

Kardong, Chapter 4

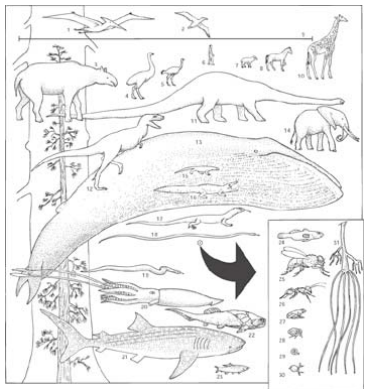
Biological Design

In other words, size and shape DO matter!

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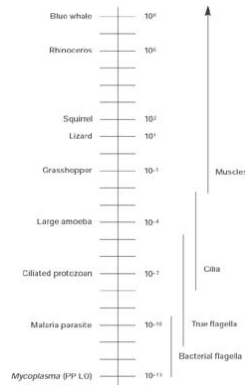
Scaling

- the study of size and its consequences
- Physical laws (physics) provide size constraints on living body forms, organs and functions



Organismal size range is great

Not all "designs" work equally well for all sizes of organisms



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Physical characteristics often produce different actions, and are dependant upon Laws of Physics

Different sizes resonate at different frequencies; hence different tones for these instruments

Tonal relationship to frequency = absolute

4

Physical limitations require proportion changes in different sized objects

Relatively larger object encloses a greater volume

Church of Little Tey 10 m

Increased volume means dimmer interior, so window area must be increased to allow more light to enter

Norwich Cathedral 10 m

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Columnar limbs support great weight
—gravity is a serious concern

(a)

(b)

Surface tension matters to a small organism

Gravity is a problem if you are large

Surface tension is a problem if you are small

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Length, area and volume relationships - Constant shape but change in body size increases surface area some but causes an even greater relative increase in internal volume

Surface area is squared = X^2

Volume is cubed = X^3

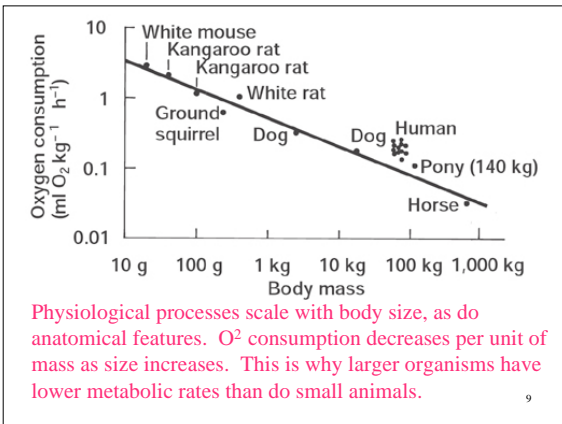
Cube	Side Length (cm)	Surface Area (cm ²)	Volume (cm ³)
Cube 1	1	6	1
Cube 2	2	24	8
Cube 3	4	96	64

Surface area: volume = 6:1, 24:8, 96:64

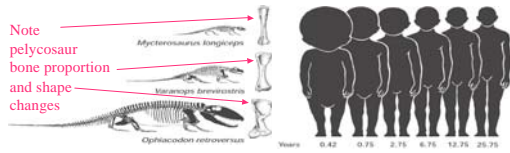
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- Physiological performance depends on surface area and volume relationships
- Therefore, larger animals must have different proportions than smaller ones
- Volume increases cause increased mass
- Body support by limbs with strength according to X-sectional area (X^2)
- Mass increases according to (X^3)
- I. e., shape changes as an organism grows to maintain proper relationship among functional regions

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- Animal morphology must be alterable to accommodate changing mass and length of areas
- Animals have different sizes at different ages

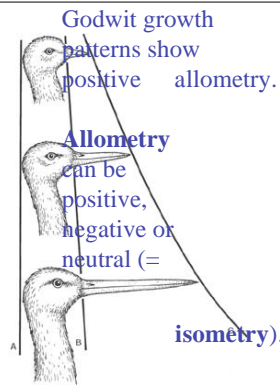


As body mass increases, bones the attachment surfaces and other surface features they bear become relatively larger. This exaggeration relates to x-sectional area of the attachment surface and the X^3 mass of the increasing volume of muscles, etc. attaching to the bone.

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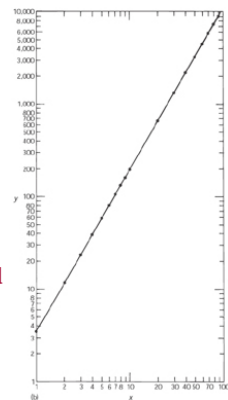
Allometry is a change in shape that correlates with size

- Phylogeny may be related to allometry if a phylogenetic trend includes a relative change in size and proportion through time



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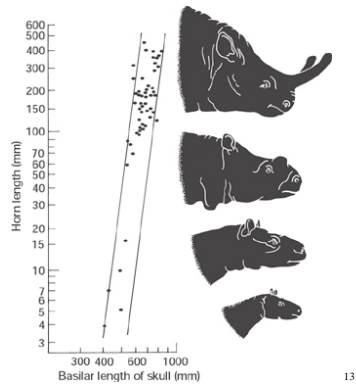
Specimen	Skull dimensions (mm)	
	x	y
A	1	3.5
B	2	11.8
C	3	23.9
D	4	39.6
E	5	58.5
F	6	80.5
G	7	105.4
H	8	132.0
I	9	161.7
J	10	194.4
K	20	642.0
L	30	1,342.9
M	40	2,238.9
N	50	3,395.1
O	60	4,827.7
P	70	6,528.1
Q	80	8,489.9
R	90	10,704.3



Allometry can be graphed and understood mathematically, and therefore compared by examining line slopes

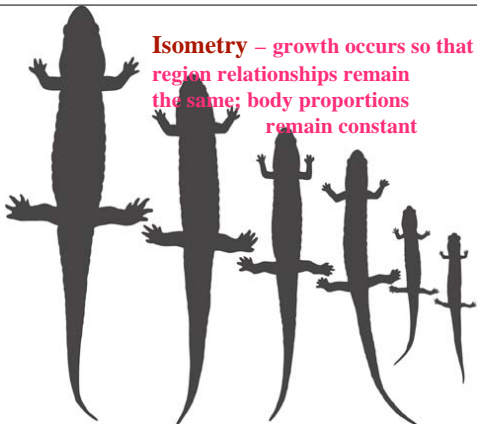
Allometric trends in phylogeny = shape change accompanied by change in size.

Horn length in titanotheres. Increase is allometric



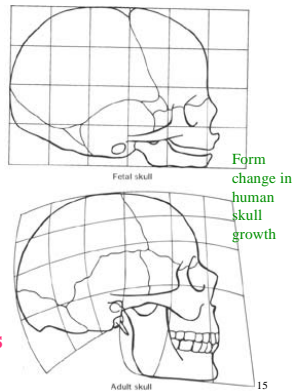
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Isometry – growth occurs so that region relationships remain the same; body proportions remain constant



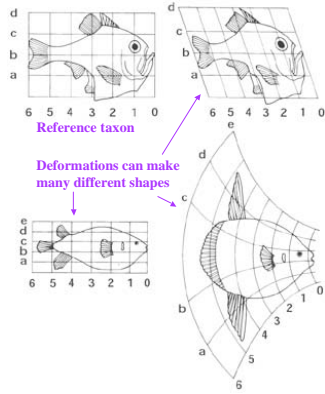
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D'Arcy Thompson Transformation Grids. These show where and by how much a region of a structure changes with respect to a different growth stage, or between taxa, or to demonstrate phylogenetic changes through time.



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Transformation grid
 use to understand phylogenetic changes. One taxon is the reference, and points plotted on it are shown in relatively the same place as deformations of the shape in comparison taxa to show shape changes of regions of descendant taxa. This can show patterns of shape change and trends through time.



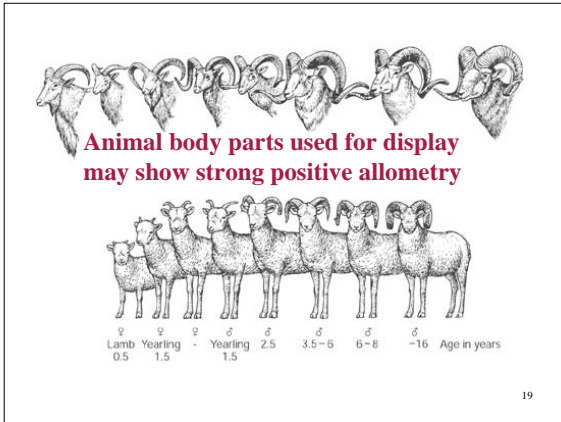
Size matters

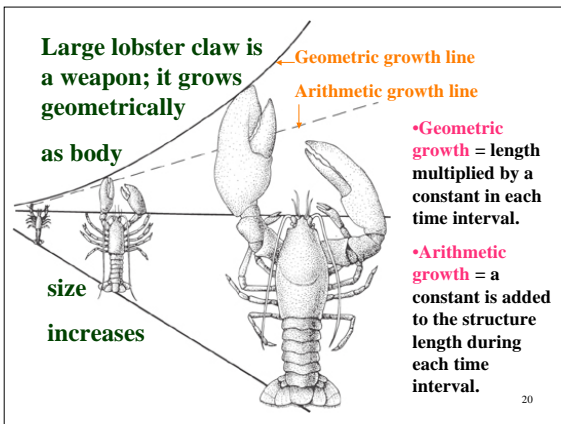
- **PROS:** Larger animals have fewer predators, longer lives, longer juvenile periods for learning.
- **CONS:** Require more food, larger territories, have longer gestation times, fewer offspring, and recover more slowly to population losses
- **Body form must be altered to support more weight = graviportal adaptations**

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- Many refinements have been added to this kind of analysis, using newer techniques
- Thin plate spline analysis
- Landmark analysis
- 3-D imaging analytical methods, which is why scans and computer reconstruction of structures can provide so much information
- However, all methods are a means of determining the changes in shape of an organism in relation to changes in the shape

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- The growth pattern of a feature may permit behavior changes.
 - Small lobster cannot use claw large enough to be sufficient weapon, although once it is larger it can.
 - Small lobsters have to hide from potential danger
 - Larger lobsters armed with VERY large, strong claw can defend itself without running away if necessary
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