sess3/student1.pdf
    c. The Red Gulch Dinosaur Tracksite has a lot of these tracks, mapped out for your at http://www.ucmp.berkeley.edu/education/dynamic/session3/images_sess3/student3.pdf
2. Use the University of California at Berkeley information above to first calculate the speed of the theropod dinosaur in the single trackway.
    a. Remember, you must measure the stride length from RIGHT track to RIGHT track, not between RIGHT and LEFT tracks.
    b. The meter stick is subdivided into 10 cm units for easy measuring.

c. Measure the foot length, and use the relationship LL = 4 * FL to calculate our dinosaur's leg length.
d. Calculate relative stride length, or RS = SL / LL
e. Return to your graph from Part I to find the dimensionless speed (DS) of our dinosaur.
f. From the DS, use Alexander's equation to determine the dinosaur's speed:
   i. $DS = S / (g*LL)^{1/2}$

3. Now, expand your investigation! Pick at least two other trackways from 1c, above, and calculate the theropods' speeds. Note which trackways you used.
4. Our OWN plaster track! Check out the dinosaur trackway from Texas! These photographs were taken by Elizabeth Brown, who also made a plaster cast of one of the tracks. The suspected dinosaur is a theropod, *Acrocanthosaurus*.
   a. The track is 50 cm long.
   b. The distance between right and right tracks is approximately 2 m.
   c. Calculate the leg length of our Texas dinosaur, and determine its speed!
5. Mystery Track Maker! Check out the newly discovered tracks on University Avenue! The actual culprit for *Athleticus concreticus* has not been identified.
   a. Each track is approximately 30 cm long.
   b. The distance between two successive left tracks is approximately 7 ft. (Don't forget to convert this measurement!)
   c. Calculate the leg length of our athletic culprit, and determine its speed. What do you suspect he or she was doing when the tracks were created?

Part IV: How Fast did They Go?

Thulborn (1982) used Alexander's equations to calculate average speeds for dinosaurs! Different research studies afterward have refined some of these numbers, but for our purpose, we'll use Thulborn's calculated values. The average speeds of dinosaurs were probably as follows:

Dinosaur	**Maximum speed**
Sauropodomorphs	5 km/hr
Stegasaurs and ankylosaurs	6–8 km/hr
Sauropods (*Apatasaurus*)	12–17 km/h; maximum 20–30 km/hr
Large theropods (*Tyrannosaurus*) and ornithopods	20 km/hr
Ceratopsians (*Triceratops*)	Up to 25 km/hr
Small therapods and ornithopods	Up to 40 km/hr
Ornithomimids	Up to 60 km/hr
People!	*23 km/hr*

So we know how fast the dinosaurs *could* move based on Thulborn's calculations. Obviously, the animals did not always run at their maximum speeds. Breithaupt and Scothmoor (2002) noted that if we consider the relative speed only (stride length [SL]/ leg length [LL]), then the ratio could help us determine if an animal was walking, running, or trotting when it made its tracks. In general

- SL / LL < 2.0: Animal was walking
- 2.0 < SL / LL < 2.9: Animal was trotting
- SL / LL > 2.9: Animal was running

1. Using these guidelines for SL / LL ratios, determine the general motion (i.e., walk, trot, or run) of the dinosaurs from Red Gulch, Texas, and University Avenue.

Part V: Let's Get Creative!
It's your turn to create your own *accurate* dinosaur trackway by reversing the procedure! Your trackway can involve either a small or large dinosaur, or a mixture of individuals.

1. First, decide *where* your trackway will be displayed. You may set up a trackway on a wall or bulletin board.
2. The available space, as well as your own dinosaur preference, will help you determine what dinosaur type, and how many footprints can be included. (You should include a minimum of two stride lengths—or three left or right prints.)
3. Reconstruct a reasonable footprint size—both left and right feet, and front and back feet if the dinosaur was quadrupedal.
4. Decide whether your dinosaur was walking, trotting, or running, and use the guidelines from Part IV for stride length (SL).
   a. You will first need to calculate your leg length (LL) from the dinosaur footprint (FL).
   b. Use the SL / LL ratios to determine how long the stride should be on your trackway. Don't forget that the stride length is measured from left foot to left foot, or right foot to right foot!
5. You must turn in a research project summary, explaining how you designed and engineered your dinosaur trackway. Please see the attached rubric for guidance.
6. Be creative, and have fun with this project!

Data Table

Runner	No. of strides	Time	Stride length (SL)	Speed (S)	Relative stride length (RS)	Dimensionless speed (DS)	Foot length (FL)	Leg length (LL)/ FL
1 walk								
1 Run								
2 Walk								
2 Run								
3 Walk								
3 Run								
4 Walk								
4 Run								
5 Walk								
5 Run								
6 Walk								
6 Run								

Research Project: Application Exercise

Teacher Name: ____

Student Name: ____

CATEGORY	**4 - Excellent**	**3 - Good**	**2 - Average**	**1 - Poor**
Amount of information	All calculations are present and all information regarding the trackway is available.	All calculations are present and most information regarding the trackway is available.	All calculations are present and some information regarding the trackway is available.	Calculations and information are missing.
Quality of information	Information clearly relates to the trackway. Scientific rigor was incorporated, and several supporting details are included.	Information clearly relates to the trackway. Scientific rigor was incorporated, and one or two supporting details are included.	Information clearly relates to the trackway. Some scientific rigor was incorporated; no supporting details are included.	Information does not relate to the trackway.
Trackway **X 2**	Trackway is neat, accurate, and adds to the viewer's understanding of the topic.	Trackway is accurate and adds to the viewer's understanding of the topic.	Trackway is neat and accurate and sometimes adds to the viewer's understanding of the topic.	Trackway is not accurate OR does not add to the viewer's understanding of the topic.
Organization	Information is very organized with well-constructed paragraphs and subheadings.	Information is organized with well-constructed paragraphs.	Information is organized, but paragraphs are not well constructed.	The information appears to be disorganized.

Total Points _________/20