Are You Smarter Than a Dinosaur?

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Summary

Students investigate the intelligence of dinosaurs by comparing the relative size of brain and body mass to living animals.

Context

Audience

undergraduate paleontology course

Skills and concepts that students must have mastered

Graphing data
Students with a basic background in major dinosaur groups and the common experience of getting "information" from the movies.

How the activity is situated in the course

stand-alone exercise

Goals

Content/concepts goals for this activity

paleoecologic interpretation of vertebrate function

understand the importance of context in understanding paleontologic data, in this case, the importance of the data on living animals

Higher order thinking skills goals for this activity

Student analysis using real data
See levels of uncertainty in real data; fitting lines by eye to noisy data.

Other skills goals for this activity

Description of the activity/assignment

Students investigate the intelligence of dinosaurs by comparing the relative size of brain and body mass to living animals. Students plot the living animals to determine a general relationship of brain and body mass and then use that relation to interpret a range of dinosaurs. The activity gives students practice in graphical data comparison and other methods of data analysis. Students also investigate how well this method works and what weaknesses it might have.

Determining whether students have met the goals

I examine student graphs, analyze their slope calculations (they don't always get it right), and evaluate their answers to the thought questions.
More information about assessment tools and techniques.

Download teaching materials and tips

- **Activity Description/Assignment:**Student Handout for Dinosaur Intelligence Lab (Microsoft Word 43kB Jun4 09)
- **Instructors Notes:**Instructor Notes for Dinosaur intelligence lab (Microsoft Word 376kB Jun4 09)
- **Solution Set:**Dinosaur Intelligence Solution Set (Microsoft Word 23kB Jun4 09)

Other Materials

- Dinosaur Intelligence Spreadsheet (Excel 87kB Jun4 09)

Are You Smarter than a Dinosaur

Instructor Notes

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This approach is different from how the scientific investigators have usually done it (e.g., encephalization quotient of Hopson) and uses a direct approach first suggested by Cleveland (1985, p. 16). I devised this as a dinosaur intelligence lab, but the temptation to rename it in line with current popular culture was irresistible.

Materials:

Students need log-capable calculators (or equivalent computer technology). Clear rulers or drawing triangles work best for fitting the straight line on Figure 1.

The initial graphing uses two pieces of log-log paper spliced to create 8 cycles along the x-axis (body mass). To fully graph all the modern animals (e.g., goldfish, hummingbird) shown in Table 2 would require further splicing to get at least 5 cycles on the y-axis (brain mass), but I haven't gone to the trouble.

I got my log graph paper from http://www.csun.edu/science/ref/measurement/data/graph_paper.html
csun 4-cycle_log-log.pdf

Figure 2 uses a simple arithmetic graph using a grid of 10 division/unit graph paper. This is labeled down on the y-axis from 0 to 3 to encompass the range of estimated intelligences. I have pre-labeled the dinosaurs on the x-axis of my version of this figure, but you could leave the x-axis blank (see below).

This lab is conducted in stages: Sections are handed out, students complete them, and we talk about the results (get people back on track, if necessary) and then continue. One disadvantage is that the better students finish faster and have to wait.

Page 1

The first page is handed out in advance to get students thinking about the problem. Although theoretically my students have experience with logarithms and log graph paper, my experience is that a refresher is advisable, hence, the paragraph at the bottom of page 1.

Page 2

After talking with the students about their thinking on the first page, I hand out page 2, Table 1, and the log-log graph paper. Table 1 is formatted so that students can just locate the order of magnitude (=exponent) on the graph and plot the number. The bat's brain mass is below the x-axis, but is close enough that it can be plotted by eye.

Note that the method given on page 2 for calculating the slope of the line works only if the x- and y- axis log scales are the same (absolute) length. If they aren't the same length, the procedure becomes much more complex. I suggest you avoid this.

The slope, not matter how the students reasonably draw it, is less than one.

When students reach this point, I poll them for their slope, post it on the board, and calculate the average. In discussing results, I point out that the average of the class slopes is close to 0.667 (in the classes where I've used this, the averages have ranged from0.62-0.66). This is useful to point out. (When students hand this in, I always check their slope calculation myself. Sometimes, they have calculated the slope of their own line incorrectly.) I also show the graph of all 283 vertebrates (see last page of this document) to show that (although there are some outliers) you could use multiple straight lines with the same slope to fit these data reasonably.

Note that the intercept is unimportant here, only the slope. In fact, Jerison argued that you would use lines of the same slope and different intercepts for different animal types (e.g., mammals vs. amphibians). That explains the lower cluster of points in the figure at the end of this document.

Page 3

I hand out page 3, but generally discuss the text on the top of page 3, rather than have them read it. They can then think about the questions at the bottom of the page.

Page 4-7

I hand out page 4, Table 2 (for my printer, this plots as living animals on page 1 and dinosaurs on page 2), and Figure 2. Cleveland (1985) discusses the inaccuracy in visual estimation of the distance above a sloping line by eye at some length.

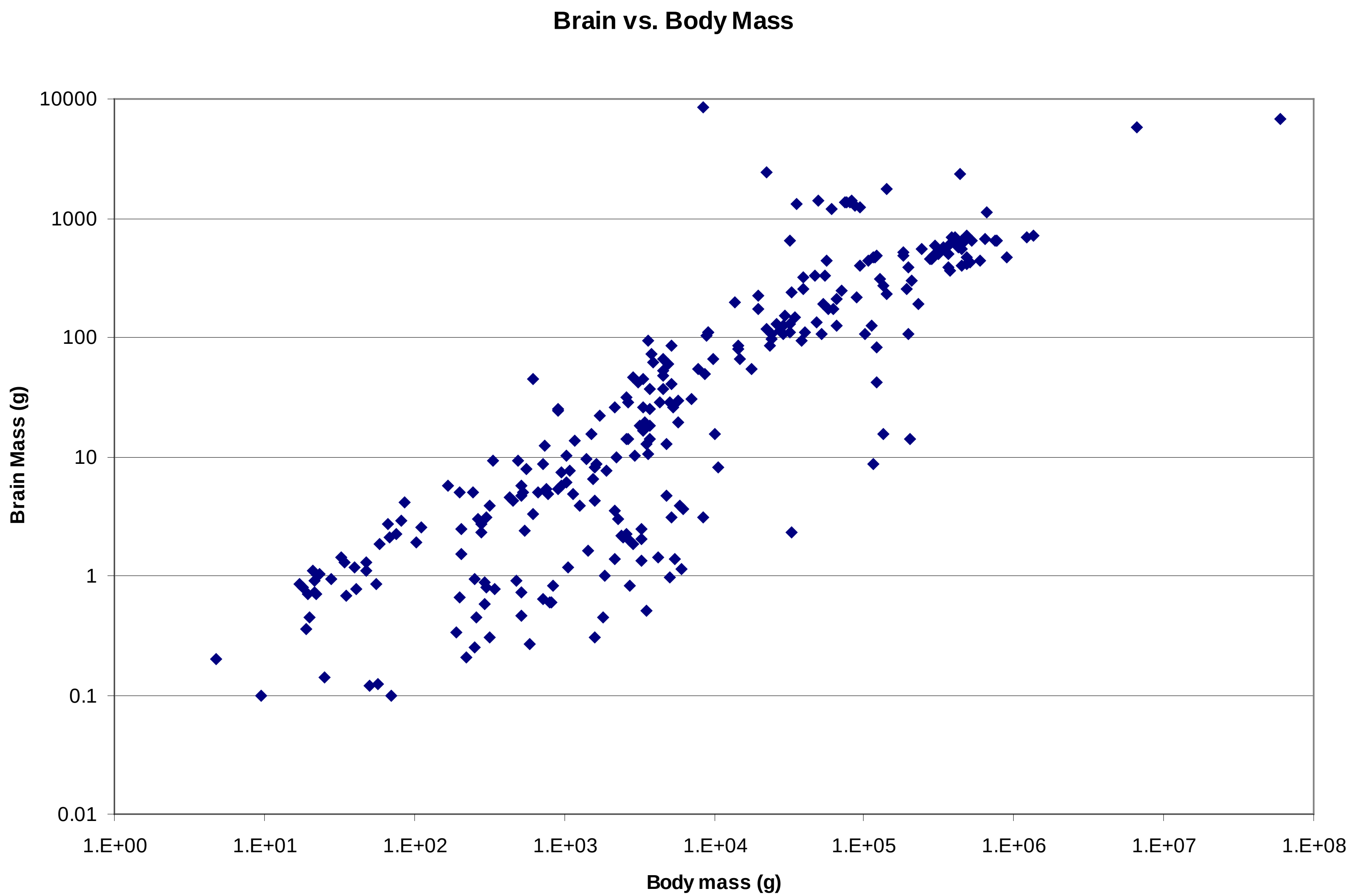
Table 2 is laid out to make the calculation easier for students. It also introduces the dinosaurs.

Keep in mind that all the calculated values for “intelligence” should be less than zero.

Figure 2 uses a simple arithmetic graph grid to plot the intelligence scores as a dot chart (Cleveland, 1985, p. 145+). Dot charts have been shown to be much more efficient at conveying graphical information than bar charts. The version I use is pre-labeled with the “intelligence scale” and the dinosaur names. I tell students to plot the living animals on the grid in decreasing order of “intelligence” in order to make comparisons with the dinosaurs easier. An alternative approach would be to plot all the animals in decreasing order of intelligence.

Students then can evaluate the results and answer the questions.

This graph shows 283 vertebrates plotted (data from Crile & Quiring, 1940).



Are You Smarter Than A Dinosaur?

(A dinosaur intelligence lab exercise)

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Context

Undergraduate paleontology course

Students with a basic background in major dinosaur groups and the common experience of getting “information” from the movies.

Goals:

understand the importance of context in understanding paleontologic data, in this case, the importance of the data on living animals.
Paleoecologic interpretation of vertebrate function.
Student analysis using real data.
See levels of uncertainty in real data; fitting lines by eye to noisy data.

Description

Students investigate the intelligence of dinosaurs by comparing the relative size of brain and body mass to living animals. Students plot the living animals to determine a general relationship of brain and body mass and then use that relation to interpret a range of dinosaurs. The activity gives students practice in graphical data comparison and other methods of data analysis. Students also investigate how well this method works and what weaknesses it might have.

Are You Smarter than a Dinosaur?

If we take our cue from the Jurassic Park movies, we might conclude dinosaurs are so intelligent that college students (or humans in general) could not outwit them on national television. Is this a reasonable conclusion?

Comment [Comment1]: S2007: up to calculating log brain - 2/3 log body took about 75 minutes

See end of file for list of figures and tables.

Log-log paper (spliced to have enough cycles) is in Dinosaur Intelligence lab folder. Original paper probably csun 4-cycle_log-log.pdf.

Hand out page 1 in advance.

Tables 0-2 are in Brains and Mass comparison 2.xls in the Dinosaur Lab subdirectory on C:

Table 0 could be used for initial discussion: is it easy to look at these data and determine any relation of brain and body mass?

We can't have dinosaurs take IQ tests, but can you think of an approach to the question?

Some scientists have thought you can by studying brain size or mass. The idea is that smarter animals have larger brains. In this lab, you will investigate this. What would you want to know to do this?

We will start by comparing living animals to have context for dinosaurs.

This lab uses logarithms, because they have a number of useful properties for this analysis:

1) differences of orders of magnitude are the same (e.g., from 5 to 10 is the same distance as from 50 to 100);
2) very different values fit conveniently on one graph so that a mole and a whale can be graphed together; and
3) turns exponents into straight line (e.g., $y = x^2$ becomes a straight line with slope 2)

An obvious limitation to brain size analysis: you have to account for the size of the animal (an elephant has a larger brain than a wolf, but it is also much larger).

In Table 1 are listed body mass (g) and brain mass (g) for a number of living animals (used by Jerison 1973 and originally derived from Crile and Quiring 1940).

Plot brain mass in grams on the y-axis and body mass in grams on the x-axis of Figure 1. Figure 1 has axes measured in logarithms on each axis.

Comment [Comment2]: Logarithms alter the spacing of numbers with a number of (potentially) useful attributes: 1) differences of orders of magnitude are the same (e.g., from 5 to 10 is the same distance as from 50 to 100); 2) it allows very different values to fit conveniently on one graph so that a mole and a whale can be graphed together; 3) it turns exponents into straight line (e.g., $y = x^2$ becomes a straight line with slope 2); and 4) it can make almost anything a straight line (this is the "potentially" part).

What is the relation between body and brain mass?

Is it easy to determine which animals are more intelligent? If so, how?

Draw a best-fit straight line to the data points (this obviously can't go through all the point and needn't go through any of them).

What is the slope of this line?[1] Is it greater or less than one?

What simple fraction (denominator 2-9) does this approximate?

[1] The easiest way to do this is to find two spots over more than one log cycle (power of 10) where the line intersects graph paper lines. Then measure the distance (in cm) along the x-axis (run) and the y-axis (rise). The slope is then y-distance/x-distance.

Jerison (1973) and Hopson (1977) concluded that the general relation of brain and body mass is

Brain mass = c (body mass)$^{2/3}$

where c is a constant that depends on the kind of animal (Jerison separated fish and amphibians from reptiles and mammals, at least initially).

Steve Gould (1977, p. 182) was apparently the first to point out that the ratio of surface area to volume in animals scales to the 2/3 power, that is, volume of sphere = 4/3 π r^3 while its surface area = 4 π r^2).

This suggests that nerve endings (and ultimately brain connections) must contact the body surface, so that (all else being equal) the brain must scale at two-thirds the body volume so there are enough nerve endings to reach all surface points.

The application to intelligence is as follows:
Animals with larger brains than you would expect for their body mass are more intelligent.

Suppose two animals are equally intelligent.

We would expect
(Brain mass)/(Body mass)$^{2/3}$ to be the same for each

Let's assume r is this ratio
(Brain mass)/(Body mass)$^{2/3}$ = r

or

Log (brain mass) - 2/3 log (body mass) = log (r)

Log (brain mass) = 2/3 log (body mass) + log (r)

Thus, on your graph, two equally intelligent animals would lie on a line with slope of 2/3.

Alternatively, a more intelligent animal would be above ("northwest") of a line with 2/3 slope going through the less intelligent one.

Is it easy to imagine lines with 2/3 slope going through each point to compare to all the other points?

We could choose one animal as a base (say, the mole), draw a line with slope of 2/3, and estimate the vertical distance above or below the line for the others. Does this seem easy?

It turns out humans are not very good at this sort of estimation even if you draw the actual line. For that reason, we won't bother to plot the dinosaurs in Table 2 on our graph.

Cleveland (1985) suggests a better approach: Graph each animal against log r, that is, against log (brain mass) – 2/3 log (body mass). The higher the value, the greater the intelligence.

This will make the comparison easy and it is what you will do:

Determine the logarithm (base 10) of the brain and body mass of the animals in Table 2. (Include at least two digits to the right of the decimal point when taking the log.)

Then calculate:

Log (brain mass) – 2/3 log (body mass)

in the appropriate column.

Note that this table includes dinosaurs (data from Jerison 1973 and Hopson 1980). Then plot the value by animal on Figure 2.

Which animal has the highest value and thus the highest implied intelligence?

For living animals, would you guess the intelligence order is reasonable? Do major groups of animals occur together? How are major groups separated? Does this system work equally well for all animals?

Comment [Comment3]: For example, aquatic animals have weight borne by water. Does this seem to affect their brain/body ratio?

Where does the highest dinosaur occur?
The other dinosaurs? What conclusions can you draw from where dinosaurs plot?

Based on this analysis, do you need to be concerned that dinosaurs, if enrolled via time machine, would embarrass you on a television show? What should we conclude about this aspect of Jurassic Park?

What weaknesses do you see in this approach?

References

Cleveland, W.S., 1985, The elements of graphing data: Wadsworth & Brooks/Cole, Pacific Grove, CA, 323 p.

Crile, G. & Quiring, D.P., 1940, A record of the body weight and certain organ and gland weights of 3690 animals: Ohio Journal of Science, v. 40, p. 219-259.

Gould, S.J., 1977, Ever since Darwin: Reflections in Natural History: W.W. Norton & Co., New York, 285 p.

Hopson, J.A., 1977, Relative brain size and behavior in archosaurian reptiles: Annual Review of Ecology and Systematics, v. 8, p. 429-448.

Hopson, J.A., 1980, Relative brain size in dinosaurs: in Thomas, RDK and Olson, EC (eds.) A cold look at the warm-blooded dinosaurs: AAAS Selected Symposium 28, p. 287-310.

Jerison, H.J., 1973, Evolution of brain and intelligence: Academic Press, NY, 482 p

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Solution Set

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The numerical answers (and graphs) are shown in the Excel workbook "Are you smarter than a dinosaur.xls", either on the key sheet or in other sheets. I comment below only on questions that seem to require further elaboration.

What is the relation between body and brain mass?

As one gets bigger, so does the other, generally.

Is it easy to determine which animals are more intelligent? If so, how?

No, it isn't easy.

What is the slope of this line? Is it greater or less than one?

It is less than one. The slope depends on the student's line. In my experience students get slopes between 0.5 and 1.

What simple fraction (denominator 2-9) does this approximate?

> *Depends on the student slope, but this is heading toward the 2/3 value.*

Is it easy to imagine lines with 2/3 slope going through each point to compare to all the other points?

> We could choose one animal as a base (say, the mole), draw a line with slope of 2/3, and estimate the vertical distance above or below the line for the others. Does this seem easy?

I would say no to both.

Which animal has the highest value and thus the highest implied intelligence?

Homo sapiens

For living animals, would you guess the intelligence order is reasonable? Do major groups of animals occur together? How are major groups separated? Does this system work equally well for all animals?

Comment [Comment1]: For example, aquatic animals have weight borne by water. Does this seem to affect their brain/body ratio?

Generally, the order seems reasonable. I have tried to convince myself the method is "unfair" to aquatic animals as their mass is offset by water, but the high ranking of the porpoise doesn't seem to fit. I follow what

Where does the highest dinosaur occur?
The other dinosaurs? What conclusions can you draw from where dinosaurs plot?

See the Excel workbook "Are you smarter than a dinosaur.xls" for values. Small theropods (the coelurosaur Stenonychosaurus) are the most intelligent and occur between the goldfish and ostrich. The others rank lower than practically all the living animals. Students can certainly discuss the ranking within dinosaurs with sauropods at the bottom.

Based on this analysis, do you need to be concerned that dinosaurs, if enrolled via time machine, would embarrass you on a television show?

Probably not.