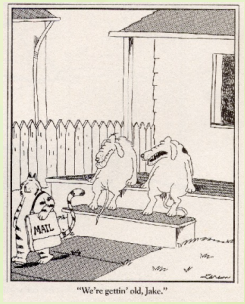
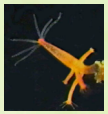
Evolutionary and comparative aspects of longevity and aging



A&S300-002 Jim Lund Reading:

Aging is nearly universal: the exceptions



- Bacteria don't age.
- Hydra don't appear to age:
- Some rockfish live 200+ years; it's not clear if they age
- Red sea urchin is still fertile at 200+ years.
- Tortoises, amphibians, American lobster
- Trees: giant Sequoia 2,000+ yrs, bristlecone pine 4,000+ yrs.

Not well studied

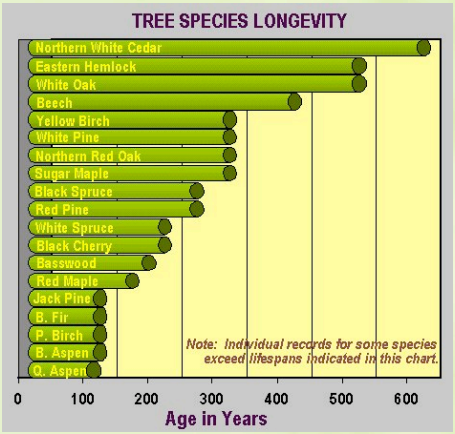
Continue growing and have no fixed size.

Slow/negligible aging

Tortoise
200+ yrs.

Bristlecone pine
4,000+ yrs.

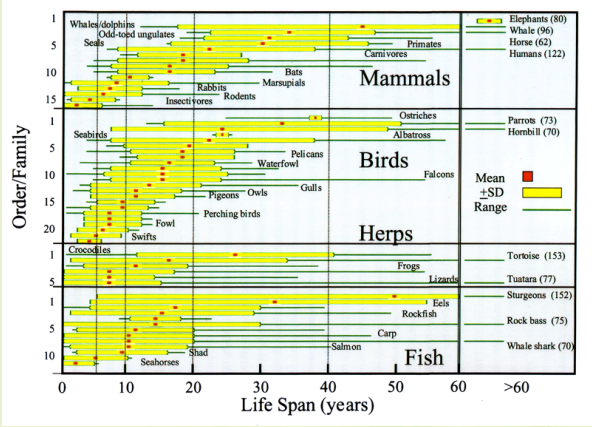
Tree lifespans



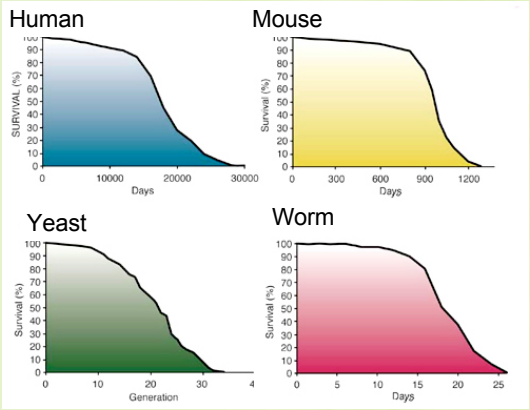
Max recorded lifespans for different species

Species	Years
Quahog clam	200+
Galapagos turtle	100+
Human	122
Indian elephant	70
Chinese alligator	52
Golden Eagle	46
Gorilla	39
Common toad	36
Domestic cat	28
Domestic dog	34
Vampire bat	13
House mouse	3

Comparing lifespans among species



Universality of aging



Special cases

- Programmed senescence:
  - Semelparous animals
    - Pacific salmon (spawning->rapid aging)
    - marsupial mice (*Antechinus stuartii*), males die during mating season of sexual stress
    - Bamboo, hormonally triggered reproduction and death.
  - Social insects. Caste-specific ls: female workers 1-2 months in the summer, 6-8 months in the fall; queens, 5+ years.
- Yeast: replicative life span = 21-23 divisions, mother cell enlarges and can be followed.

Life courses and aging

Long-lived animals tend to have longer juvenile periods.

Typical animals (mammals/birds):

- Final adult size (growth stops).
- Reproductive phase, then it ceases.

Animals with slow/negligible aging

- Reproduction continues.
- Growth continues.

Clearest in long-lived trees!

Aging model organisms

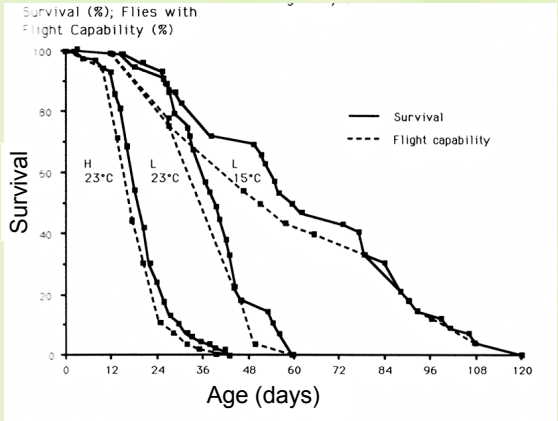
- Yeast, *Saccharomyces cerevisiae,* 21-23 generations
- Worm, *Caenorhabditis elegans,* 2 weeks @ 20ºC, 10 days @ 25.5ºC
- Fly, *Drosophila melanogaster,* 2-3 months
- Mouse, *Mus musculus,* 2 yrs.
- Rat, *Rattus norvegicus,* 2.5 yrs.
- (Humans), 78 yrs.

(Average lifespans)

Longevity and time to attain reproductive maturity at puberty for various mammals

	Maximum life span (months)	Length of gestation (months)	Age at puberty (months)
Man	1440	9	144
Finback whale	960	12	—
Indian elephant	840	21	156
Horse	744	11	12
Chimpanzee	534	8	120
Brown bear	442	7	72
Dog	408	2	7
Cattle	360	9	6
Rhesus monkey	348	5.5	36
Cat	336	2	15
Pig	324	4	4
Squirrel monkey	252	5	36
Sheep	240	5	7
Gray squirrel	180	1.5	12
European rabbit	156	1	12
Guinea-pig	90	2	2
House rat	56	0.7	2
Golden hamster	48	0.5	2
Mouse	42	0.7	1.5

Lifespan is temperature dependent (in exotherms)



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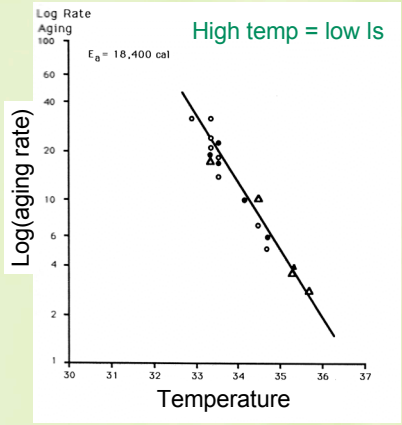


Diseases of aging can differ

Common causes of death:

- Yeast: bud scarring
- Worm: proliferation of intestinal bacteria, can't feed.
- Fly: mechanical damage, can't feed.
- Mouse: cancer
- Rat: cancer, kidney disease
- Humans: heart disease, cancer

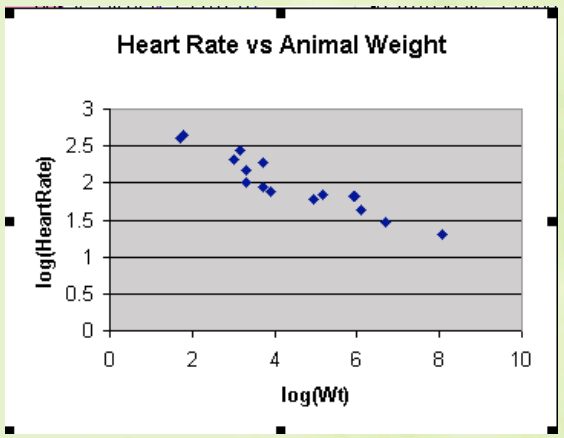
Commonalities in aging (increased death rates, stress, disease)

- Physiological changes
  - muscle degeneration (movement slows)
  - Heart rate slows
  - Organ function declines
- Cell loss with age
- Loss of stem cells
- Neural degeneration
- Cellular changes
  - DNA damage
  - Pigmented deposits
  - protein turnover slows

Scaling laws--allometry

- As length (L) of an organism increases:
  - Mass goes up as the cube of L.
  - Surface area goes up as the square of L.
  - Muscle scales as the cross-section of muscle (square of L).

Scaling laws--allometry



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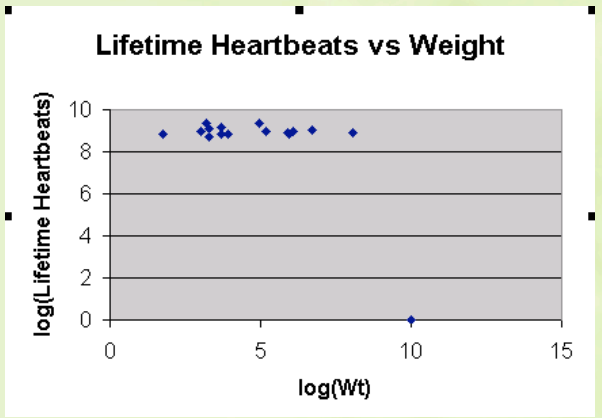
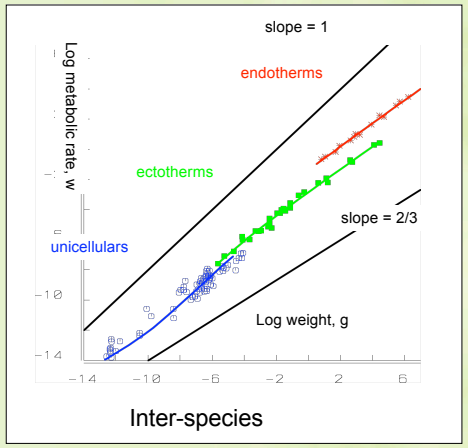


Scaling laws--allometry

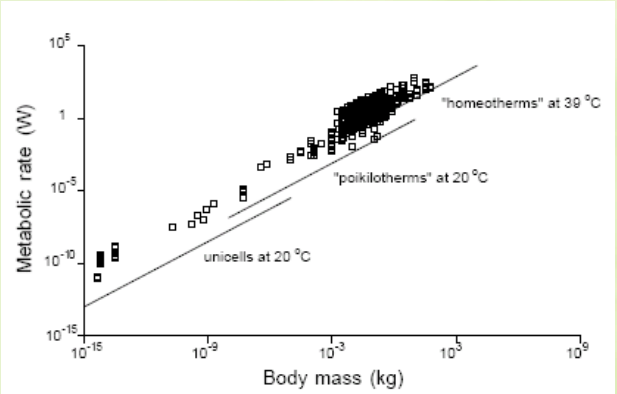
- Kleiber's Law: $R \sim M^{3/4}$
  - Metabolic rate scales as 3/4 power of mass.

Metabolic rate scales with weight



Inter-species

Temperature-compensated metabolic rates of all organisms scales to 3/4



Gillooly et al., 2001, Science

Evolutionary aspects of aging

- Organisms must survive long enough to reproduce--ls matches the ecological niche.
- Events after reproduction aren't subject to selection.
- Lifespan is an evolutionarily labile trait--increases and decreases in ls have frequently occurred.

Lifespans generally correlate with specific metabolic rates, but there are some interesting exceptions.

Changes in lifespan between species

- "Easiest" way to change lifespan is by reducing the specific metabolic rate.
- Under selection for particularly long or short lifespans some groups of animals have increased lifespans by other methods.
  - Occurs in animals with low mortality due to environment or predation.

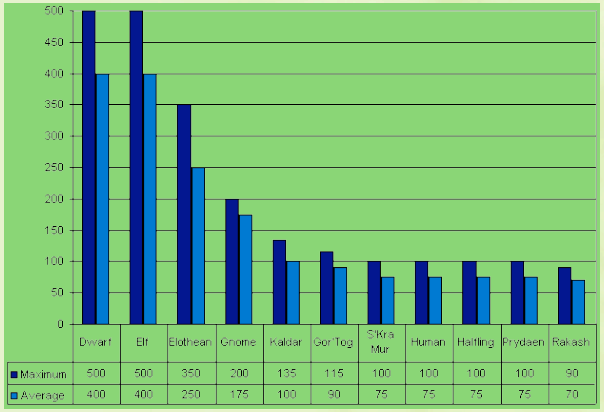
Unusually long-lived organisms

- Some birds, esp. tropical bird and some sea birds.
  - Green-Winged Macaw, 50 yrs.--size of a grey squirrel, 4 yrs.

Unusually long-lived organisms

- Bats are very long-lived for their size and metabolic rate.
  - Little brown bat 30 yrs., size of a mouse, 2.5 yrs.

Lifespans of imaginary species



	Dwarf	Elf	Elothean	Gnome	Kaldar	Gor Tog	S'kra Mur	Human	Halfling	Prydaen	Rakash
Maximum	500	500	350	200	135	115	100	100	100	100	90
Average	400	400	250	175	100	90	75	75	75	75	70