

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

PACKET A: Horses, forces, and fun with math

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Horses are often used as a classical example of evolution. When we say “horses” we really mean the horse *family*, Equidae. Living Equidae has just one genus, *Equus*, which includes zebras, domestic horses, and several kinds of wild ass (donkeys and their relatives). However, this classic evolutionary story is sometimes portrayed as a straightforward, “linear” example of evolution- horses lost their toes as grasslands spread in order to run faster on hard ground. In addition to making this seem like horses had “directionality” in their evolution, it’s also not even clear what the initial (or major) driver of toe loss was in horses. Horse evolution more resembles a tree rather than a straight line. This phylogeny depicts the many equid lineages that went extinct. Looking back in time on horse evolution, it’s easy for us to provide an “obvious” reason why horses lost their toes. However, Brianna’s work is the first time that someone is actually exploring the forces that would have been present on extinct equid legs.

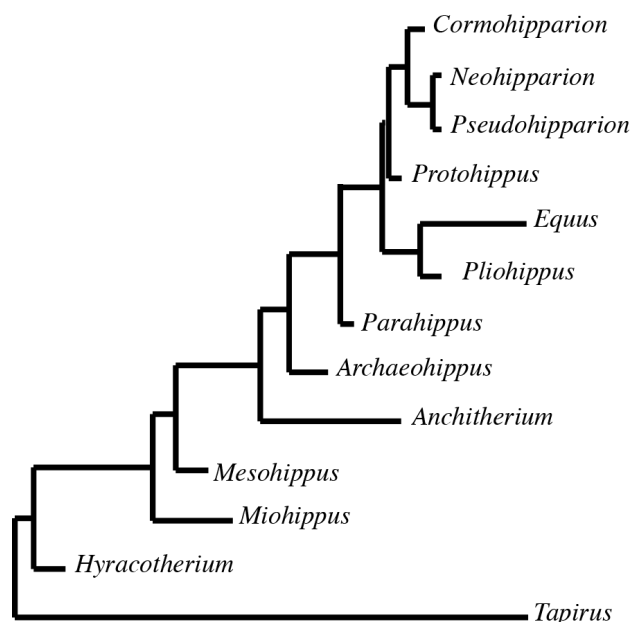


Figure 1. A modified phylogeny depicting equids studied in McHorse et al. 2017.

To understand how modern day equids managed to remain so large and athletic with only a single toe, we have to examine the structure of their bones. We will work through the following activity together in groups to explore the relationship between cross sectional area (area through the skinny side of the bone) and body mass in horses.

To investigate the biomechanics of digit reduction, Brianna measured several characteristics of leg bones of extinct and living horses. She measured **bone length and radius, cross sectional area** (a measure of resistance to compression that usually comes from the body weight of the

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animal), and **second moment of area** (a measure of resistance to bending, which comes when the bones are at an angle to the ground).

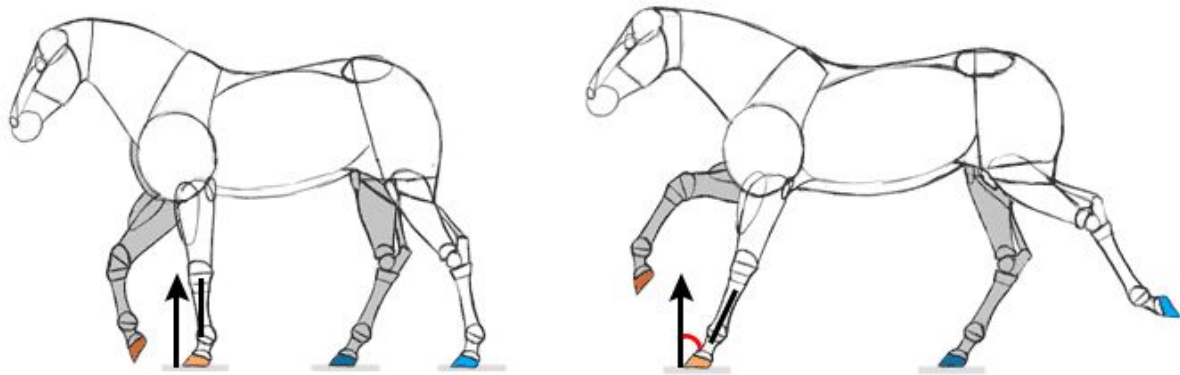


Figure 2. A sketch depicting the direction of forces present on horse legs at different speeds. On the left, forces are mostly in line with the bone (**compression**); on the right, the angle makes for significant **bending** forces.

Exercise I: Are bone measures larger in larger equids?

1. Take 5-10 minutes to make a scientific drawing of the 3D printed MCIII (the third metacarpal) in your group. If you were a researcher, what aspects of the bone would you draw (think about scale, different orientations, cross sections)? Try to show these in your drawing.

Large bone: *Equus*

Medium bone: *Mesohippus*

Small bone (careful, it's fragile!): *Hyracotherium*

2. Share your drawings with other members of your group.

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3. Write your hypotheses below for the relationship between cross sectional area (CSA) and equid body mass and second moment of area (SMoA) and equid body mass (2 hypotheses). I.e. if one species has a larger body mass than another, do you predict that its cross sectional area and second moment of area are larger or smaller?

Cross sectional area & body mass:

Cross sectional area will increase as body mass increases.

Second moment of area & body mass:

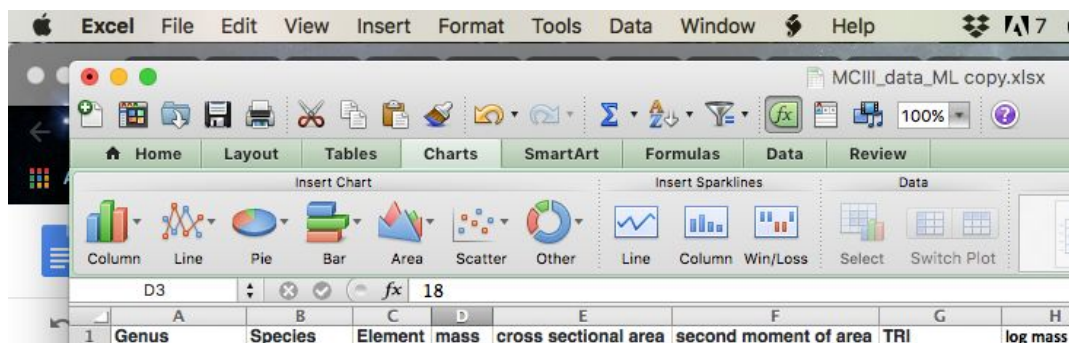
Second moment of area will increase as body mass increases.

4. Graph raw CSA vs. body mass and SMoA vs. body mass using Brianna's data in Excel to test your hypothesis. Follow instructions below to create the graph.

- In the Excel sheet open on your computer, find the tab called "Graph1-CSA & SMoA vs. Body Mass".
- Use your cursor to highlight all the data, including the labels ("mass", "cross sectional area", and "second moment of area"), in columns D, E, and F. It should look like this:

	A	B	C	D	E	F	G	H	I	J
1	Genus	Species	Element	mass	cross sectional area	second moment of area	TRI	log mass	log A	log I
2	Hyracotherium	vasacciense	MCIII	9	0.18215	0.0018342	0.888664601	2.197224577	-1.702924756	-6.30114686
3	Hyracotherium	sp	MCIII	18	0.2909	0.0087449	0.888664601	2.890371758	-1.234775713	-4.739284606
4	Archaeohippus	blackbergi	MCIII	20	0.33286	0.0133481	0.713390501	2.995732274	-1.100033298	-4.316381226
5	Archaeohippus	nanus	MCIII	20	0.51664	0.0221194	0.713390501	2.995732274	-0.660408972	-3.811300227
6	Mesohippus	barbouri	MCIII	47.7	0.54367	0.0154932	0.760651945	3.864931398	-0.609412834	-4.167354061
7	Mesohippus	barbouri	MCIII	47.7	0.65632	0.0298066	0.760651945	3.864931398	-0.421106804	-3.513025433
8	Miohippus	gidleyi	MCIII	53.8	0.87727	0.0383905	0.736747967	3.985273467	-0.130940466	-3.259945246
9	Pseudohipparion	gratum	MCIII	61	1.28258	0.1933644	0.532561443	4.110873864	0.248873674	-1.643178787
10	Parahippus	leonensis	MCIII	76.6	0.98189	0.0993283	0.607029533	4.338597077	-0.018275993	-2.309324754
11	Neohipparion	affine	MCIII	136.1	2.44145	0.6777173	0.483151547	4.91338991	0.892592125	-0.38902504
12	Neohipparion	coloradense	MCIII	136.1	1.77234	0.3827146	0.483151547	4.91338991	0.572300707	-0.960465737
13	Cormohipparion	occidentale	MCIII	151.3	2.82629	0.8478429	0.526070833	5.019264621	1.038964898	-0.16505992
14	Pliohippus	pernix	MCIII	155.3	2.69241	0.7966586	0.328586669	5.04535873	0.990436703	-0.227329048
15	Protohippus	floblairi	MCIII	161.5	1.56603	0.2591801	0.587252562	5.084505143	0.448543754	-1.350232092
16	Protohippus	floblairi	MCIII	161.5	1.58972	0.3055028	0.587252562	5.084505143	0.4635579	-1.185796335
17	Protohippus	simus	MCIII	161.5	1.63016	0.2870775	0.587252562	5.084505143	0.48867817	-1.248003065
18	Tapirus	bairdii	MCIII	250	2.87407	0.3779812	0.789866667	5.521460918	1.055729144	-0.97291082
19	Equus	niobrarenis	MCIII	350	7.058488	4.3701		5.857933154	1.954230864	1.474785892
20										

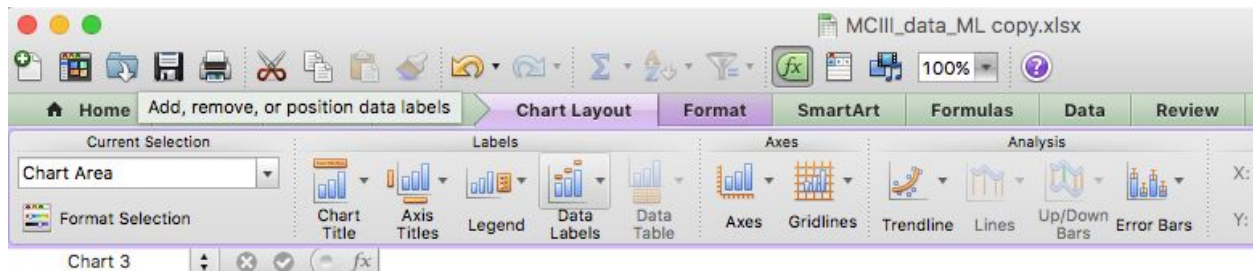
c. Then click the "Charts" tab, then "Scatter":



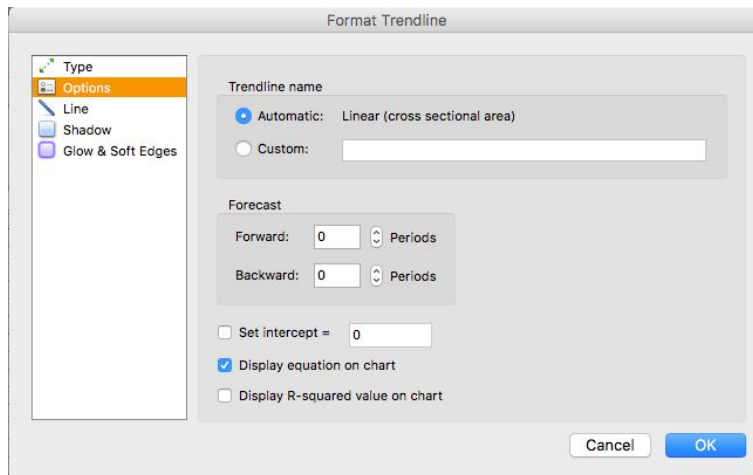
d. Add labels and a title to your axes so you can better interpret the graph. Click on a white space within the chart you just made, then the "Chart layout" tab should appear. Click the

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appropriate buttons to add a Chart title and Axes titles describing your graph. See the image below.



e. Add a trendline. Click the trendline button in the image above, then scroll down to “Trendline options”. Excel will ask you which data series for which you want to insert a trendline. Pick either cross sectional area or second moment of area data series. A box will appear- click the box next to the option “Display equation on chart”. Click OK. Repeat for the second data series.



5. Interpret your scatter plot. Are your hypotheses regarding cross sectional area, second moment of area, and body mass correct?

Yes or no, but they should observe that both measures increase as body mass increases.