Are You Smarter Than A Dinosaur?

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Introduction And Goals

In this lab, students investigate the intelligence of dinosaurs by comparing their body/brain mass ratio to that of living animals. This lab uses data from Jerison (1973) and Hopson (1977, 1980), but uses an "intelligence" measure that was developed by Cleveland (1985) as a simpler approach to analysis.

Goals for the lab are as follows:

1) Paleoecologic interpretation of vertebrate function.
2) The importance of context in understanding paleontologic data, in this case, the value of the data on living animals.
3) Analysis using real data.
4) See uncertainty in real data; fit lines by eye to noisy data.

Lab Introduction

The lab opens with questions for students to consider in advance:

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?

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

I vary this depending on the audience. For example, for a honors dinosaurs class, I have suggested that Jurassic Park implies that if dinosaurs enrolled at UNCP, then there would be no humans in the honors college. This gets the students engaged by indignation.

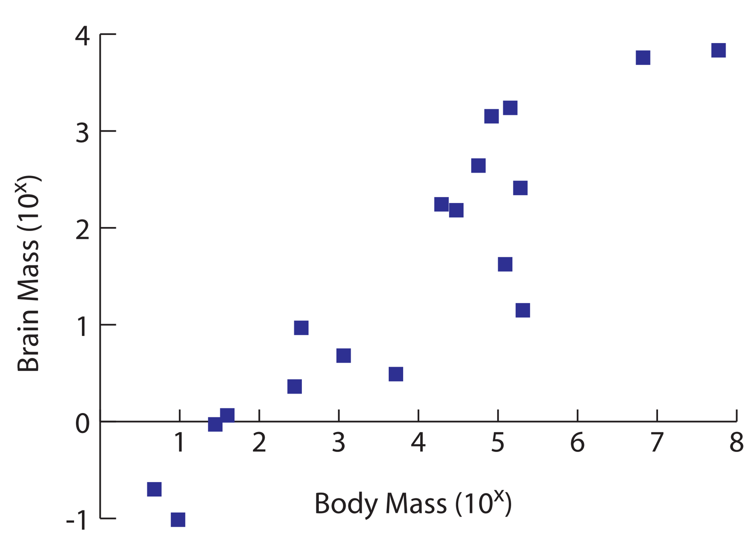

Figure 1. Body vs. Brain Mass (g) for the modern animals in the table.

Context From Modern Vertebrates

The Table below lists body mass and brain mass for a number of extant animals (used by Jerison 1973 and originally from Crile and Quiring 1940). Formatting the numbers this way makes plotting on log-log paper easier (see Figure 1).

Table 1

Group	Species	Body mass (g)	Brain mass (g)
Primates	Homo sapiens	8.30E+04	1.42E+03
Cetacea	Porpoise	1.42E+05	1.74E+03
Primates	Chimpanzee	5.67E+04	4.40E+02
Marsupials	Baboon	1.95E+04	1.75E+02
Aves	Crow	3.37E+02	9.30E+00
Proboscidea	Elephant	6.65E+06	5.71E+03
Carnivore	Wolf, Timber	2.99E+04	1.52E+02
Chiroptera	Bat, Vampire	2.80E+01	9.36E-01
Insectivores	Mole	3.96E+01	1.16E+00
Carnivore	Lion, Cubs	1.91E+05	2.58E+02
Rodents	Rat, Norway	2.78E+02	2.30E+00
Cetacea	Whale, Blue	5.92E+07	6.80E+03
Marsupials	Opossum	1.15E+03	4.80E+00
Aves	Ostrich	1.23E+05	4.21E+01
Osteichthyes	Tuna	5.21E+03	3.09E+00
Reptiles	Alligator	2.05E+05	1.41E+01

Brain vs. Body Mass

Students can see that the data are roughly linear and fit a straight line by eye. They then calculate the line's slope. This is the point where the most errors creep in, because they have to measure the arithmetic distance along x- and y-axis correctly.

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).

Students can see that the data are roughly linear and fit a straight line by eye. They then calculate the line's slope. This is the point where the most errors creep in, because they have to measure the arithmetic distance along x- and y-axis correctly.

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

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

When students reach this point, I poll them for their slope, post it, and calculate the average. This shows that the class average is close to the 2/3 value determined by Jerison, et al. (In my classes, average slopes range from 0.62-0.66).

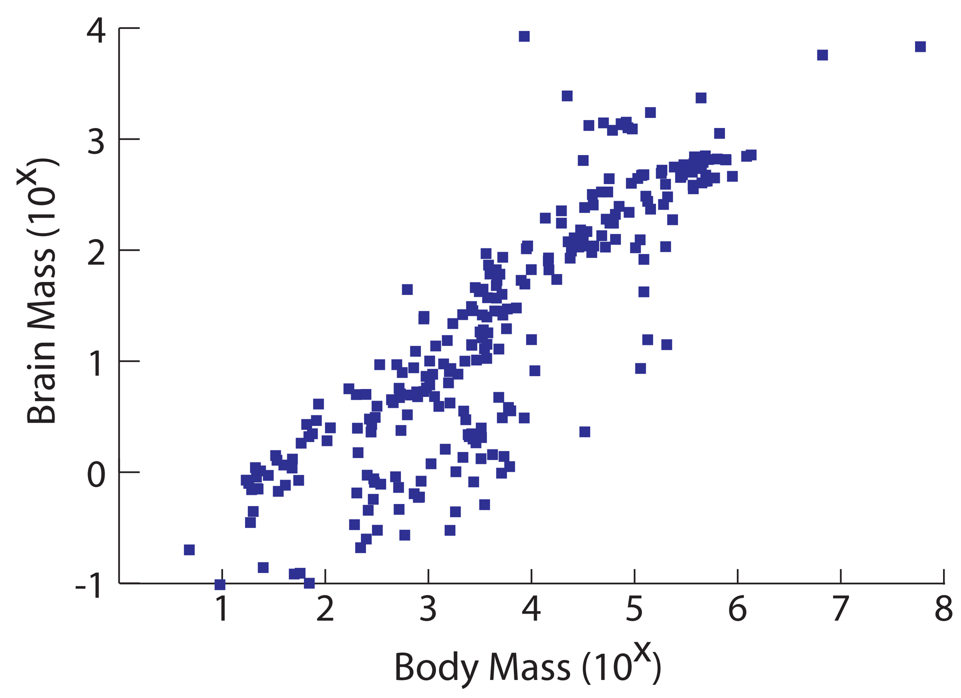

Figure 2. Body vs. Brain Mass (g) for 283 vertebrates. I show students this graph to show congruence with theirs.

Jerison (1973) 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 (see the clouds in Fig. 2; Jerison separated fish and amphibians from reptiles and mammals).

Gould (1977) pointed out that the ratio of surface area to volume in animals scales to the 2/3 power. This suggests that as nerve endings contact the body surface, so (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.

Suppose two animals are equally intelligent.

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

If r is this ratio: (Brain mass)/(Body mass)$^{2/3}$ = r

Take the log and re-arrange as

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

Thus, two equally intelligent animals would lie on a line with slope of 2/3. Alternatively, a more intelligent animal would be above a line with 2/3 slope going through the less intelligent one.

How do Dinosaurs Rank?

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

Humans are not very good at estimating vertical distance above a non-horizontal line. Cleveland (1985) describes the work that demonstrates this and 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.

The students then determine the logarithms of the brain and body mass of the modern vertebrates (Table 1) plus a set of dinosaurs (Table 2) and calculate the equation above. They then plot each value on a dot plot (Figure 3) and analyze the results.

Table 2

		Body (g)	Brain (g)
Carnosaur	Allosaurus	2.30E+06	167.5
Ornithopod	Anatosaurus	3.40E+06	150
Sauropod	Brachiosaurus	8.70E+07	154.5
Ornithopod	Camptosaurus	4.00E+05	23
Sauropod	Diplodocus	1.17E+07	50
Ornithopod	Iguanodon	5.00E+06	125
Ceratopsian	Protoceratops	2.00E+05	15
Stegosaur	Stegosaurus	2.00E+06	28
Ceratopsian	Triceratops	9.40E+06	70
Theropod	Tyrannosaurus	7.70E+06	202
Coelurosaur	Stenonychosaurus	4.53E+04	37
Ankylosaur	Euoplocephalus	1.90E+06	41

Data from Jerison (1973), Hopson (1977)

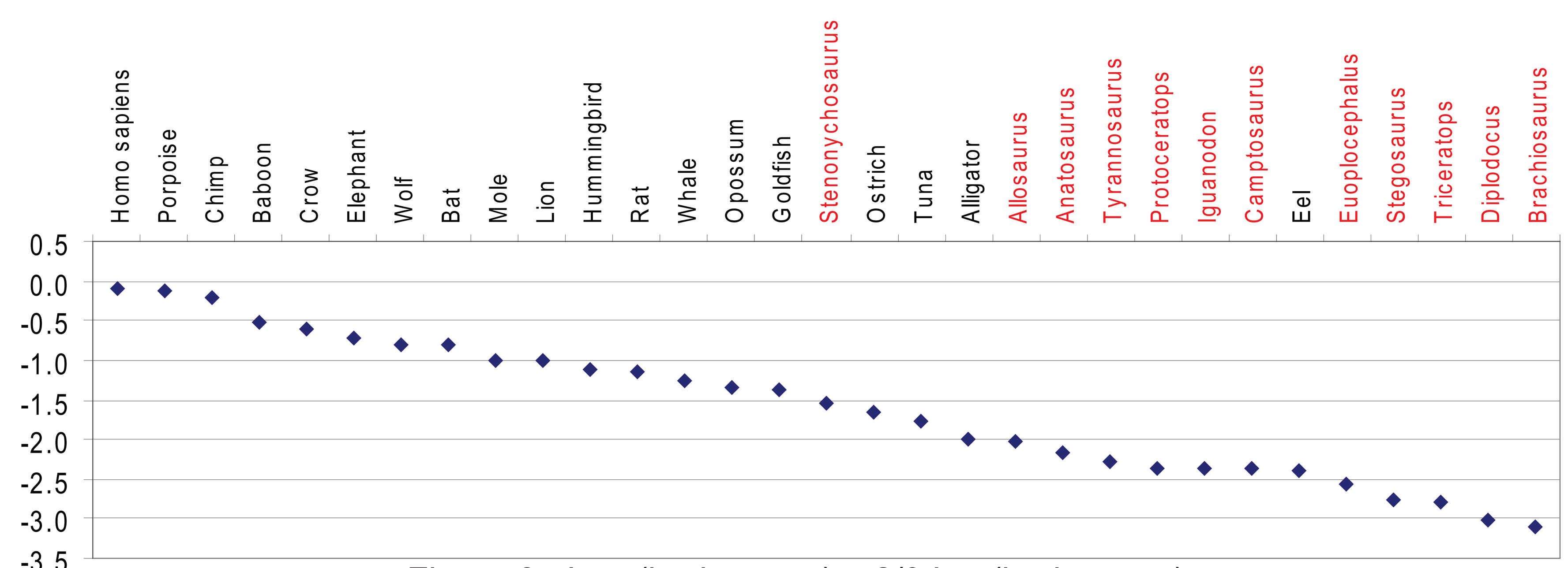

Figure 3. Log (brain mass) – 2/3 log (body mass)

Analysis of results

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?

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?

Unusual Materials Required

The graphing requires two pieces of 4x4 log-log paper spliced to create 8 cycles along the x-axis (body mass).

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.

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