To Romp Through The Kingdoms or Not To Romp Through The Kingdoms: That Is The Question!

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Abstract

Traditionally, college curricula include a general biology II course that entails a procession through the kingdoms of life. These courses focus on animal and plant taxonomy, and may cover some biological processes, i.e. respiration, reproduction, etc. Here, we present an alternative to teaching this type of course. We base this method on work by biologist John Tyler Bonner (*Why Size Matters: From Bacteria to Blue Whales*, 2006) and others who illustrate the limitations and advantages of size on life processes within organisms. Through lecture and laboratory exercises, we develop specific size rules, e.g. the metabolic rate of an organism is directly proportional to its size. Students discover how size governs generation time, digestion, etc. through observations, measurements, and data analysis. We employ several organismal examples per size rule to illustrate the unity and diversity of life. Centered on the theme of size, this course has brought to the fore front the kingdoms of life as well as key biological mechanisms.

Methods

<u>Text</u>: *Why size matters: From Bacteria to Blue Whales* by John Tyler Bonner

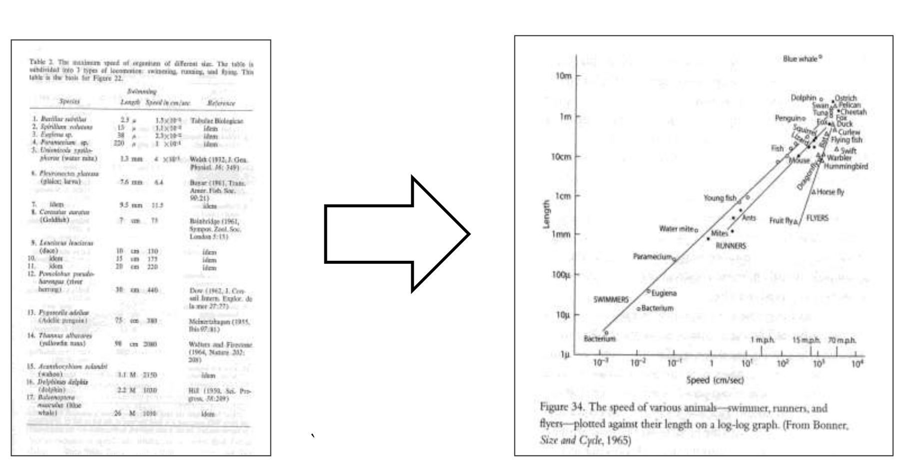
Size Relationships:

Strength	□	$Weight^{2/3}$
Surface	□	$Weight^{2/3}$
Complexity	□	$Weight^{a}$
Abundance	□	$Weight^{-b}$
Metabolic rate	□	$Weight^{c}$

<u>Lab Handouts</u>: These include the following parts- title, background, exercise, questions, relationship, and references

<u>Motic Camera and Imaging Software</u>: most labs require students to collect images of model organism, e.g. *Volvox*, *C. elegans*

<u>Microscoft Excel</u>: Use this program to construct graphs and determine whether relationship is directly or indirectly proportional



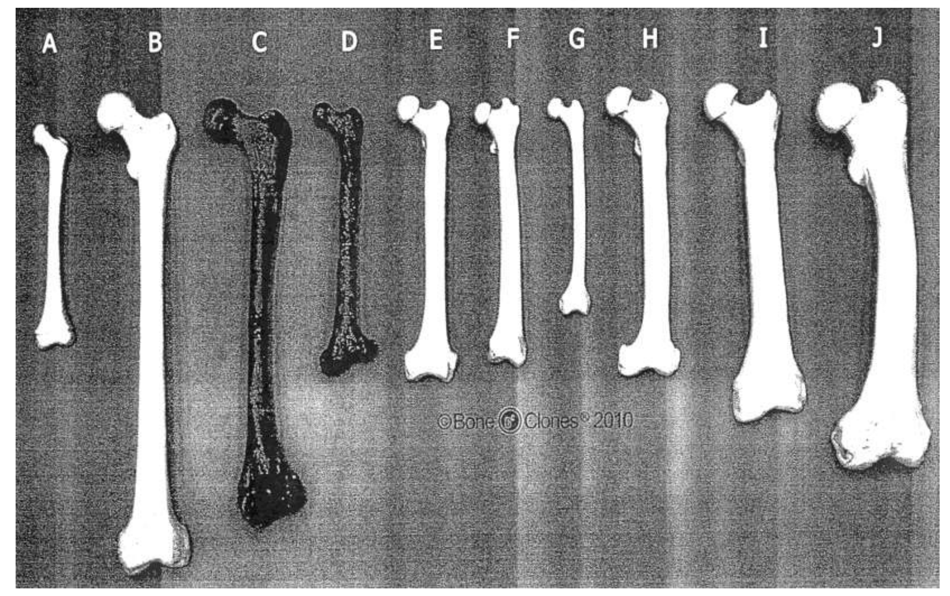
From Bonner (1965)

<u>Project Portfolios</u>: Compiled from size relationship labs using graphs, images, and primary scientific literature

<u>Project Presentations</u>: Select one size rule to present significance, background, methods, data, and conclusions

<u>Project Paper</u>: Compose an introduction, describe lab support, and conclusion for studying all size rules in organisms

Size Rule 1: Strength α Weight



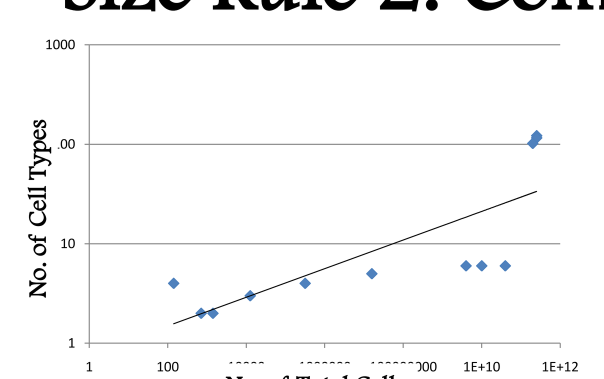
<u>Concepts</u>: allometry, scaling, conversions, equation of the line, proportionality

<u>Exercise</u>:

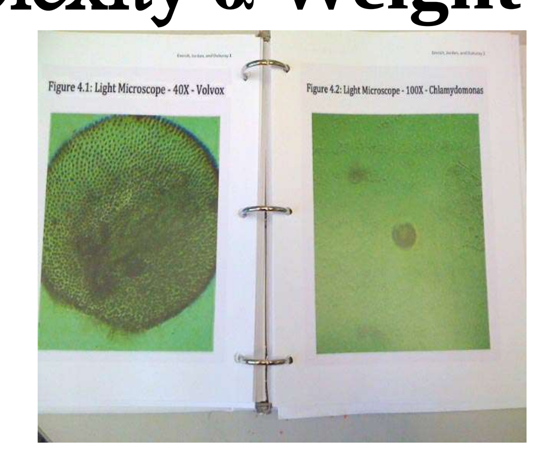
1. Measure the height and width (diameter) in inches of femurs of various primates.
2. Using the scale bar provided, calculate the approximate length and diameter in centimeters.
3. To obtain *"strength"*, square the diameter values.
4. To obtain *"weight"*, multiply strength by height.
5. Place the values in weight order on an excel spreadsheet.
6. Create a graph and determine the slope of the line.

<u>Questions</u>: 1) Based on the above exercise, what is the relationship between strength and weight. (The slope of the line is the exponent for weight below.) 2) Find an example of this relationship illustrated in a scientific paper. Briefly explain the study.

Size Rule 2: Complexity α Weight



Redrawn from Bell and Mooers (1997)



<u>Concepts</u>: division of labor, number of cells types multicellularity, biological complexity, quorum sensing

<u>Microscopy Exercises</u>:

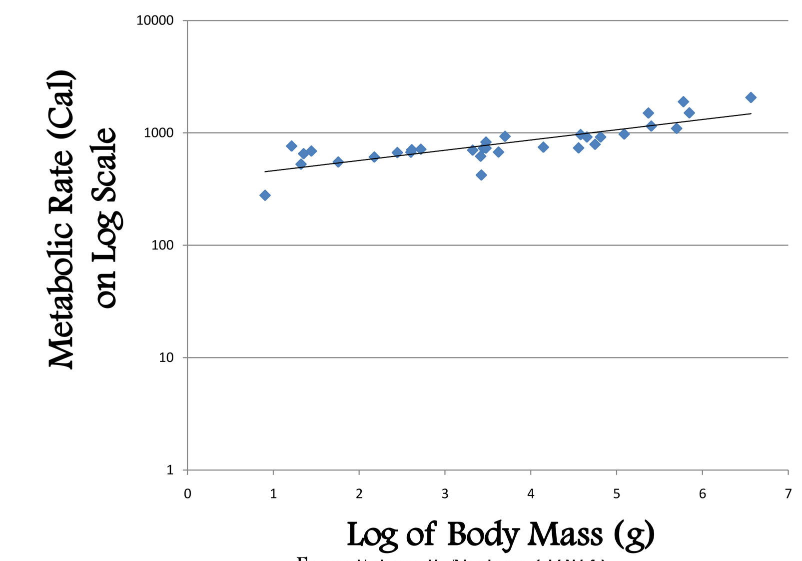
1. Volvocales identification using a simple dichotomous key , different methods for coverslipping
2. Image 3 examples of the major tissue types using histological slides

<u>Questions</u>:

1. Focus on the volvox species, what is the advantage gained by producing somatic cells that are incapable of reproduction?
2. How and why is quorum sensing involved in the division of labor? Find a scientific paper that illustrates quorum sensing.
3. What is the relationship between complexity and weight? Explain in detail and provide an example from the literature.

Size Rule 3: Metabolic Rate α Weight

<u>Elephant-to-Mouse Curve</u>



From Schmidt-Nielsen (1984)

<u>Concepts</u>: metabolism, metabolic rate, heat production, longevity, locomotion, speed, independent variable, dependent variable, generation time, longevity

<u>Exercises</u>:

1. Construct the elephant-to-mouse graph
2. The number of heart beats of a hummingbird in its lifetime equals the number of heart beats of a whale in its lifetime. This is due to differences in metabolic rate that are a direct result of size differences. Find the heart rate of an animal of your choice (do not do humans). For example, an elephant's heart beats 25 beats per minute, while a shrew's heart beats 600 beats per minute.

<u>Question</u>:
Explain the relationship between metabolism and size. Provide your own example to illustrate your point(s) using an example scientific paper.

Extensions of Size Rule 3: Generation Time α Weight Longevity α Weight

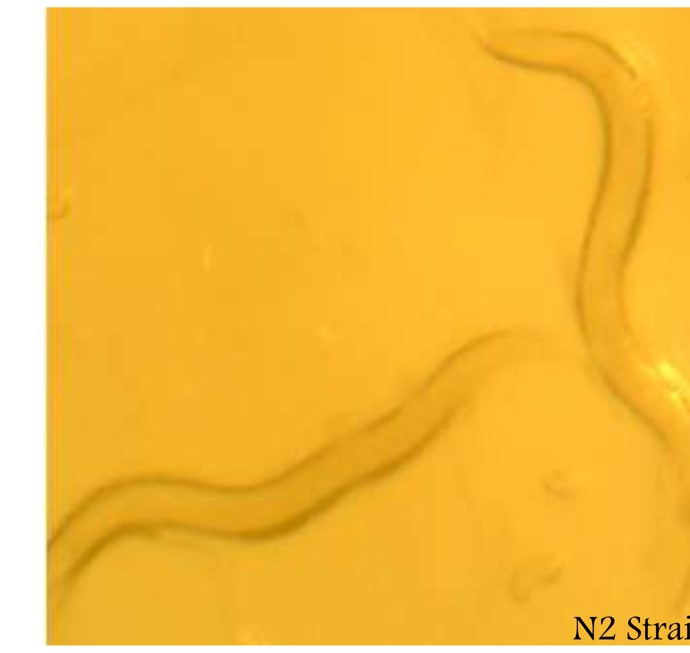
<u>Exercise A</u>:
Using the length and generation time data table make a log-log plot graph on Excel

<u>Exercise B</u>:

1. Calculate the height and age of select campus trees
2. Construct 2 graphs adding campus trees along previously chosen champion tree data- age vs. height and age vs. circumference.

<u>Questions</u>:

1. Using the generation time to length graph, why don't all organisms fall exactly on the line? Propose at least one hypothesis.
2. Explain which method for determining the height of a tree was preferred by your group. Did all the methods consistently provide the same answer? Why or why not? How do your trees measure up to champion trees? Explain the age limitations for trees?



<u>Exercise C</u>:

1. Research aging genes in *Caenorhabditis elegans*- Find a scientific study that evaluates how the mutation of a particular gene influences longevity in the nematode.
2. Order *C. elegans* mutant for the above gene
3. Make observations and image control and mutant *C. elegans*

<u>Question</u>:
Find a scientific paper that studies the relationship between longevity and size in nematodes. Explain the study.

Learning Outcomes

- Demonstrate the ability to learn biological concepts by discovering size rules that govern life processes
- Demonstrate mathematical proficiency and data presentation savviness using Excel
- Demonstrate the ability to search for scientific papers and develop critical thinking skills to select relevant studies using PubMed

References

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