Lecture 1: Allometry I
January 10 / 2013

THESE NOTES ARE FROM LECTURE AND COMBINE SOME ASPECTS FOUND FROM THESE WEBSITES:
http://hep.ucsb.edu/courses/ph6b_99/0111299sci-scaling.html
http://en.wikipedia.org/wiki/Allometry
http://en.wikipedia.org/wiki/Kleiber%27s_law

Organisms must integrate physiological functions and systems. This integration which is necessary for optimal performance scales differently for different species. However, it scales closely to body size. During evolution, organisms went from uni-cellular to multi-cellular. As more cells are packed together, the cell's surface area becomes less and less of what limits the organism as a whole.

The surface area affects excretion as well as many other processes
- Excretion occurs through the membranes (diffusion)
- Diffusion through the capillaries, lungs and kidneys

Specifically in mammals, body size can explain 95% of the metabolic rate variations. This will influence and affect every physiological aspect and system. Mice have a high metabolic rate/gram compared to elephants.

Allometry: the study of the relationship between size and shape. In more complex words: Differential scaling of functions and features according to body size.

Allometry can be compared within or across species.

Intraspecific allometry: big animals within a species grow faster, die faster
Interspecific allometry: big animals across species grow slower, longer life

Across Mammals, body size can vary greatly.
- All the way from 2 grams to 136000000g
- Phylogenetically there is an evolutionary increase in body size! This idea is called Orthogensis.

When animals have few predators, they can invest and grow to be larger and thus become more efficient and resistant to environmental fluctuations. When animals are highly predated, they are unable to invest and grow and thus they are forced to quickly grow and reproduce. They mature quickly and forced to have many offsprings.

Orthogenesis is the evolutionary idea of the increase in body size due to certain physiological advantages that might affect the organism; the idea of dissipation of heat is one of these advantages.

The idea of change in size to gain certain advantages can be seen in horses and rats. Horses evolved to be larger to help with their running as it improves the cardiovascular system.

Looking at the allometry of human development:
Human babies have a large head compared to body size, as the human baby grows, the limbs grow faster than the head and so the head size related to the body changes.

Brain size can also be compared across primates.
The human brain is around 1350g vs. chimpanzee/orangoutang 400g. The number of cells may allow more sophisticated physiological process. This increases the brain size.

An example of this is through an Island example that impacted body size. Food and predator limitations affected body size.

Some animals got smaller, small animals got bigger. They had features that were strange… but they were homo eructs like but they had the brain size of 400g that small… they had tools and so chimp can't be like that.. but this is challenged with that indian woman from world record 2012. Her skull size can't hold a human brain size. Not all of these things are strictly related to size. brain size can be altered to meet different physiological needs. She is fairly intelligent yet her brain size is not the same as others. This just shows that the "hobbits" who had 400g brain sizes in the island might actually be homo errecuts. Size changes can happen and yet keep the same brain functions.

Allometry of the cube:
We can look at the relationship of the length of the side of the cube related to the surface area. The cube with the side length of 2, it's SA is a sqaure of 4 and the volume is 8.

Length	Surface area	Volume:
$L = 3$	$L^2 = 9$	$L^3 = 27$

$$Y = aX^{\text{surface area/volume}}$$
$$= aX^{SA(L^2)/VOL(L^3)}$$
$$= aX^{2/3} = aX^{0.67}$$

Thus, as we scale using the square-cube law, the exponent should be around 0.67. From this we get the Allometric equation: most factors that change with body size across and within species can be described by the equation

$$Y = aX^b$$

B is basically the exponent or the slope
Y would be the variable we are looking at and X is body size.

Isometric vs allometric scaling:

An organism which doubles in length isometrically will find that the surface area available to it will increase fourfold, while its volume and mass will increase by a factor of eight. This can present problems for organisms. In the case of above, the animal now has eight times the biologically active tissue to support, but the surface area of its respiratory organs has only increased fourfold, creating a mismatch between scaling and physical demands. Similarly, the organism in the above example now has eight times the mass to support on its legs, but the strength of its bones and muscles is dependent upon their cross-sectional area, which has only increased fourfold. Therefore, this hypothetical organism would experience twice the bone and muscle loads of its smaller version. This mismatch can be avoided either by being "overbuilt" when small or by changing proportions during growth, called allometry.

We understand linear relationships better, however physiological relationships are exponential (curved). By converting relationships to a log scale, we obtain a straight (linear) line.

Due to the difference in the way we scale things, the b of the inter-specific allometric scaling (between species) factor is 0.75. One can say that allometry does not obey the surface area rule of 0.66! It rather has the value of 0.75 (increasing relationships) or -0.25 (for decreasing relationships).

For most factors the b of the intra-specific allometric scaling (within species) factor is closer to 0.66 (increasing) or -0.33 (decreasing). Thus you can say that the square-cube law is followed within species.

As the organisms gets bigger, they should conform to this rule. But not all of them do. Exponential increase in surface area and volume for any unit of length.

As we look at metabolic rate and body size, the metabolic rate increases at a much greater rate but not proportional to the increase in body size.

As animals get bigger, their surface area gets exponentially smaller compared to the volume. This poses an issue when we compare metabolic rates between different species with different body size. Yes the elephant has a bigger overall metabolic rate, yet the mice has a bigger metabolic rate per gram.

To make it simpler... 1 mg of elephant compared to 1 mg of mice in terms of metabolic rate.. You would see that the mice would have a higher metabolic rate!

If you scale animals up or down you can get how this affects the physiological functions:
- If we scale a mouse to an elephant size, the organism would not be able to dissipate the heat produced by it’s cells quickly. The mouse would heat and blow up! Mice are unable to deal with this heat better. The scaling does not occur proportionally though, the scaling is less than 1 when it comes to the b (exponent) The exponent is 0.75 and not 0.66.