Themes 2

- send answer to iClicker Question 8A now.
- Exam I information (Monday 3/1)

Size & Scale

- principles (M&Ms)
- consequences I: bone strength (50-foot woman)

iClicker Question 8B

Due in lab **this** week:
⇒ pre-lab for Aipotu IV (lab manual p 51 and on-line)
⇒ Molecular Phylogeny lab report

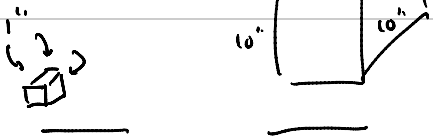
Exam 1: Monday 3/1 (info in Themes 2 handout)

- Last names A - G in McCormack Cafe (3rd floor above stairwell)
- Last names H - Z here (1 bonus point for going to correct place!)

bring a scientific calculator

Size & Scale principle: proportional scaling

ex. cubes



← "10-times larger"

cube			change	in general
• length of each side	1 inch	10 inches	10-fold larger	x-times larger
• Surface area	6 square inches	600 in^2	100-fold larger	x^2-times larger
• Volume	1 cubic inch	1000 in^3	1000-fold larger	x^3-times larger
• Surface / Volume ratio	$6/1 = 6$	$600/1000 = 0.6$	10-fold smaller	x times smaller

~ true for any shape

& since density $\left(\frac{\text{weight}}{\text{volume}}\right)$ of living things ~ constant

if size ↑ 10x proportionally, ⇒ weight ↑ 1000x

example: M&Ms

m&m	diameter (measured)
mini	9mm
regular	13mm

) increased $\frac{13}{9}$ fold or "1.44x larger"

weight : mini = 276 mg

estimate weight of regular using proportional scaling

which is it?

a) 276 mg x 1.44 = 399 mg

b) 276 mg x $(1.44)^2$ = 576 mg

c) 276 mg x $(1.44)^3$ = 832 mg

measure regular m&m = 859 mg

∴ proportional scaling ~ works for different shapes

Application I : surface to volume ratio

assuming ① proportional scaling

② all m&ms have same thickness of coating

which m&m has higher % chocolate?

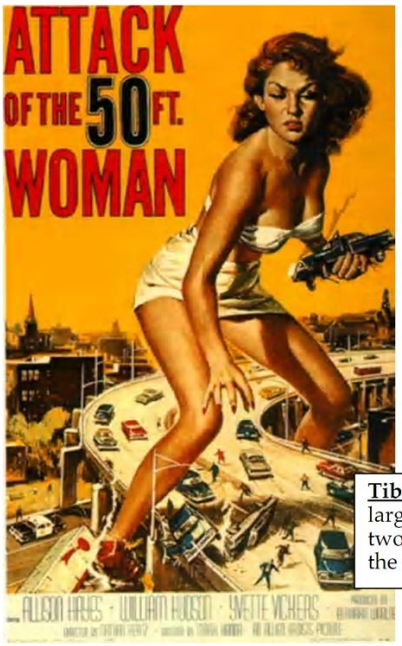
mini both = regular

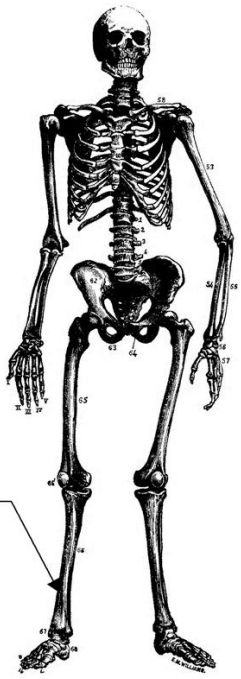
why? bigger m&m → lower $\frac{\text{surface}}{\text{volume}}$ ratio ∴ $\frac{\text{coating}}{\text{chocolate}}$

∴ more % chocolate

Bio 112 Size & Scale

(1) Fictional Example





Tibia - the larger of the two bones in the lower leg.

Application II - bone strength

bone ↓ force

force required to break depends on
"thickness" - more precisely
- area of cross section

for most bones, if force is greater than

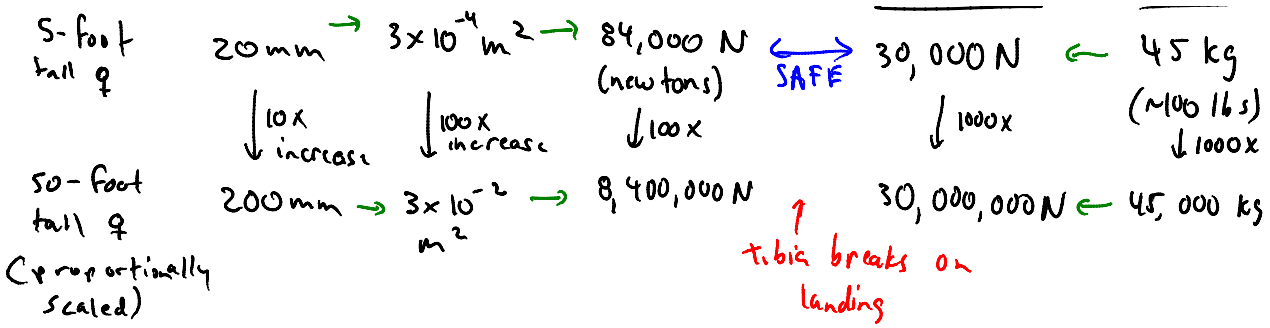
280 $\frac{MN}{m^2}$ Mega Newtons (force) / per square meter (area) } bone will break

∴ max force a given bone can stand

= 280 $\frac{MN}{m^2}$ x (cross section area of bone)

*can measure forces in real animal (dog)
& calculate approximate #s for other cases

tibia diameter	tibia cross section area	strength of tibia (force to break)	actual force on tibia when jumping	body weight
small	→ 2×10^{-4} →	94		



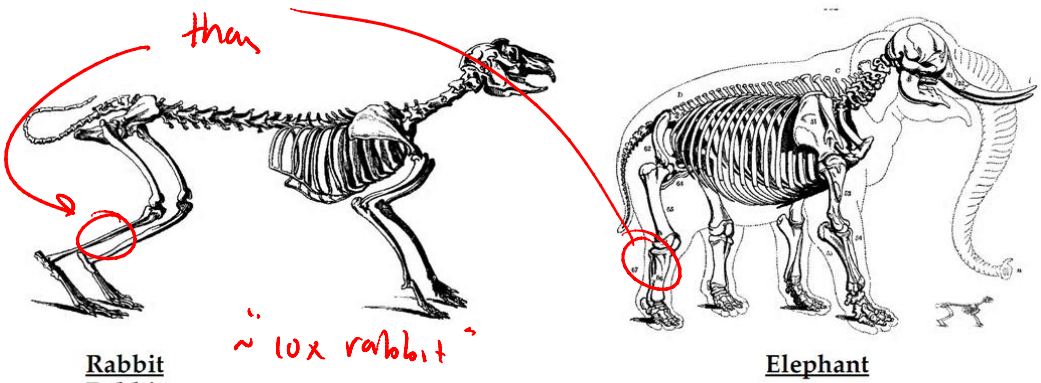
bone is 100x stronger but she's 1000x heavier

Conclusion: to make 10x larger creature, bones must be more than 10x bigger

(2) Real-Life examples

4-legged mammals:

more than 10x thicker than



~ 10x rabbit

Rabbit
Rabbit
enlarged to elephant size

Elephant
correct relative sizes

Notice that the elephant is not just a scaled-up rabbit; the leg bones are much thicker.
Notice also that the elephant stands with knees locked & legs vertical while the rabbit's legs (which must support much less weight) can be bent at rest.

▪