

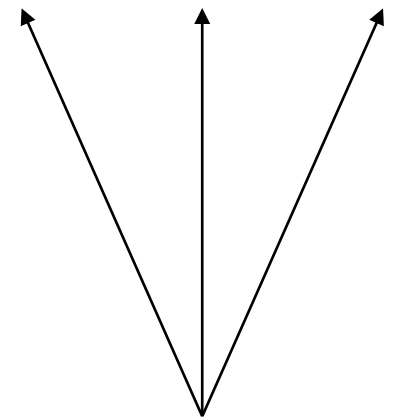
Organizing your ideas





Details

**Implications
or 2nd level ideas**



Main Idea

Lecture 2. Scaling & Metabolism

- does body size matter?
- allometry and isometry
- how to compare animals of different sizes?

General Sherman, Biggest Tree in the World



http://en.wikipedia.org/wiki/File:General_Sherman_Tree_wide.jpg

83m (275 ft) tall
trunk volume 1,487 cubic meters!



<http://www.airlinesafety.com/editorials/AboutTheEditor.htm>

diameter at ground 11.1m (36.5 ft)
1.4m above ground 7.7m (25.1)
18m above ground 5.3m (17.5ft)
4

Largest Animals



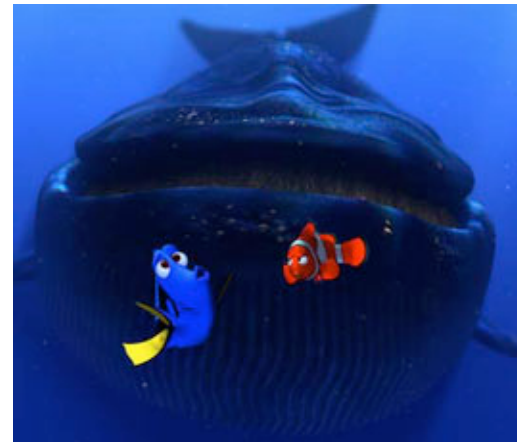
<http://media.photobucket.com/image/blue%20whale/crashmedic505/BlueWhale.jpg>

Blue Whale

33m (108ft)

180 metric tons (180 x 1000 kg)

200 short tons (x 2000 lb)

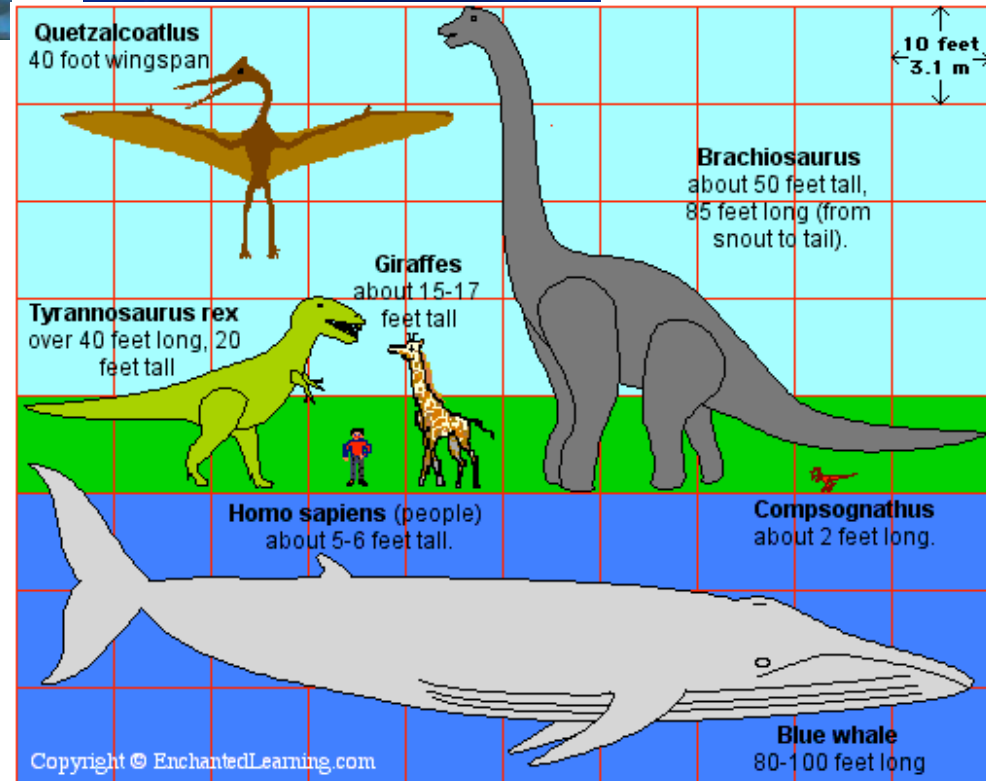


African Bush Elephant

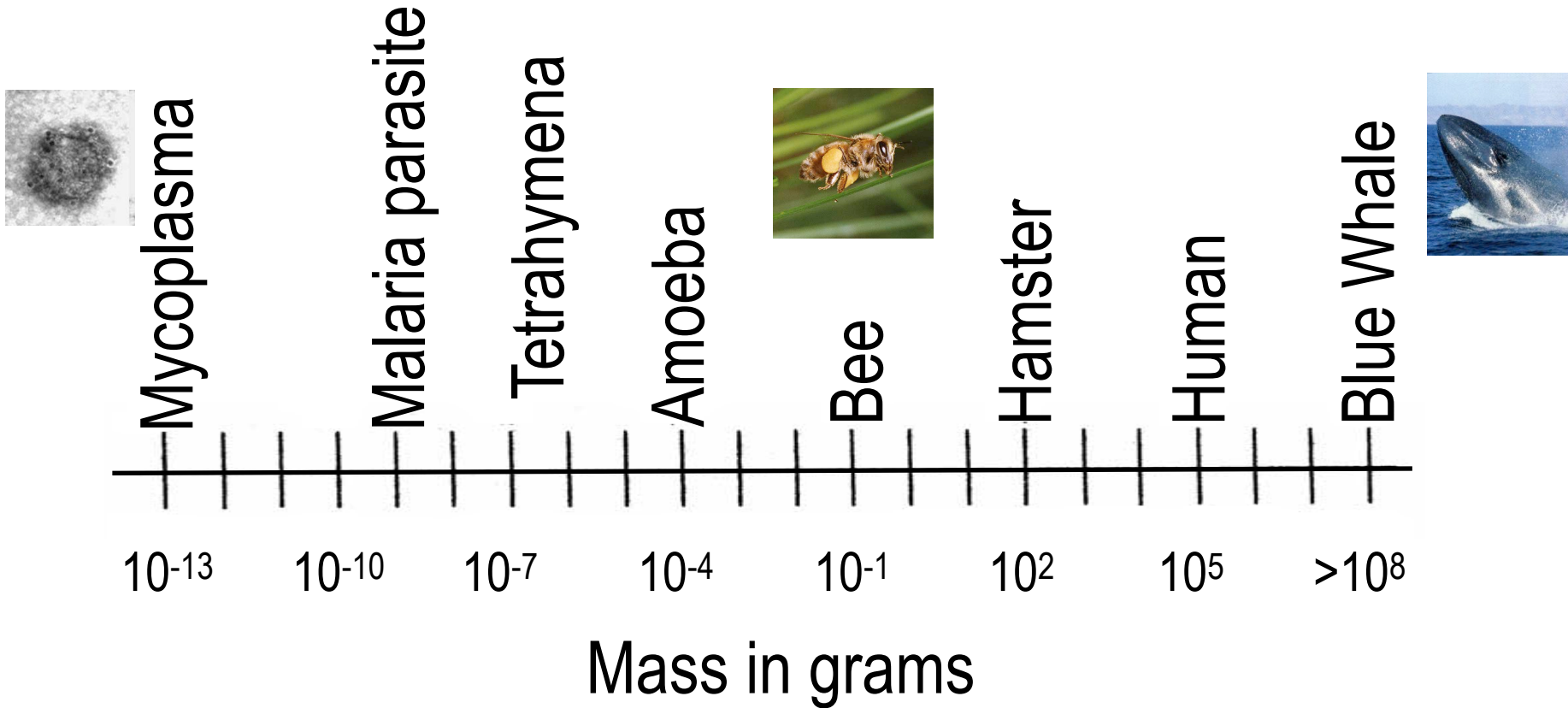
7.3m x 3.5m

9000 kg

http://en.wikipedia.org/wiki/File:Elephant_near_ndutu.jpg

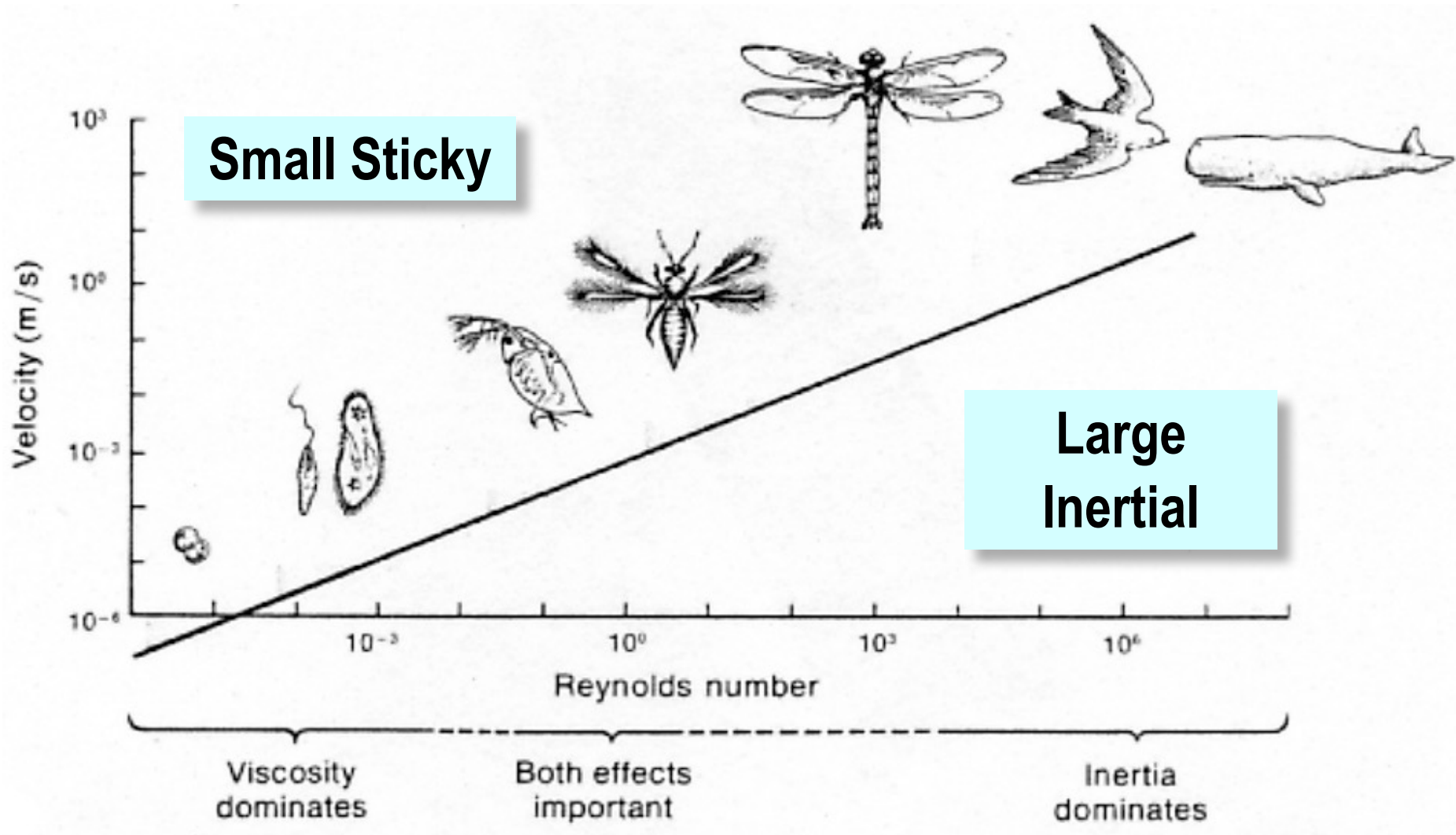


The Scale of Life



The difference between the smallest and the largest organism is 10^{21} !

Novel Worlds

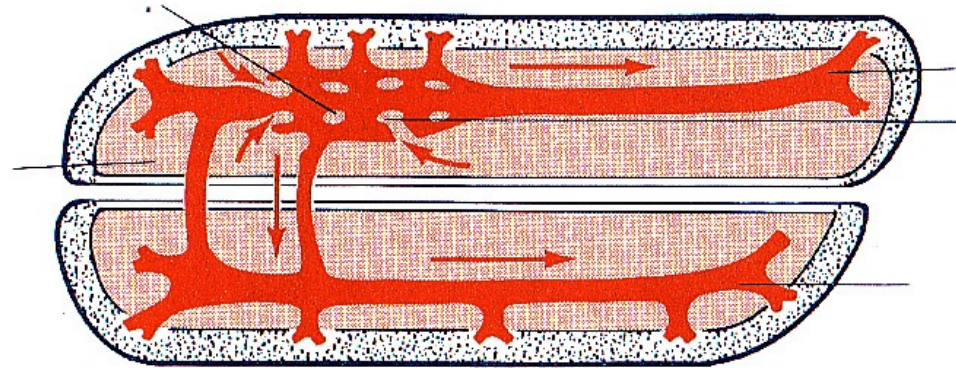


Novel Systems

To get large organisms evolve novel transport systems

Circulation

**Diffusion
Inadequate at
Larger Sizes**



Does Size Matter?

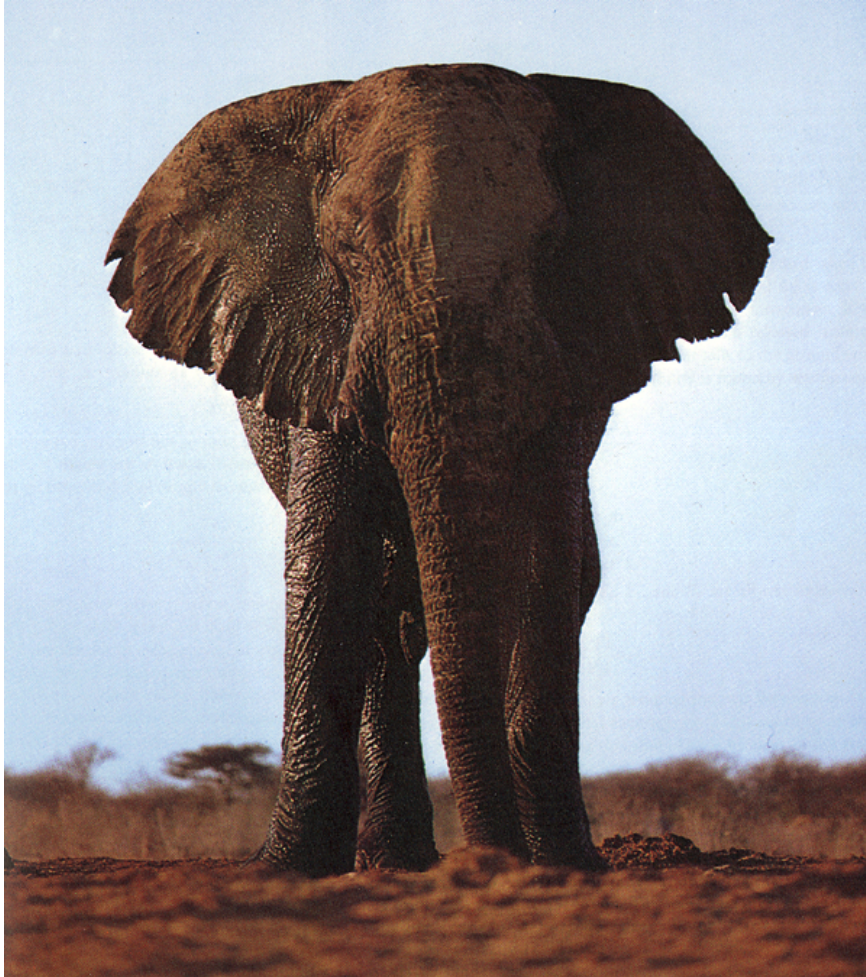
Big - Get Hurt

You can drop a mouse down a thirty yard mine shaft; and on arriving at the bottom, it gets a slight shock and walks away... A rat is killed, a man broken and a horse splashes.

— J.B.S. Haldane 1928

Size matters!

Importance of Scaling



Tusko
On
Drugs

In 1962, three men at the University of Oklahoma, lead by Louis Jolyon "Jolly" West, injected LSD into an elephant for the first time.

Their stated intent was to determine if LSD would induce "musth", a naturally occurring condition in which elephants become violent and uncontrollable.

297-Mg. Shot of LSD Kills Bull Elephant



Newspaper Story about Death of Elephant Injected with LSD (Medical Tribune Sep 3, 1962)

Photo by Erowid, © 2002 Erowid.org

The 7000-pound bull elephant named Tusko was injected with a huge dose of LSD (297 mg) into one buttock with a dart rifle... "Five minutes after the injection he trumpeted, collapsed, fell heavily onto his right side, defecated, and went into *status epilepticus*. ... The picture was that of a tonic left-sided seizure in which, mild clonic movements were present."
-- West LJ, Pierce CM, Thomas WD. Science, 1962, 1100-1103.

Tusko was overdosed, and died.

What Happened?

Dose: Direct Proportionality

Human

$$0.02 \text{ mg / 1 kg} = 1.4 \text{ mg / 70 kg}$$

Elephant

$$= 70 \text{ mg / 3500 kg}$$

Cat

$$0.1 \text{ mg / 1 kg} = 0.5 \text{ mg / 5 kg}$$

Elephant

$$= 350 \text{ mg / 3500 kg}$$

Gave Elephant 300 mg!

Drug Dose

<u>Mass</u> (kg)	<u>Animal</u>	<u>Metabolic Rate</u> (ml O ₂ /g/h)	<u>Dose Based on Metabolic Rate</u> (mg)	
20	Cat	0.3	2	(0.1 mg / kg)
70	Human	0.2	4.7	(0.06 mg / kg)
3500	Elephant	0.1	117	(0.033 mg / kg)

350% Overdose!

1 kg of elephant tissue requires only 1/3 the O₂ that cat tissue does.

Metabolic rate is not directly proportional to body mass!!!!!!

Log Metabolic rate vs Log Body mass

- the slope of the line is not 1.

**Can we describe how
organisms get larger?**

Scaling Relationships

Scaling - Geometric Similarity or Isometry

Organisms are similar if the large one is an enlarged picture of the small one.

Newton's Law
of Similarity



Regal horned lizards

i.e., All body lengths increase at the same rate

If organisms were cubes:

Scaling Surface Area to Volume

$\lambda = 3$
means:

Three times the length
Nine times the area
27 times the volume

Surface area to Volume ratio has a huge effect on many physiological functions as animals get larger!

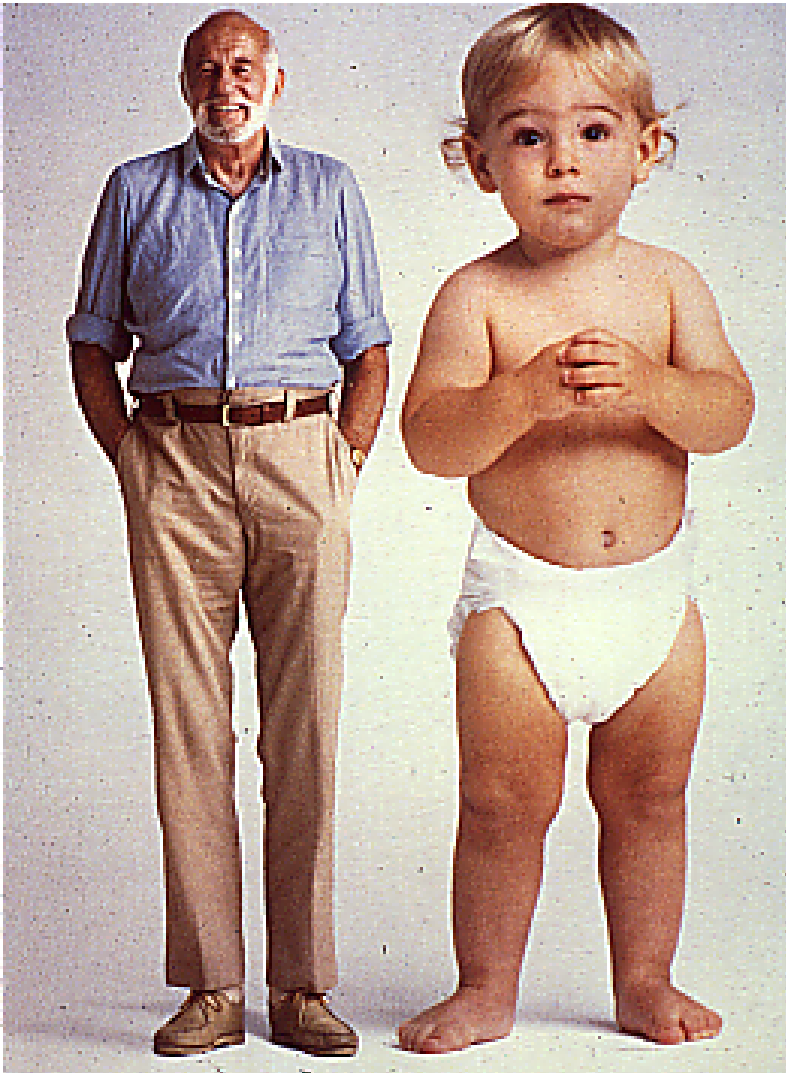
$$\text{surface area} \propto (\text{length})^2$$

$$\text{volume} \propto (\text{length})^3$$

$$\text{surface area} \propto (\text{volume})^{2/3}$$

These are the relationships we expect based on isometry

Allometry



**Non-Geometric
Scaling is
called Allometric
Scaling
(Greek allios,
different).**

General Sherman compared to Bonsai



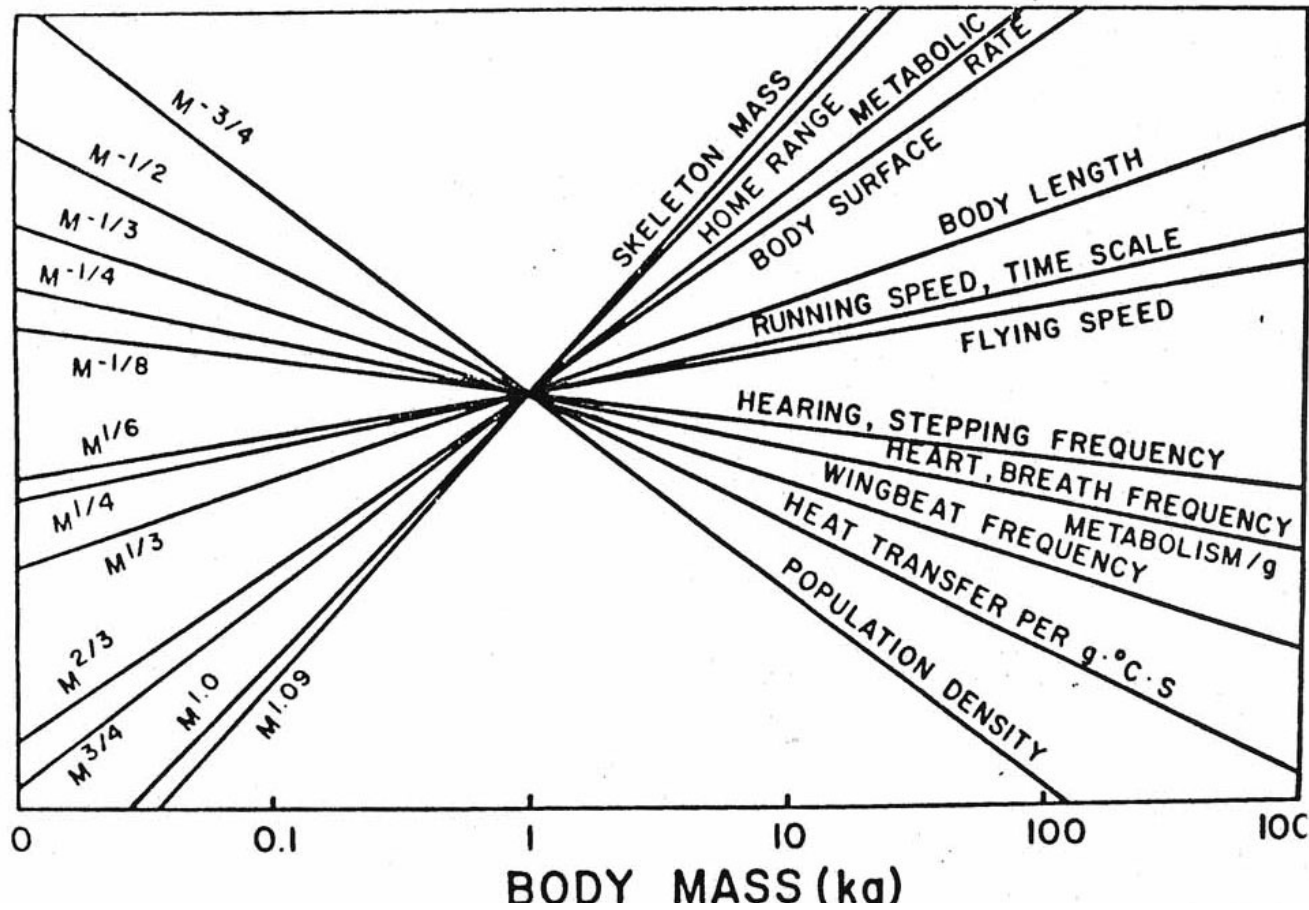
Giant Sequoyah
275 ft tall
25 ft diameter



Sequoyah Bonsai
9 in tall
.75 in diameter

Scaling - size dependence of physiological properties

Nearly all structural and functional variables scale!



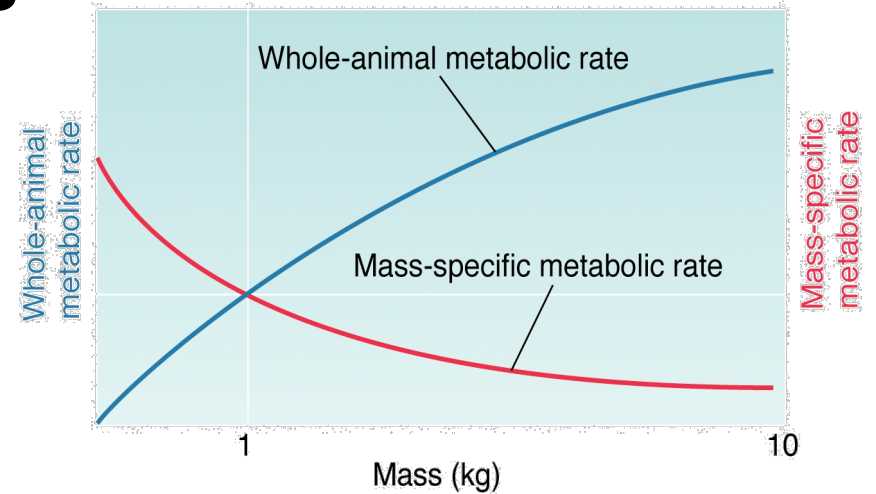
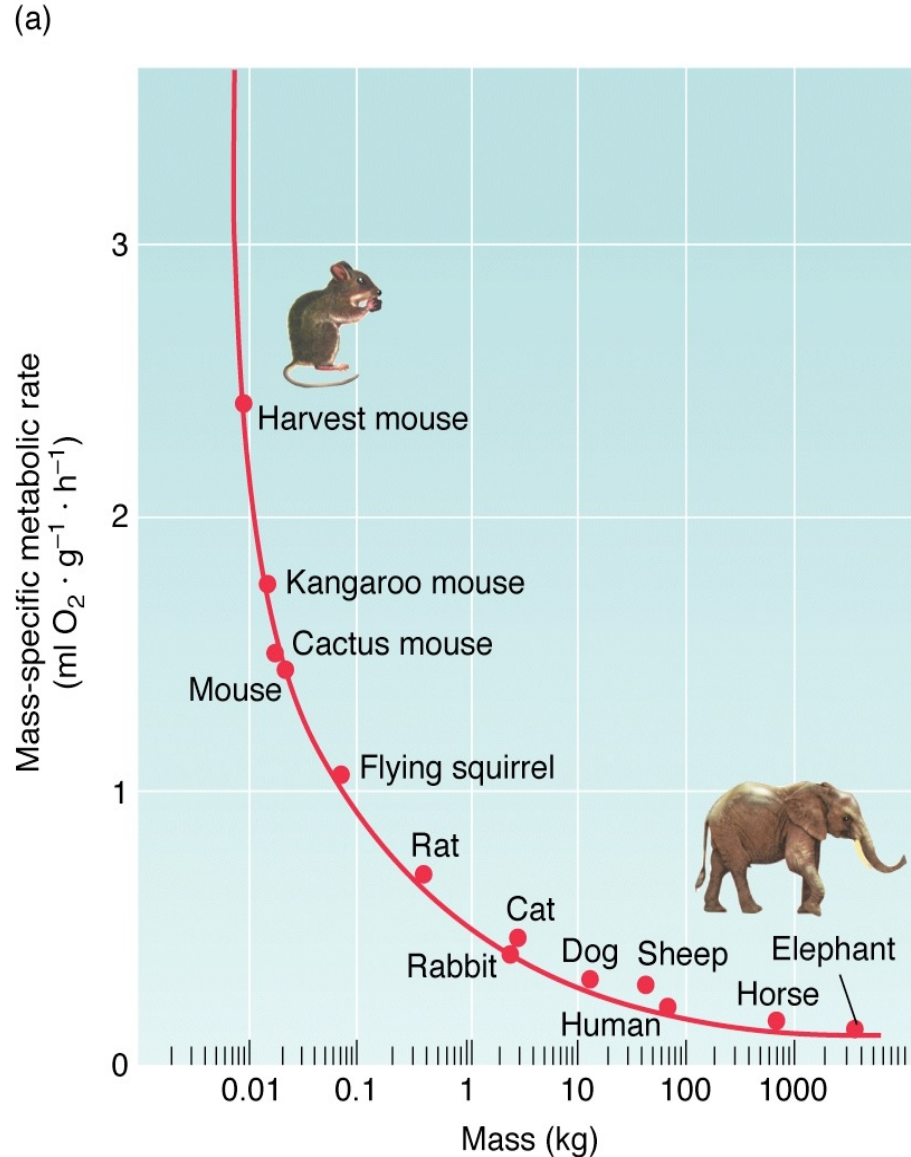
(on log-log plot)

Most relationships do not have a slope of 1.0!

Metabolic Rate is a Power Function of Body Mass

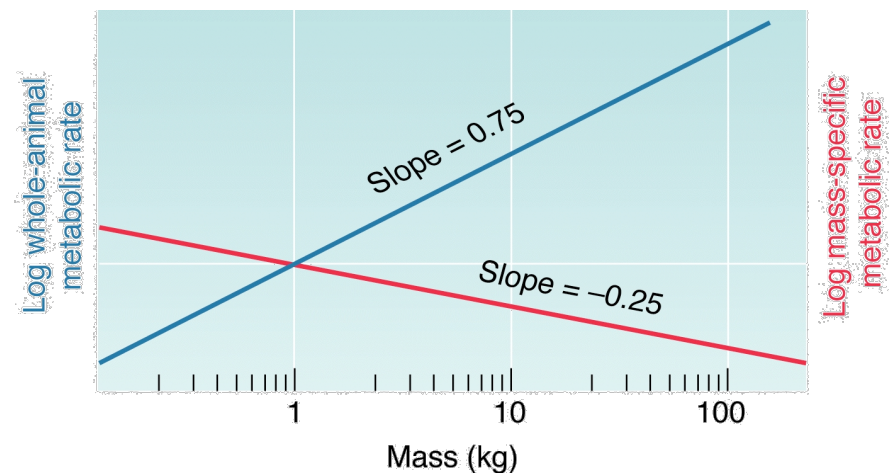
“Mouse to Elephant Curve”

Metabolic Rate = $a \cdot \text{Mass}^b$



MR = aM^b

MR/M = $aM^{(b-1)}$



Why?

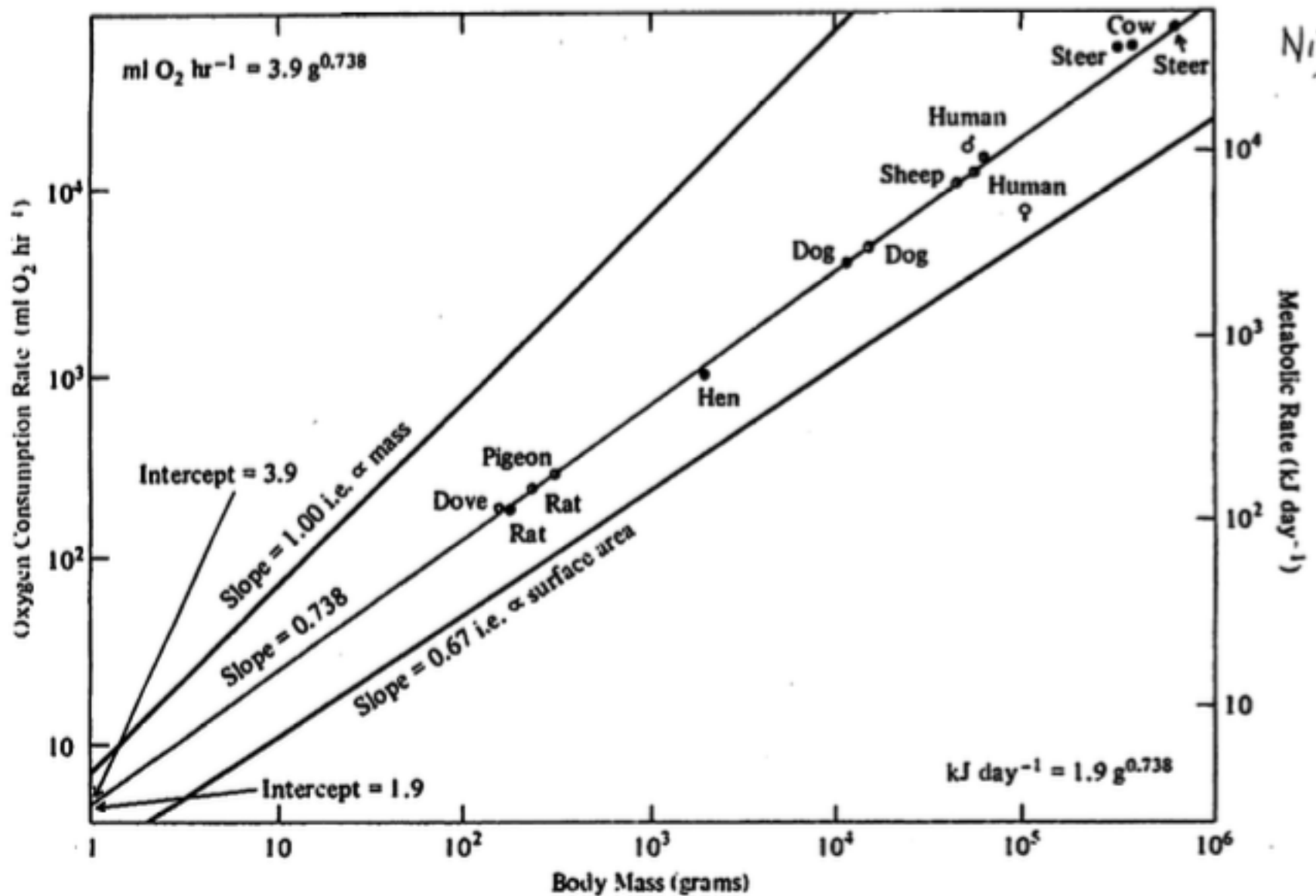


FIGURE 4-6 Relationship between \log_{10} metabolic rate and \log_{10} body mass for mammals and birds. (Modified from Kleiber 1932.)