Life Sciences Outreach Faculty Speaker Series for High School Biology Teachers
How Biologists View Structure and Function
Fall 2018

PACKET B: Horses, forces, and fun with math

S. Pierce Lab: Phil Lai and Brianna McHorse

Note: Throughout this exercise, we will stop and check in together as a group. Stop when you see:
CHECK IN____

Exercise II: Are CSA and SMoA different than expected in larger equids?
6a. Through most of evolutionary history, horses had three toes, but those toes varied in size. If a 400kg horse was just standing still, how much weight do you think would be on each leg?

400kg/4 legs = ~100kg per leg (if they are knowledgeable, they might suggest that 60% of the weight is in the forelimbs, so that's 120 per foreleg and 80 per hind leg; that's fine).

Now estimate very roughly how much weight would be on **the center digit of a single limb** in 1) a horse with three equally-sized toes; 2) a horse where the side digits are ½ the size of the center digit; and 3) a monodactyl (single-toed) horse like Equus. (KISS)

Then, 100/3 is ~33kg for center digit in 1), 100/4 * 2 = ~50kg for the center toe in 2), and then all 100kg for the center toe in 3).

6b. What do you predict for the forces on **just the center digit** of a monodactyl (one-toed) horse vs. a three-toed horse? In which species are the forces higher?

I predict that the single digit of a one-toed horse will have greater forces on the digit than the center digit of a three-toed horse.

CHECK IN____

7. Take 5 minutes and use the small click-together cubes to make larger cubes of 2x2, 3x3, 4x4, 5x5, 6x6 cubes, as assigned by Brianna. Assume that each cube has a length of 1 unit.

a. Report the length the larger cube you made (e.g., 2 for the 2x2 cube), its surface area, and its volume to Brianna so she can enter into the groups spreadsheet.
b. While you're waiting for other groups, warm up those math skills with the following: If length is x, write the relationship of:
   i. Length (L) as a function of length $L = x^1$
   ii. Area (A) as a function of length $A = x^2$
   iii. Volume (V) as a function of length $V = x^3$

c. Check back in with the entire group to interpret Graph 2 (How length, surface area, and volume increase).

d. What can we say about how length, volume, and area increase in relation to each other as a cube gets bigger?
Volume increases the fastest, surface area the next fastest, and length increases the least. In fact, length increases at a rate of 1 (slope = 1/1) .

***CHECK IN*____**

8. What should the slope of a log-log plot be if we want to plot area (y-axis) vs. length (x-axis)?
2 (because area has power 2, e.g., cm^2)

9. Fill in the expected slopes of the following relationships, under conditions of isometry. Remember that the dependent variable (y-axis) is given first.

Area vs. length	2
Volume vs. length	3
Length vs. area	1/2
SMoA vs. length	4
Area vs. volume	2/3
SMoA vs. volume	4/3

10a. If horse A is “bigger” - i.e., has more mass - than horse B, do you expect the cross-sectional area of horse A’s bone to be larger, smaller, or the same size relative to horse B? Think back to your first graph.
It should be bigger (.....but not as much bigger as horse A’s mass is than horse B’s mass)

10b. Will there be a bigger difference in their **masses** or in their bone **cross-sectional area?** Explain your reasoning. (Hint: compare the slope of the volume line and the surface area line on your Graph 1)

Mass should have a greater difference than cross-sectional area, because mass increases more rapidly. (for any given unit change in length in their first graph, you get a bigger jump in volume than in area)

11. You are about to make a log-log plot of MCIII cross-sectional area (y-axis) vs. body mass (x-axis) in horses. If MCIII scales with isometry, what do you expect the slope of the line to be?
2/3

12. In the Excel sheet on your computer, go to the tab “Graph4- log(CSA) vs. Body Mass. Repeat the graphing procedure from Graph 1 on log cross sectional area and log body mass for all twelve equid taxa. What is the slope of the data?
They find slope of the trendline as they did for the cubes example above. It should be > 0.667.

13. In the Excel sheet on your computer, go to the tab “Graph5- log(CSA) vs. Body Mass. (You will have to highlight the log mass column, then hold the “command” button while highlighting the SMoA column.) Repeat the log-log plot for MCIII SMoA vs. body mass. What is the expected slope of the line under conditions of isometry? What is the actual slope of the data?
Expected = 4/3 or 1.333, actual is > 1.333.

14. Were your hypotheses of isometry correct?

15. Why would larger equids have a greater resistance to compression and bending than expected if you just scaled up the resistance present in the MCIII of a smaller horse?
They might have a larger a resistance to bending because that toe is taking on more weight than would be expected, because the larger equids that were studied also had fewer toes.
Internal geometry compensates for digit reduction with positive allometry.

CHECK IN____

Life Sciences Outreach Faculty Speaker Series for High School Biology Teachers
How Biologists View Structure and Function
Fall 2018

Wrap up discussion re: Doing museum collections research

1) What steps do you think took place to put this project together? (E.g.: sending a formal request to borrow the bones)
Finding out from colleagues which museums have the right type/age of horses, database searches, measuring in collections, emailing collections, coming up with TRI as a measure, learning how to math the beam bending, permissions, CT scanning, LOTS of programming, processing the scans, BoneJ, collecting body mass data for the species (sometimes calculating it), writing, mentoring students, learning to use GitHub…

2) How do other scientists and the public access the results of this study? How would you go about verifying this study?
GitHub, MorphoBank, paper SI, contacting museums (e.g. Jamie), etc. Ask them if they share/borrow materials?