Life history, longevity and aging

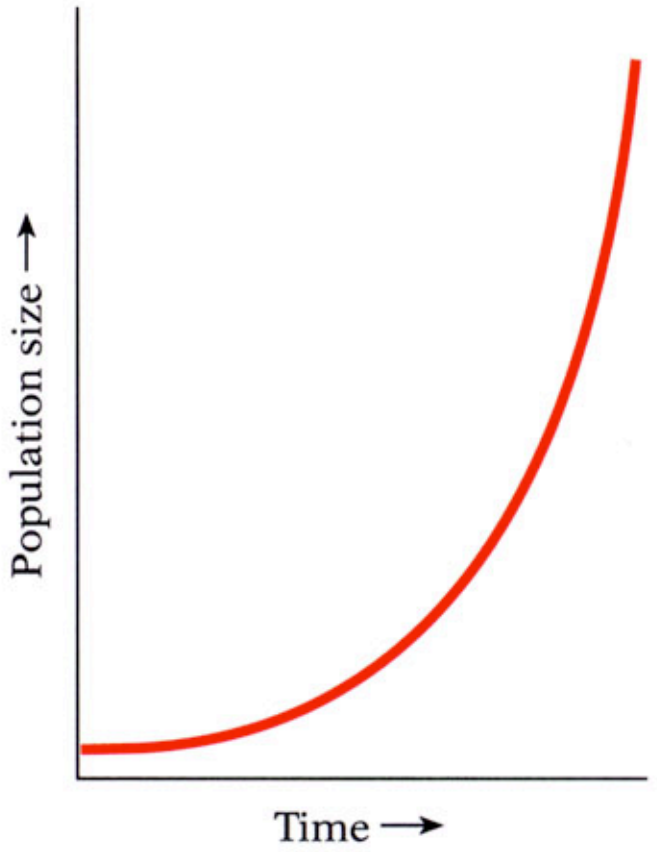
- Population ecology
- Life history evolution
- Reproductive value
- Longevity and senescence

Exponential population growth

b = birth rate
d = death rate
r = intrinsic rate of population growth

$dN/dt = (b-d)N$
$= rN$

"r-selected"



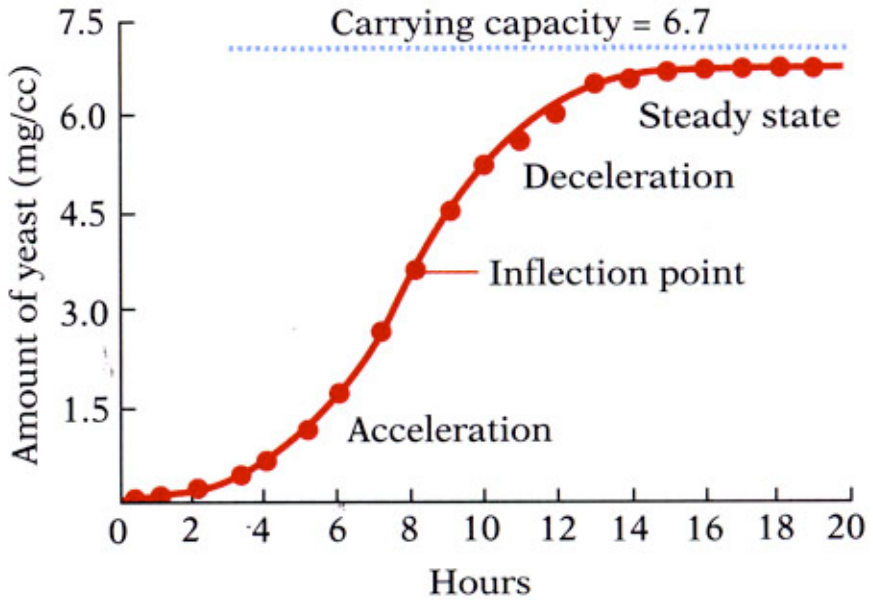
39.5 Exponential growth curve

Logistic population growth

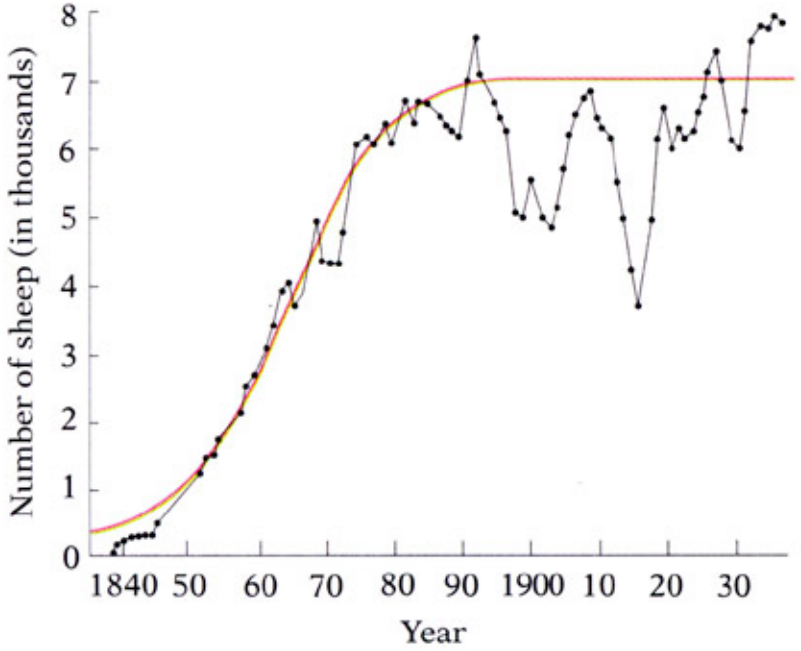
Addition of a density dependent term results in logistic growth

K = carrying capacity

$dN/dt = rN (K-N)/K$ "K-selected"



39.6 A representative logistic growth curve



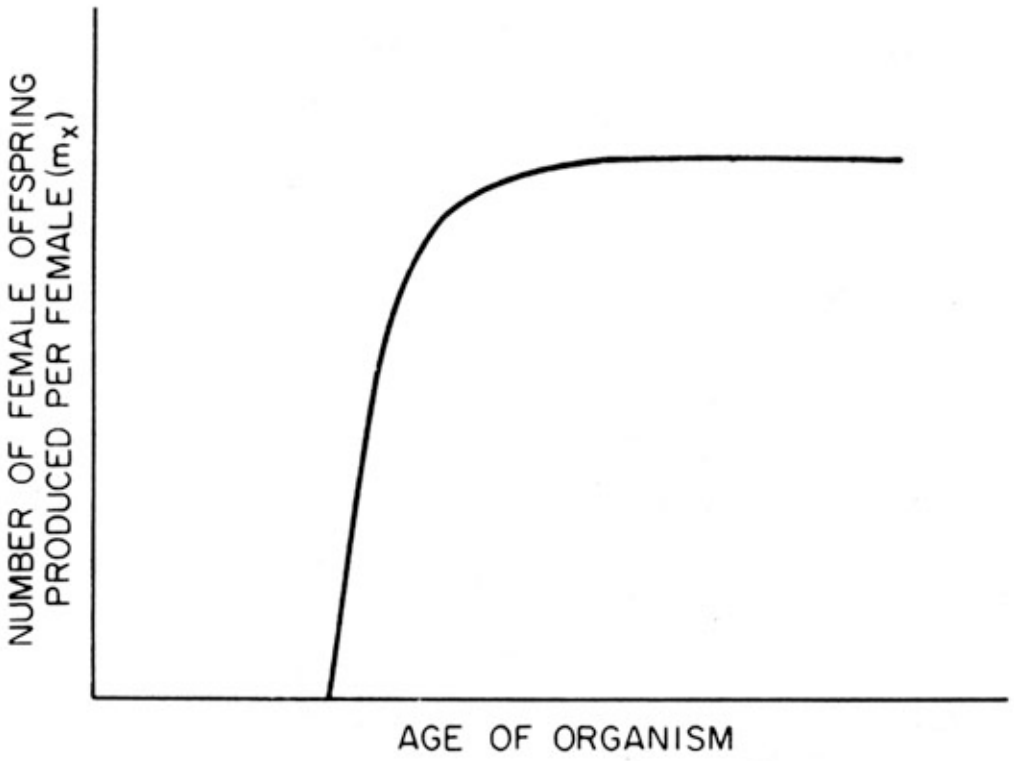
39.7 Growth curve of the sheep population introduced into South Australia

Age-specific population growth

- Age-specific survivorship (l_x)
- Age specific reproduction (m_x)
- Net reproductive rate: $R_o = \Sigma\, l_x m_x$
  - Stable population: $R_o = 1$
  - Growing population: $R_o > 1$
  - Declining population: $R_o < 1$

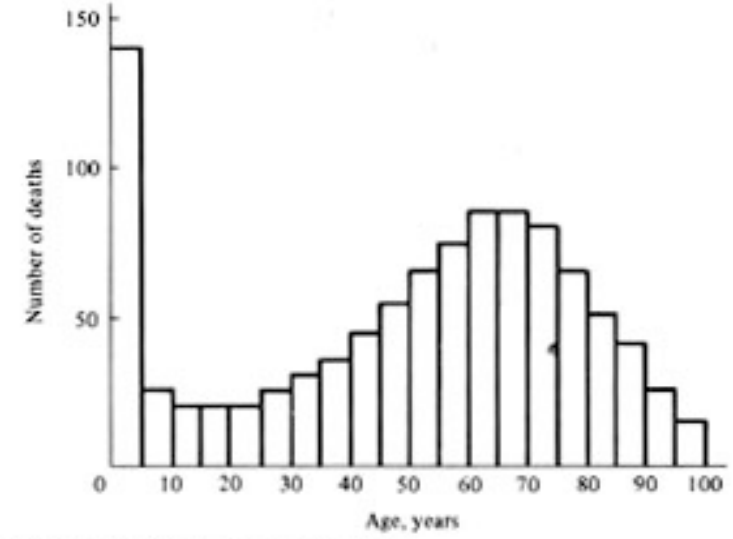
The age-specific survival (l_x) and fertility (m_x) pattern specifies an organism's life history pattern.

Fertility (m_x) patterns

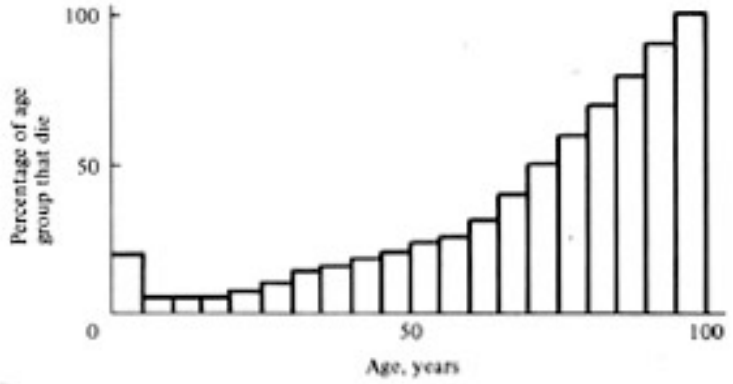


5 FERTILITY CURVE for human louse. This example is typical of organisms that reach sexual maturity at a definite age and remain fecund until death.

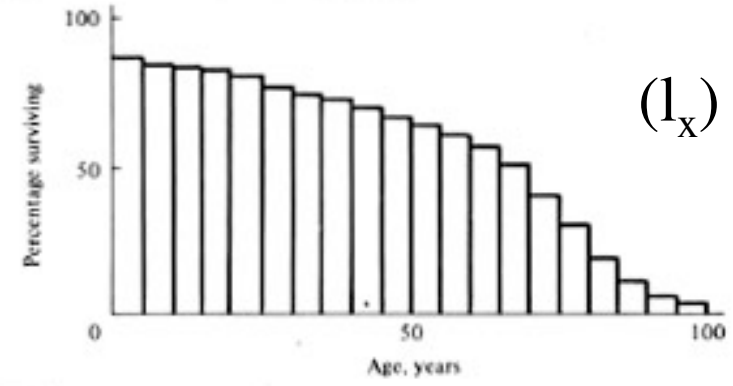
Estimating Survivorship (l_x)



(a) Frequency distribution of age at death

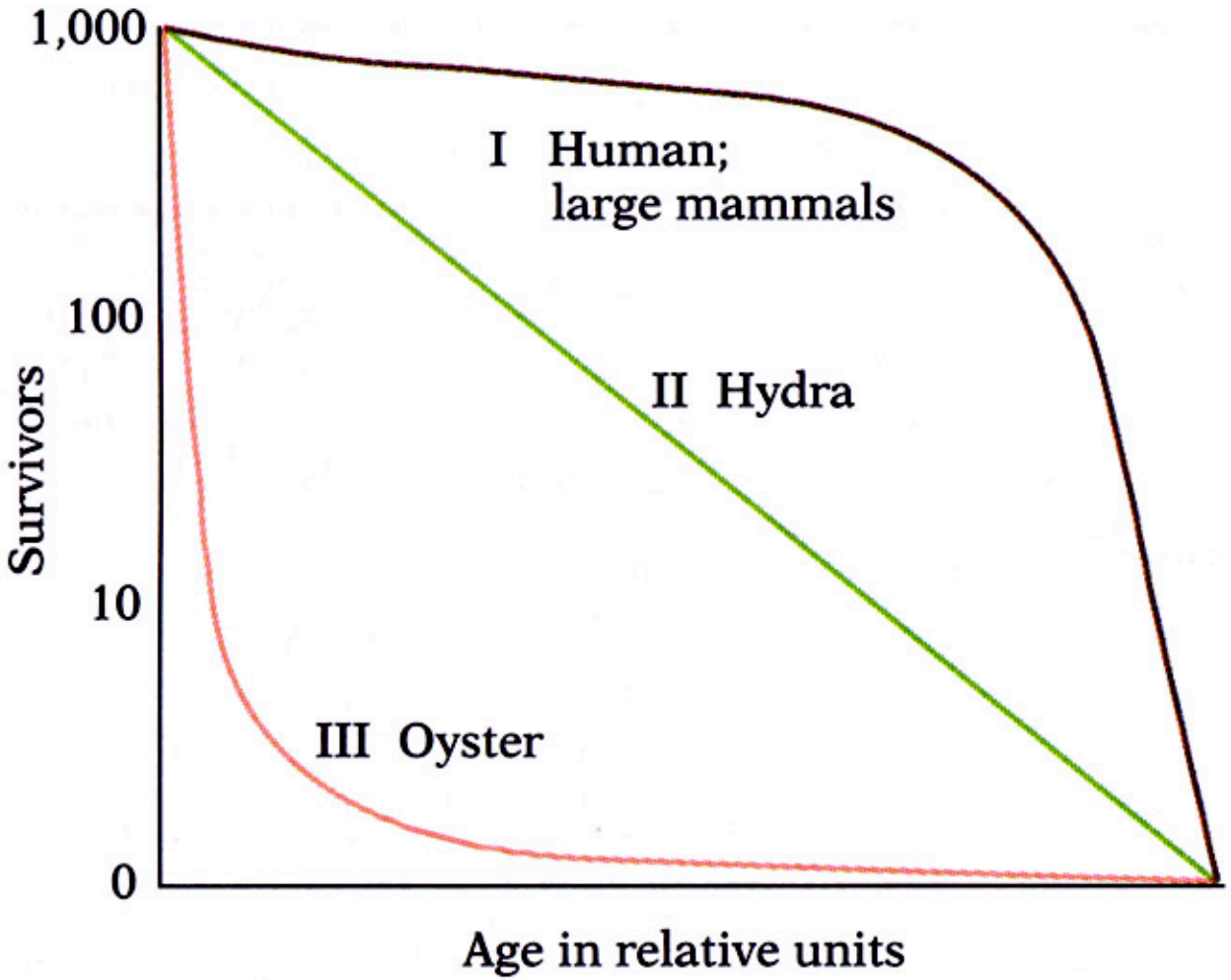


(b) Force of mortality in various age groups

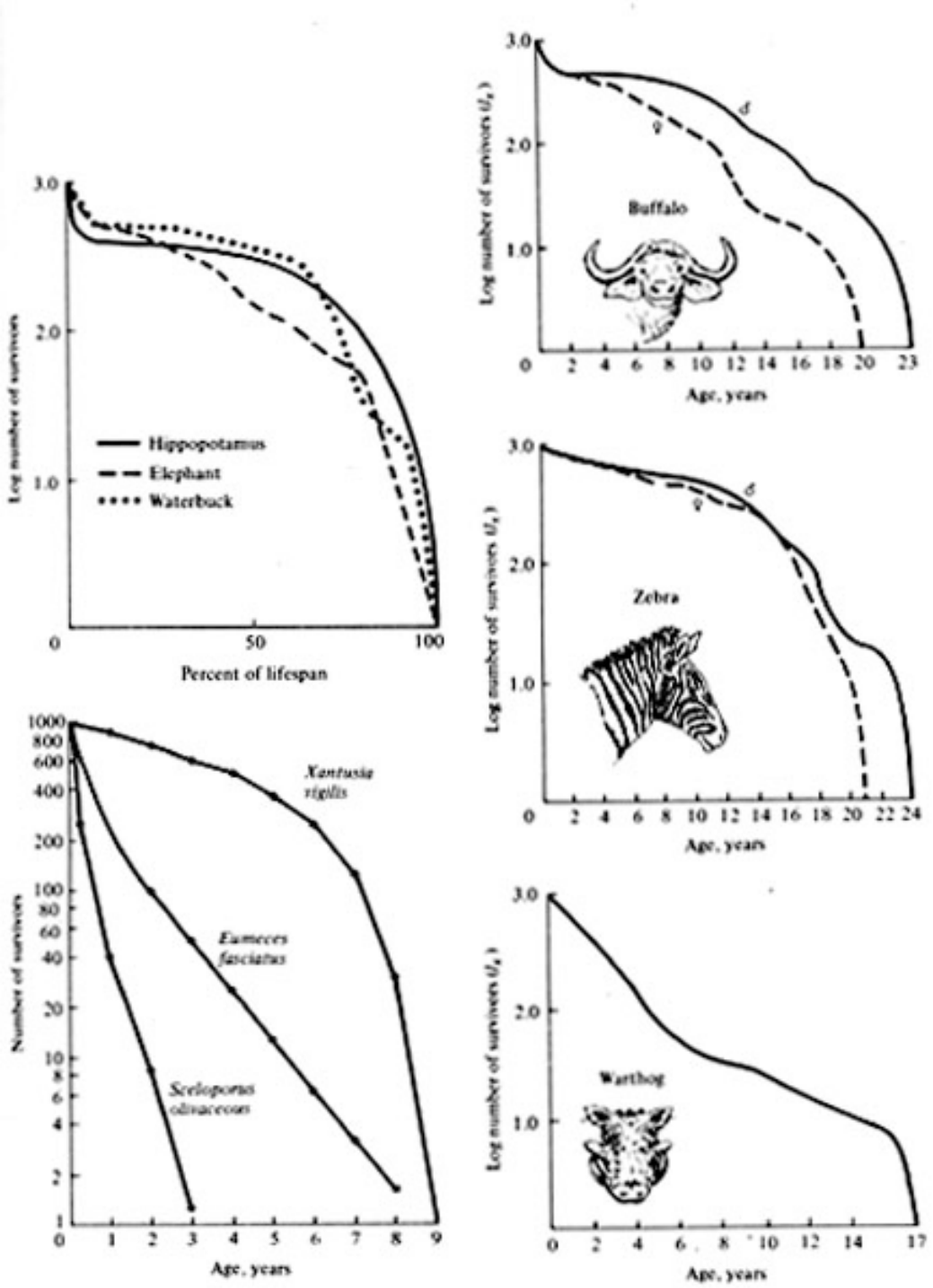


(l_x)

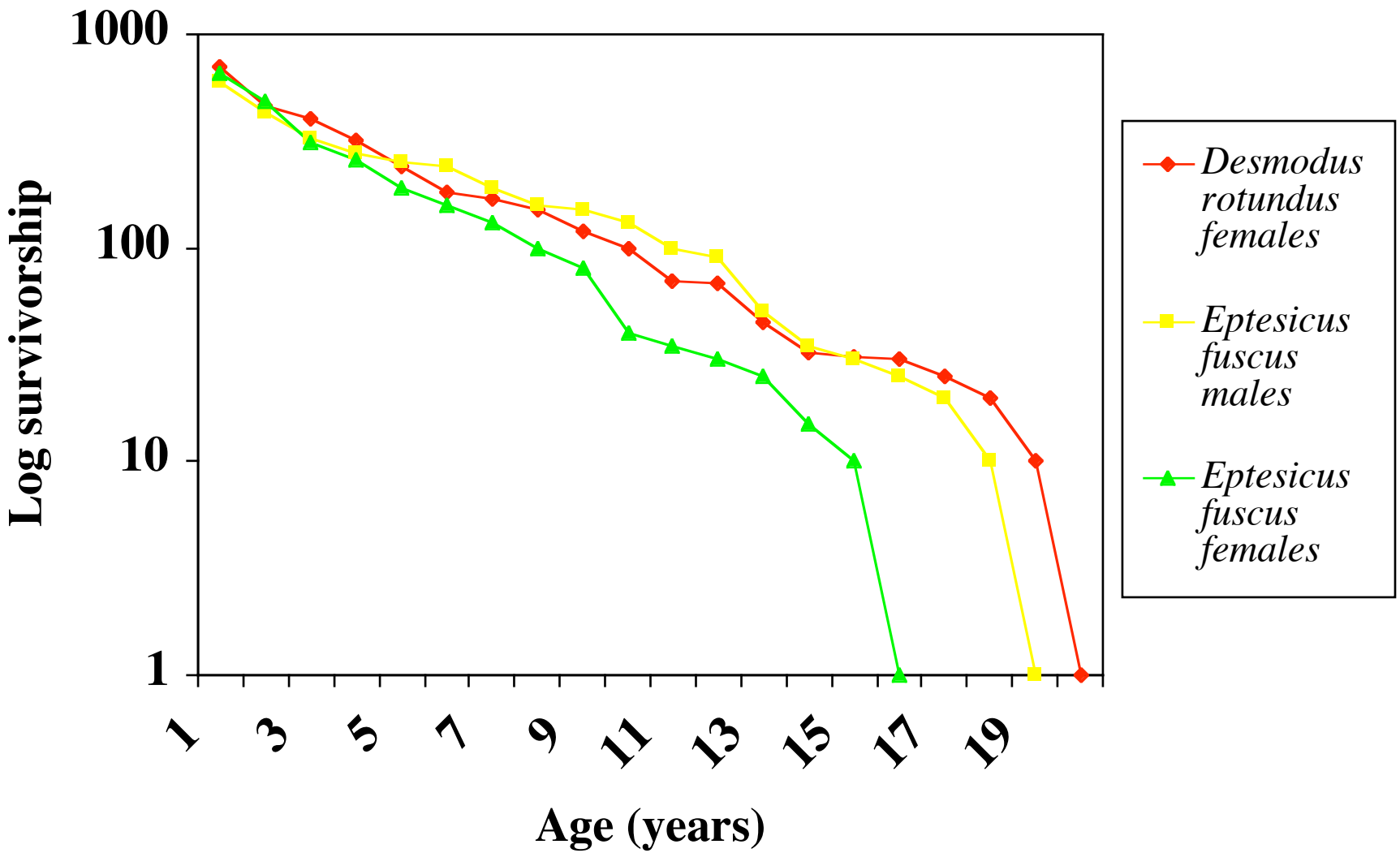
Survivorship types



Survivorship curve examples



Bat survivorship curves



r vs K selected

TABLE 4.4 Some of the Correlates of *r* and *K* Selection

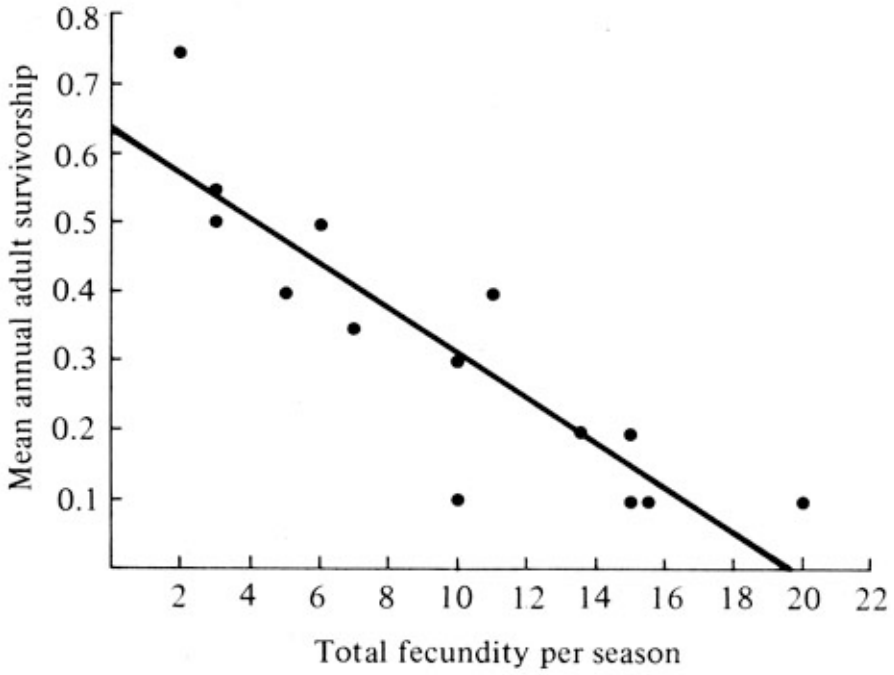
	r Selection	*K* Selection
Climate	Variable and/or unpredictable; uncertain	Fairly constant and/or predictable; more certain
Mortality	Often catastrophic, nondirected, density independent	More directed, density dependent
Survivorship	Often Type III	Usually Types I and II
Population size	Variable in time, nonequilibrium; usually well below carrying capacity of environment; unsaturated communities or portions thereof; ecologic vacuums; recolonization each year	Fairly constant in time, equilibrium; at or near carrying capacity of the environment; saturated communities; no recolonization necessary
Intra- and interspecific competition	Variable, often lax	Usually keen
Selection favors	1 Rapid development 2 High maximal rate of increase, r_{max} 3 Early reproduction 4 Small body size 5 Single reproduction	1 Slower development 2 Greater competitive ability 3 Delayed reproduction 4 Larger body size 5 Repeated reproductions
Length of life	Short, usually less than 1 year	Longer, usually more than 1 year
Leads to	Productivity	Efficiency

Source: After Pianka (1970).

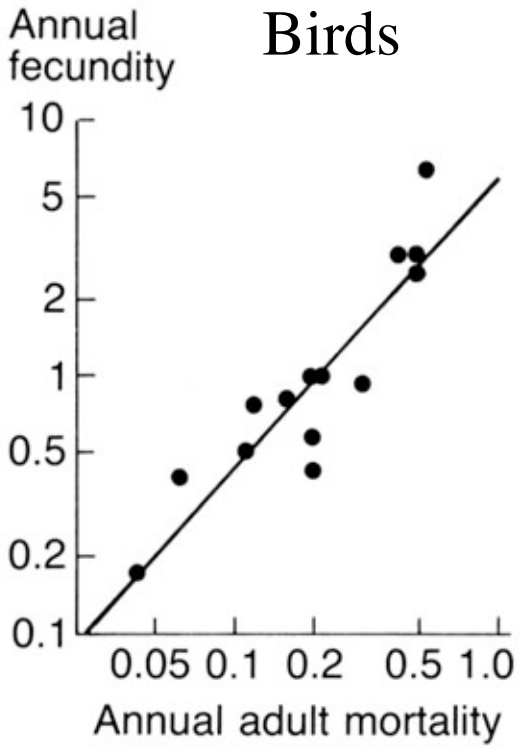
Life history trade-offs

expected with limited resources

Lizards



Birds



Due to allocation of resources between maintenance and reproduction

Figure 28–1
Relationship between annual fecundity and adult mortality in several populations of birds ranging from albatross (low) to sparrow (high). (From data in Ricklefs 1977).

Reproductive value

- Age-specific expectation of offspring (how much is a female worth in terms of future offspring?)
- Assuming a stable population (R = 1)
- $V_x = (\Sigma_{t=x} m_t \, l_t)/l_x$
  - the number of female offspring produced at this moment by females of age x or older / the number of females which are age x at this moment
- Reproductive value peaks near puberty in human populations

Reproductive value curves

Beetle

Lizards

Crustacea

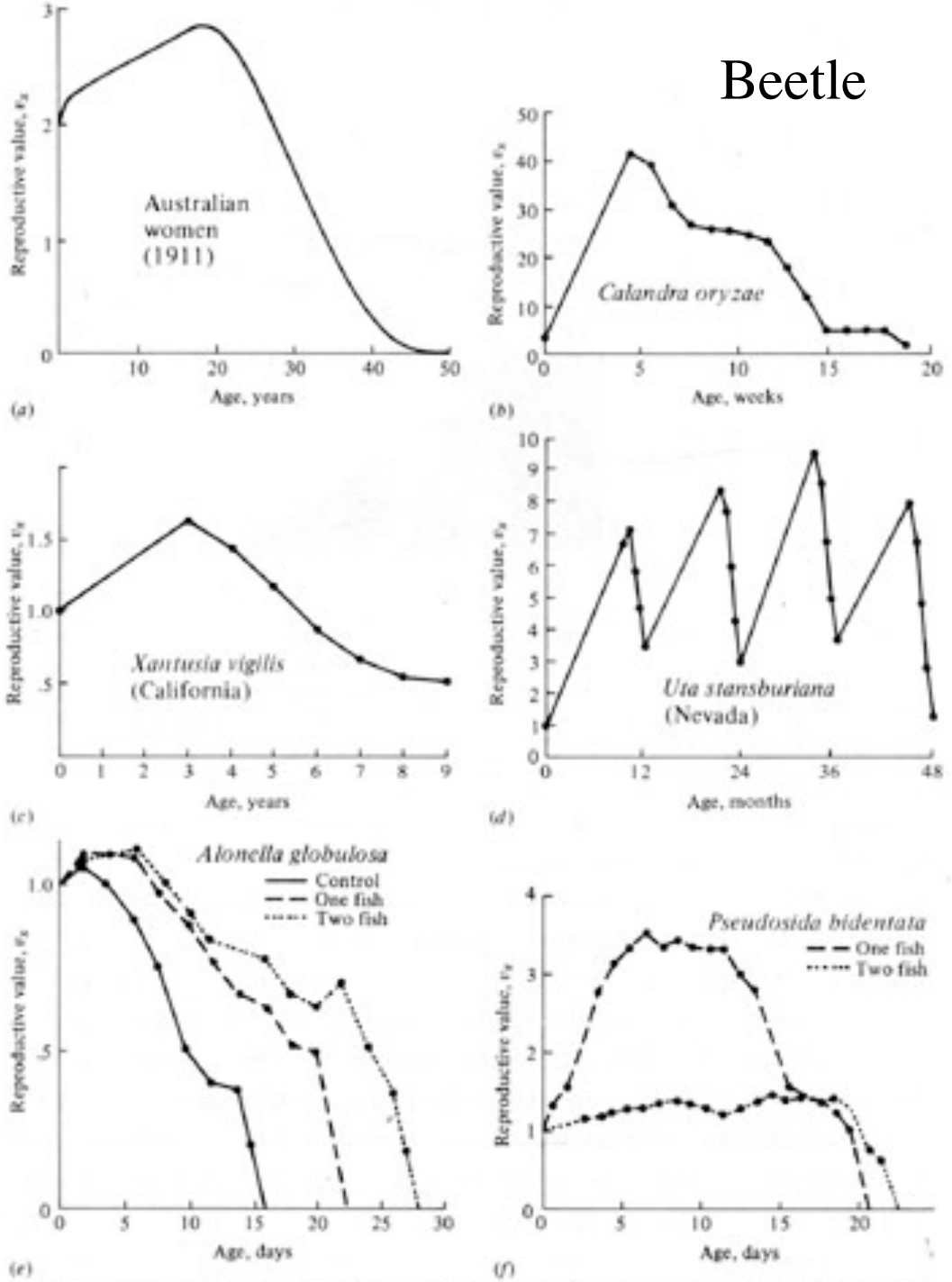


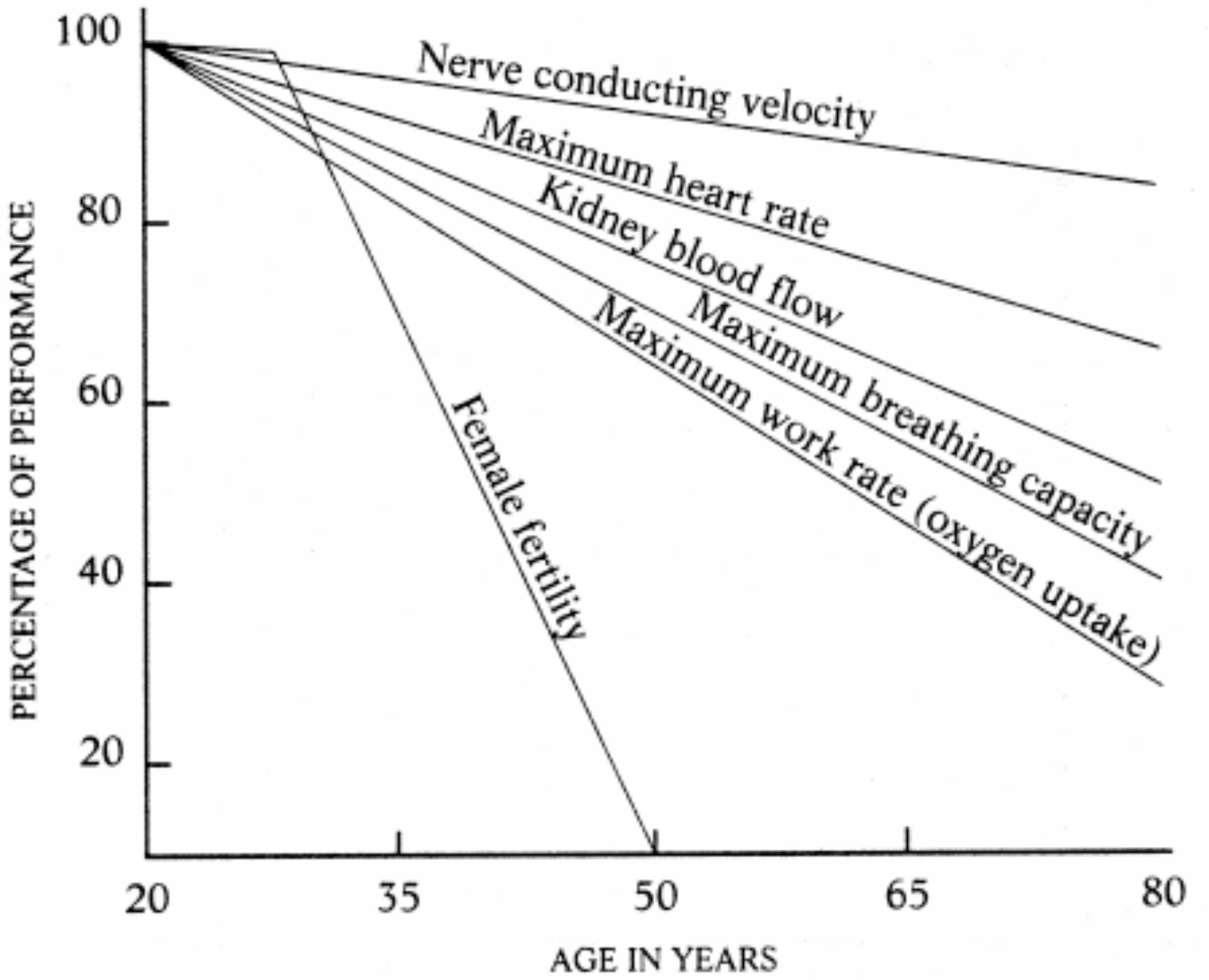
FIGURE 4.5 Reproductive value plotted against age for a variety of populations. (*a*) Australian women, about 1911. [From Fisher (1958a).] (*b*) *Calandra oryzae*, a beetle, in the laboratory. [From data of Birch (1948).] (*c*)

Evolutionary theory of aging

- The risk of extrinsic mortality should influence life span because the force of natural selection declines with age
- Consequently, mutations with late-acting deleterious effects will not be eliminated (referred to as antagonistic pleiotropy)
- Senescence should result and shorten life span in proportion to mortality risk
- Expect that investing in early reproduction will detract from survival - the “disposable soma” idea

Aging

Human aging


100
80
60
40
20
PERCENTAGE OF PERFORMANCE
Nerve conducting velocity
Maximum heart rate
Kidney blood flow
Maximum breathing capacity
Maximum work rate (oxygen uptake)
Female fertility
20
35
50
65
80
AGE IN YEARS

Human longevity

- How old was the oldest human?
  - Jeanne Calment, 122 years old
- How old is the oldest human”
  - Edna Parker, 115 years old
- Is longevity sex-biased?
  - Yes, 90 of 100 oldest humans are female
- Can we live longer?

Ageing

In almost every country, the proportion of people aged over 60 years is growing faster than any other age group, as a result of both longer life expectancy and declining fertility rates.

This population ageing can be seen as a success story for public health policies and for socioeconomic development, but it also challenges society to adapt, in order to maximize the health and functional capacity of older people as well as their social participation and security.

GENERAL INFORMATION

What is "active ageing"?

Q&A on ageing
What are the public health implications of global ageing?

MULTIMEDIA

10 facts on ageing and the life course

RELATED TOPICS

- Oral health in elderly people
- Nutrition: meeting the nutritional needs of older persons
- Physical activity and older people
- WHO Study on Global Ageing and Adult Health (SAGE)

TECHNICAL INFORMATION

Older people in emergencies

Older people and primary health care (PHC)

- More about ageing

PUBLICATIONS

Age-friendly primary health care (PHC) centres toolkit

Towards age-friendly primary health care [424kb]

New guide on building age-friendly cities

- More publications about ageing

KEY WHO INFORMATION

Director-General
Director-General and senior management

Governance of WHO
WHO Constitution, Executive Board and World Health Assembly

Media centre
News, events, fact sheets, multimedia and contacts

International travel and health
Publication on travel risks, precautions and vaccination requirements

World Health Report
Annual report on global public health and key statistics

Bat Methuselahs

Myotis brandti (38 yrs, 8 g)
Myotis lucifugus (34 yrs, 7 g)
Myotis blythii (33 yrs, 23 g)

Plecotus auritus (30 yrs, 7 g)

Rhinolophus ferrumequinum (31 yrs, 24 g)

Pteropus Giganteus
(31 yrs, 1 kg)

Aging studies and bats

- Bats are long-lived because they save energy by going into torpor or hibernate (Bouliere 1958)
- But, nonhibernating tropical bat species live as long as temperate species (Herreid 1964)
- Furthermore, bats live longer than expected for their body size even after adjusting for metabolic differences (Jurgens and Prothero 1987)
- And, marsupials, which have lower metabolic rates than bats, have much shorter life spans (Austad and Fischer 1991)
- Flying mammals live longer than nonflying mammals (Holmes and Austad 1994)

Possible factors influencing extrinsic mortality risk in bats

- Body size
- Group size
- Cave roosting
- Diet
- Hibernation (Latitude)
- Reproductive rate

Longevity records for bats

Data sources on longevity

56 from publications
8 from unpublished studies

Distribution by source

Captive - 16

Field - 48

ANOVA: $F_{1,62} = 1.3, P = 0.25$

Distribution by family

Pteropidae - 5

Emballonuridae - 1

Megadermatidae - 1

Rhinolophidae - 4

Noctilionidae - 1

Phyllostomidae - 8

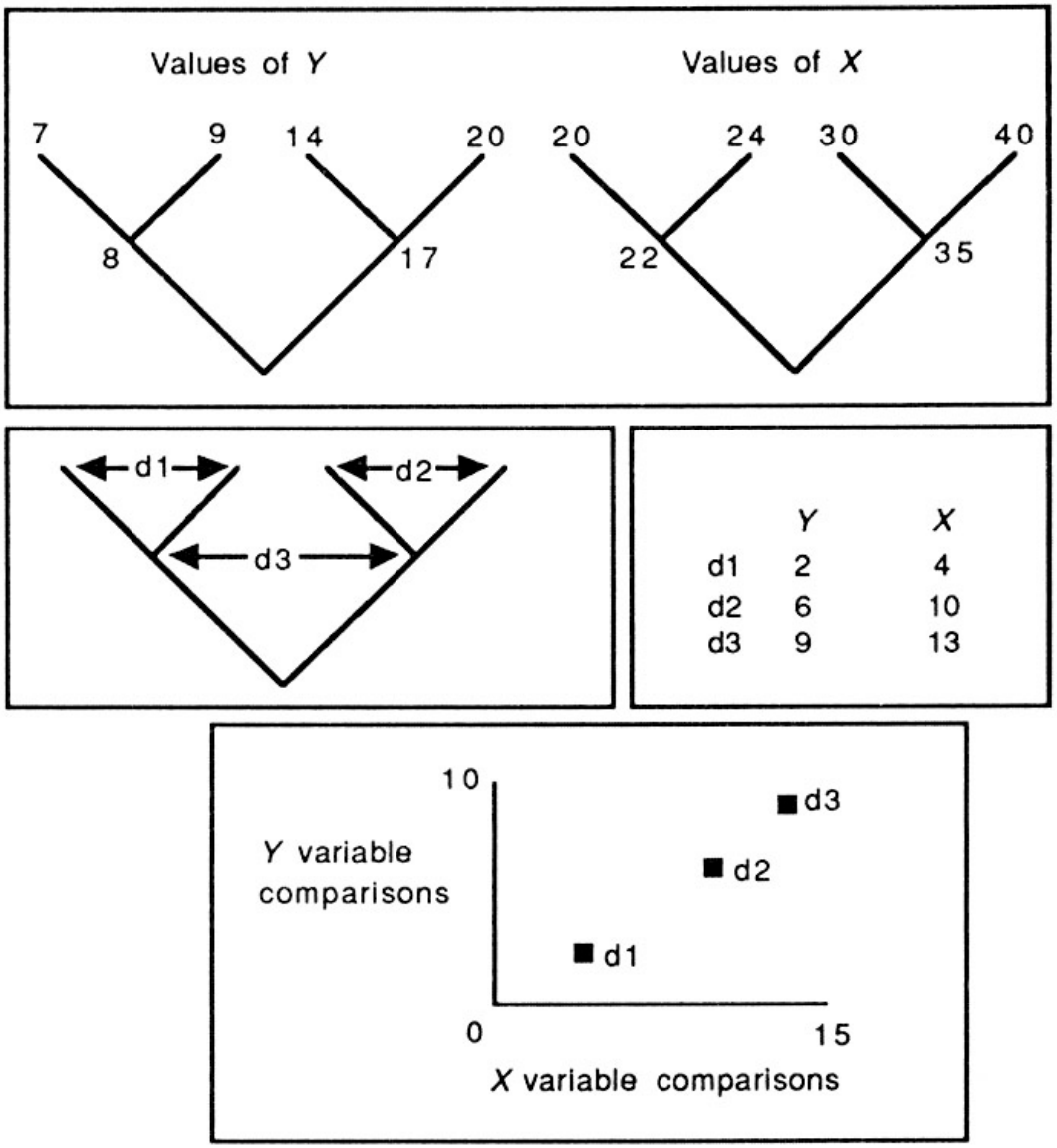
Molossidae - 2

Vespertilionidae - 42

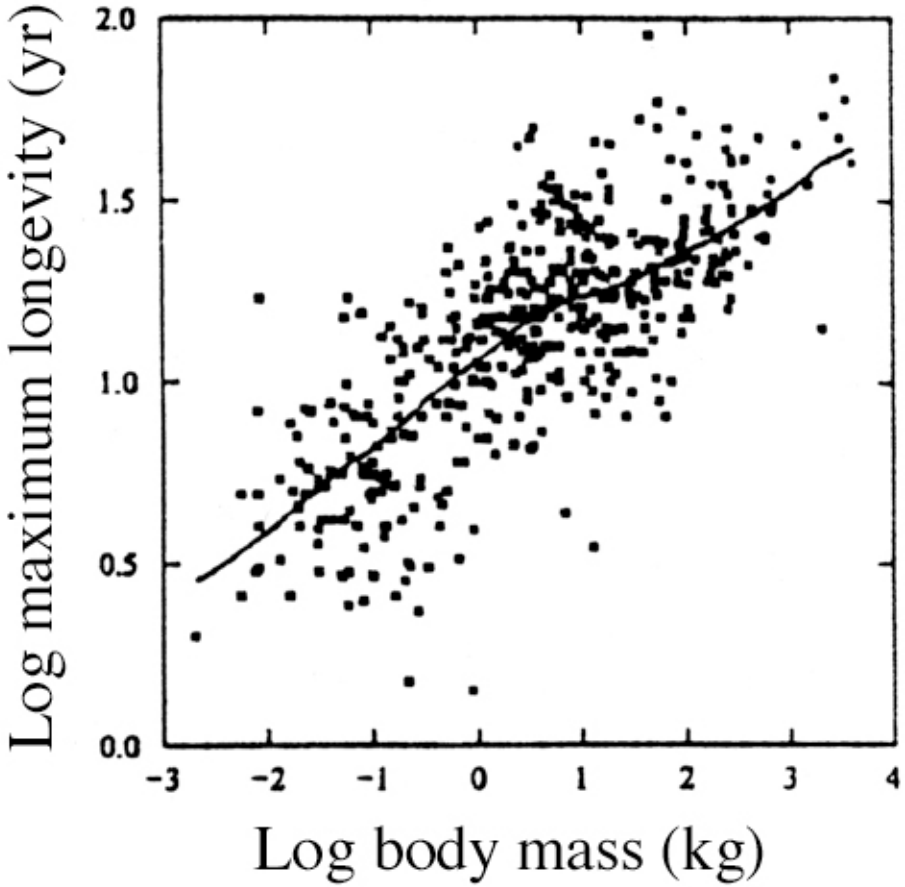
ANOVA (log long): $F_{7,56} = 2.1, P = 0.064$

Under a Brownian motion model of evolution, d1, d2, and d3 provide independent comparisons. Path length differences are ignored in this illustration.

Phylogenetically independent contrasts were used to infer correlated evolution

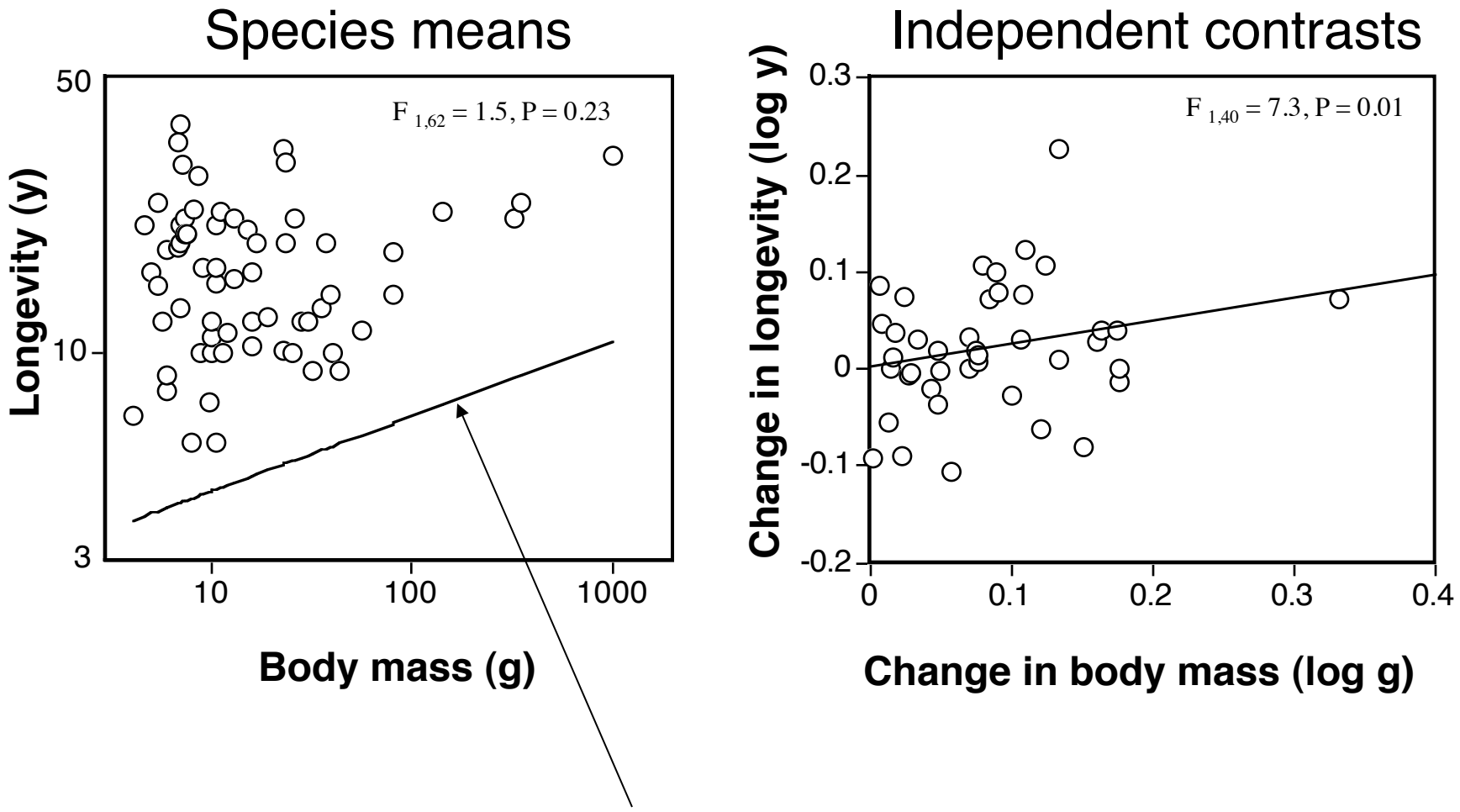


Longevity and body mass in nonflying eutherian mammals



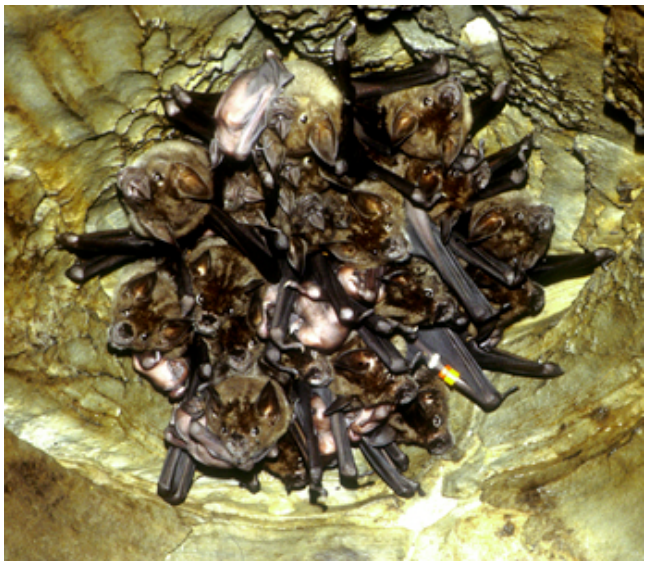
(Austad & Fischer, 1991)

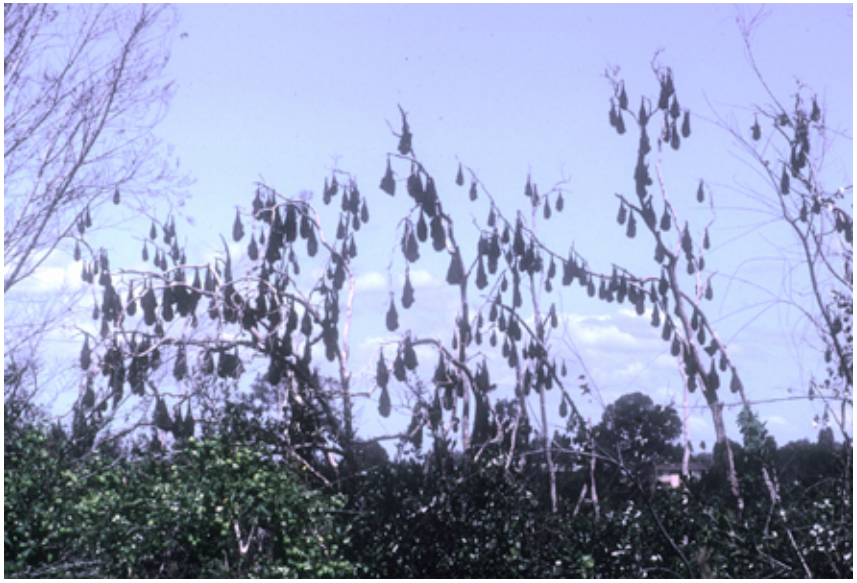
Longevity and body mass in bats



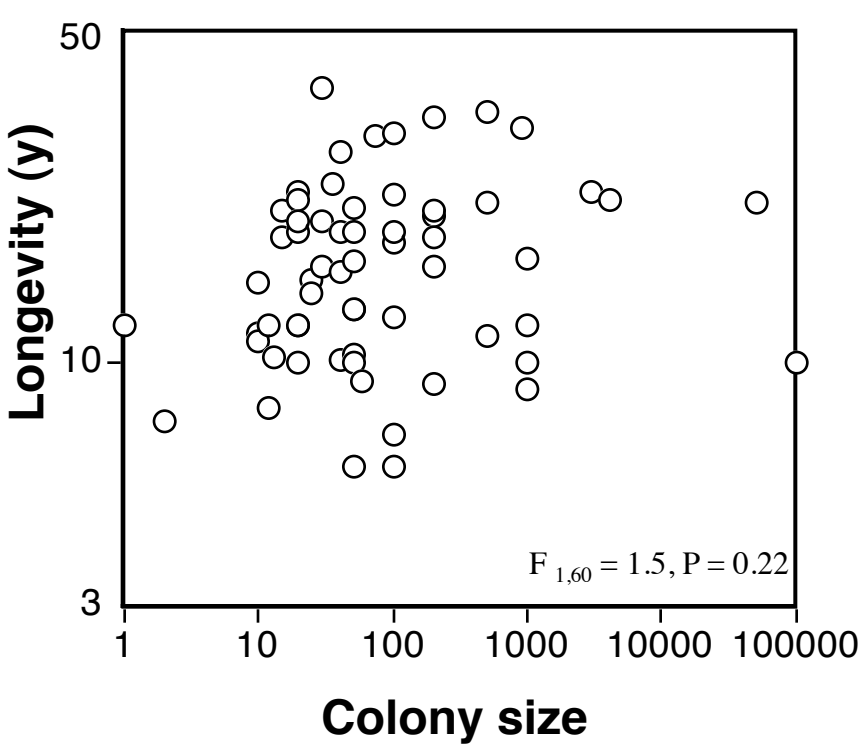
Allometric relationship for 463 spp of nonflying placental mammals (Austad & Fischer 1991)

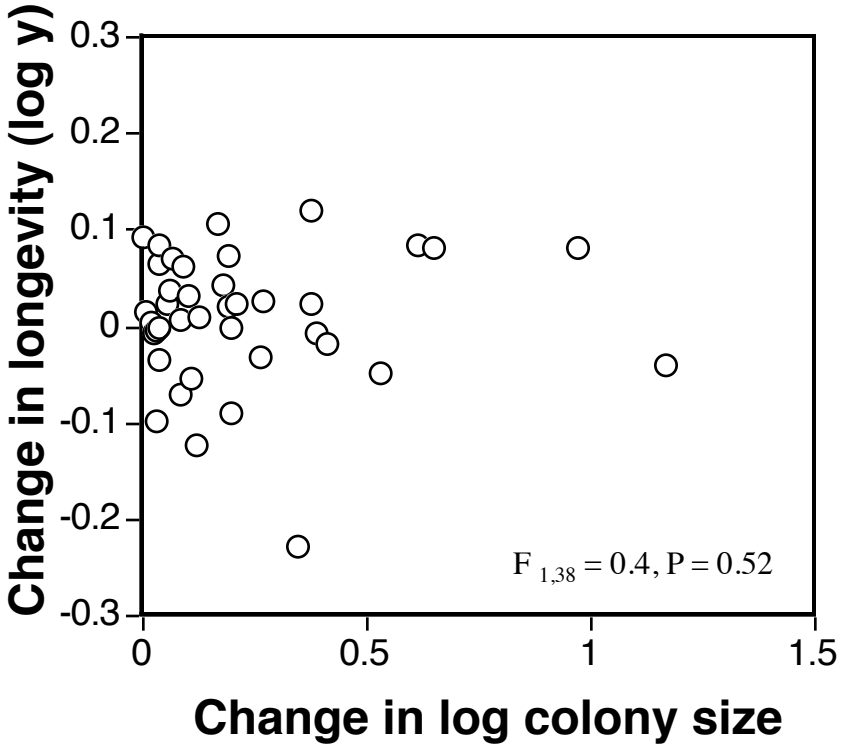
Roosting and group size variation



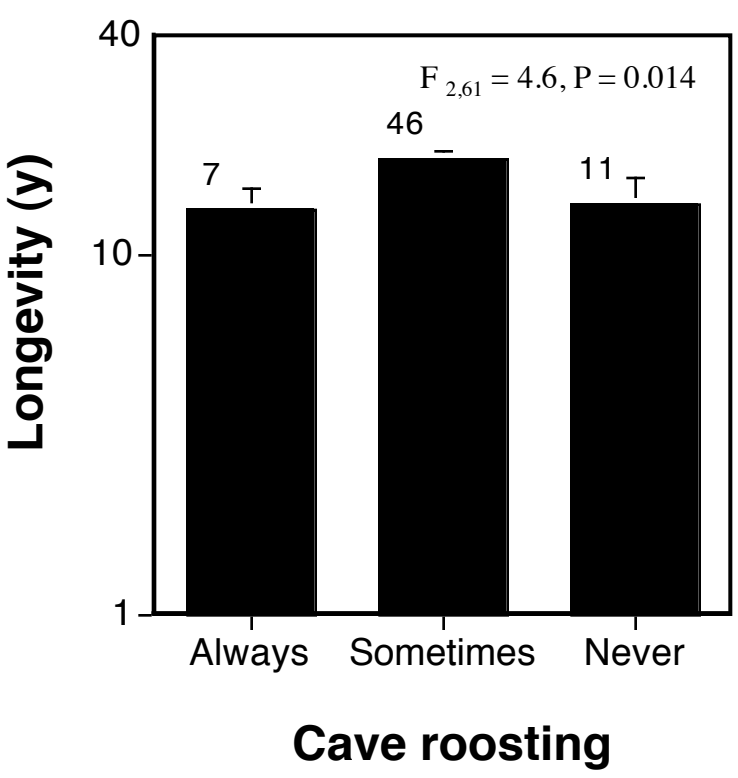


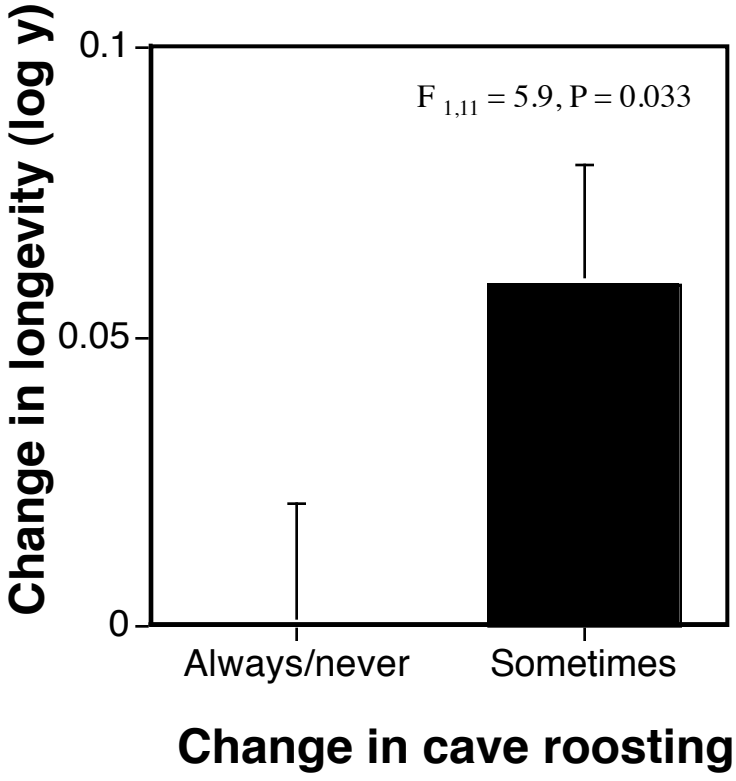
Colony size and longevity





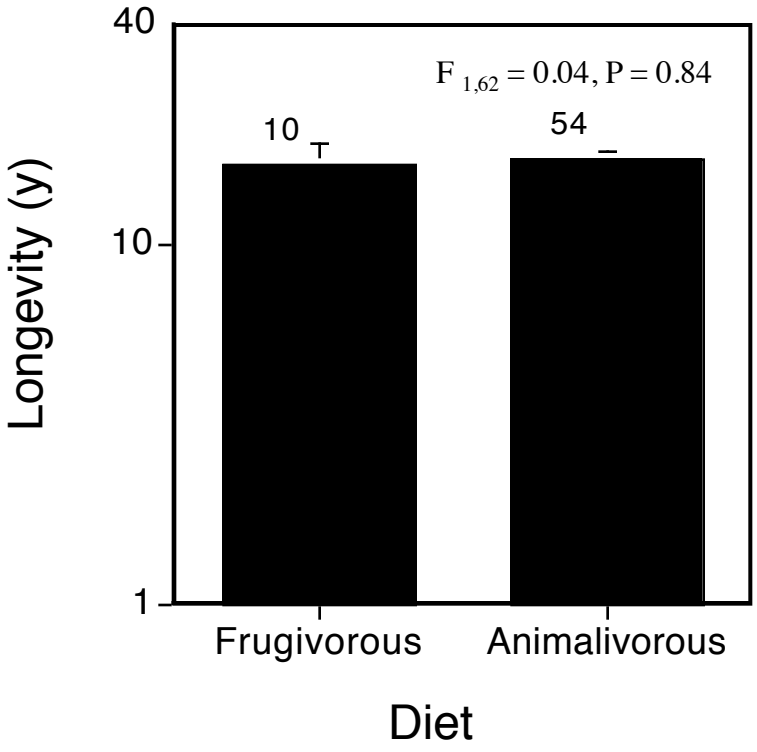
Roosting habits and longevity

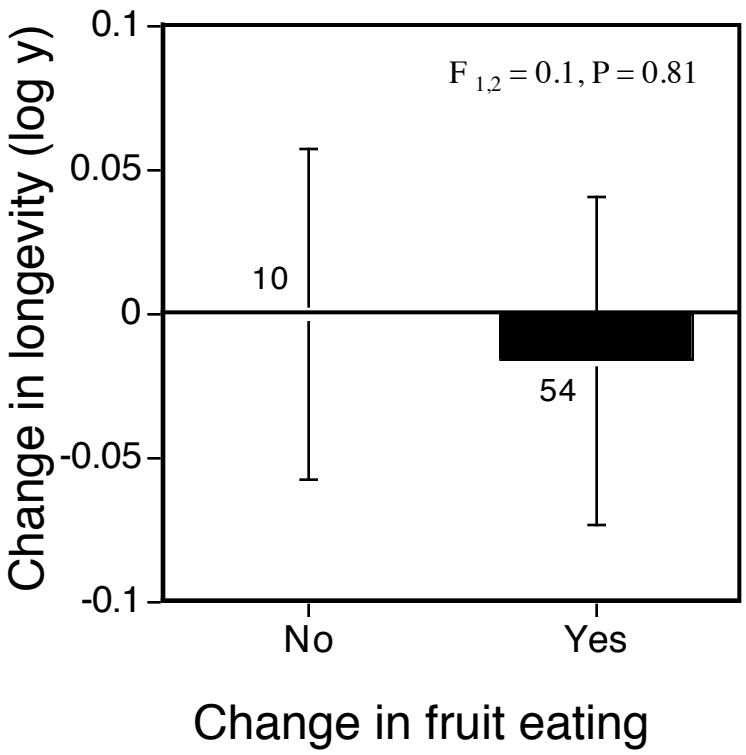




Bat diets

Frugivory and longevity





Reproductive effort variation

1 pup/yr

Rhinolophus darlingi

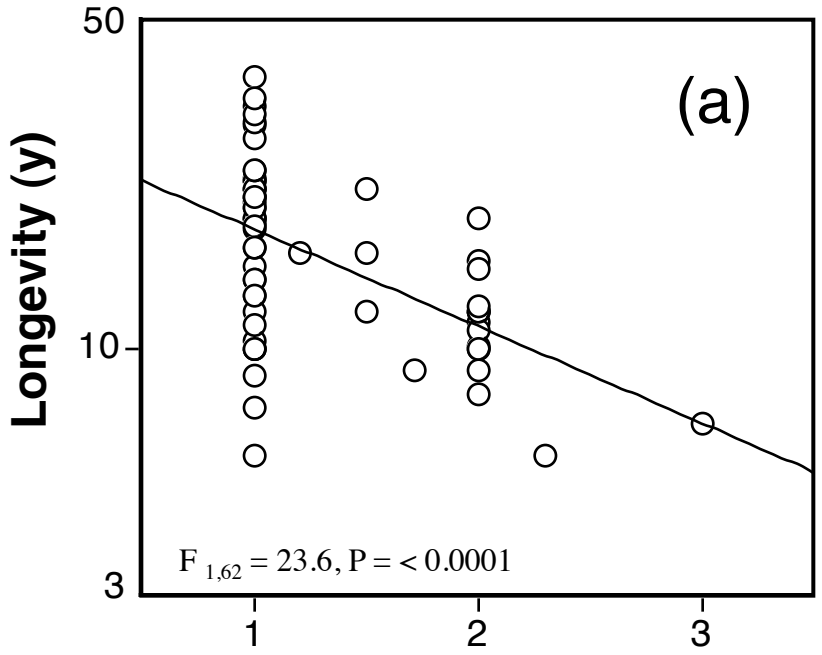
1 pup/4-6 mos

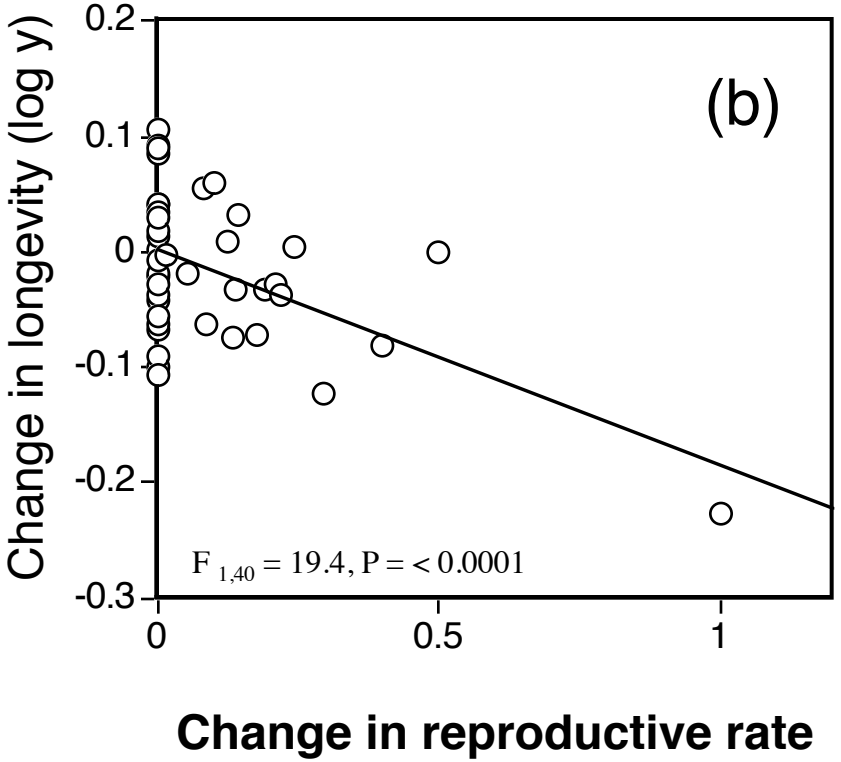
Carollia perspicillata

2 pups/yr

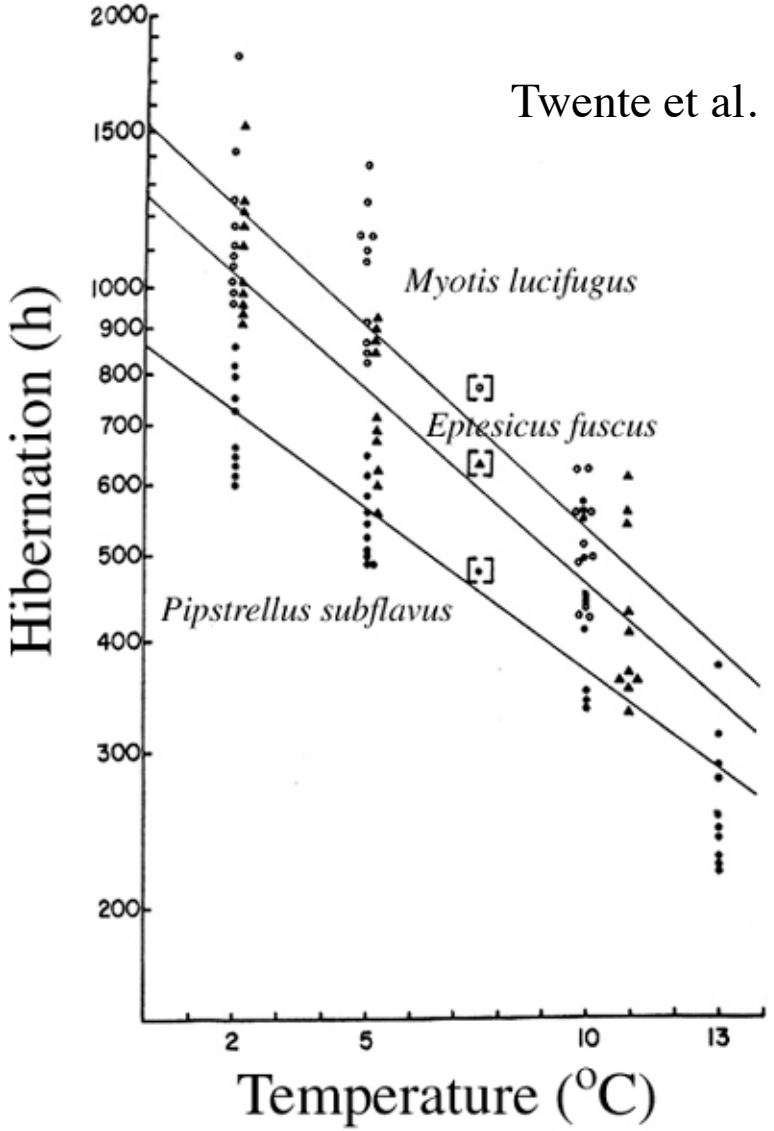
Nyctophilus gouldi

Reproductive effort and longevity



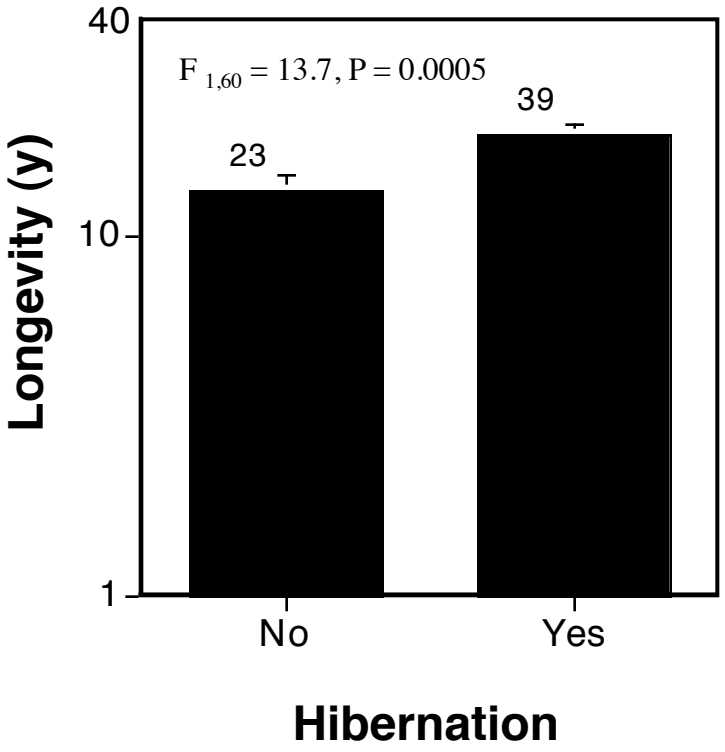


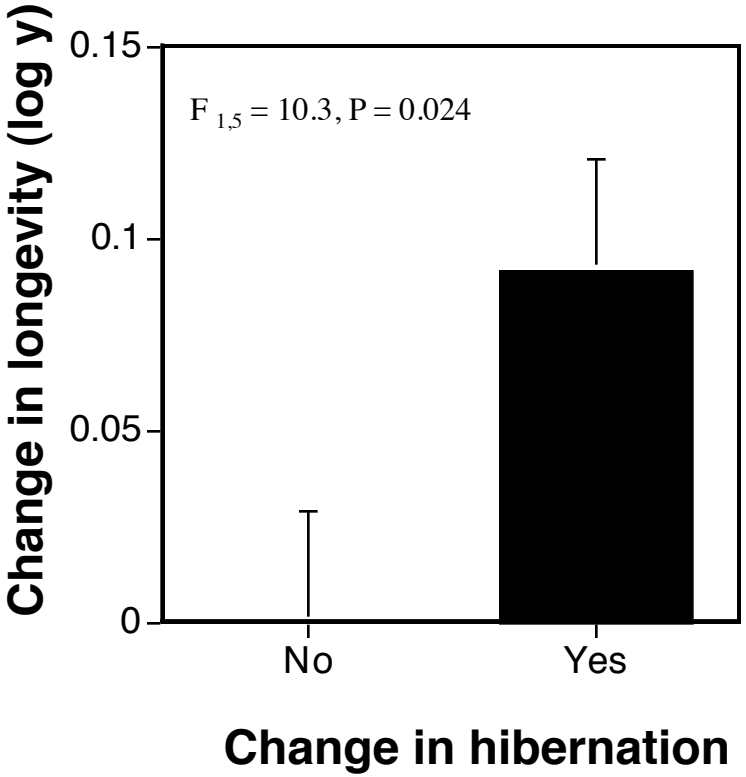
Hibernation



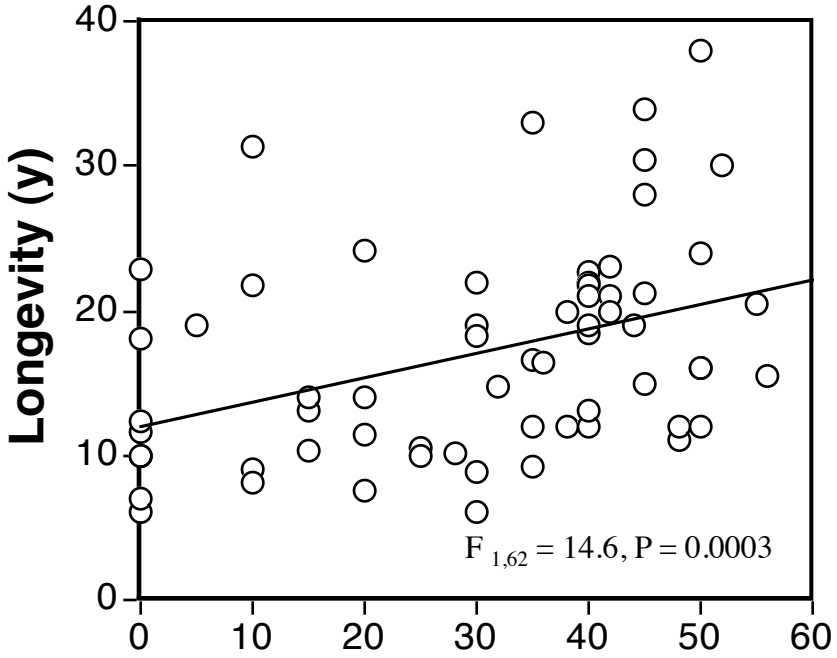
Twente et al. 1985

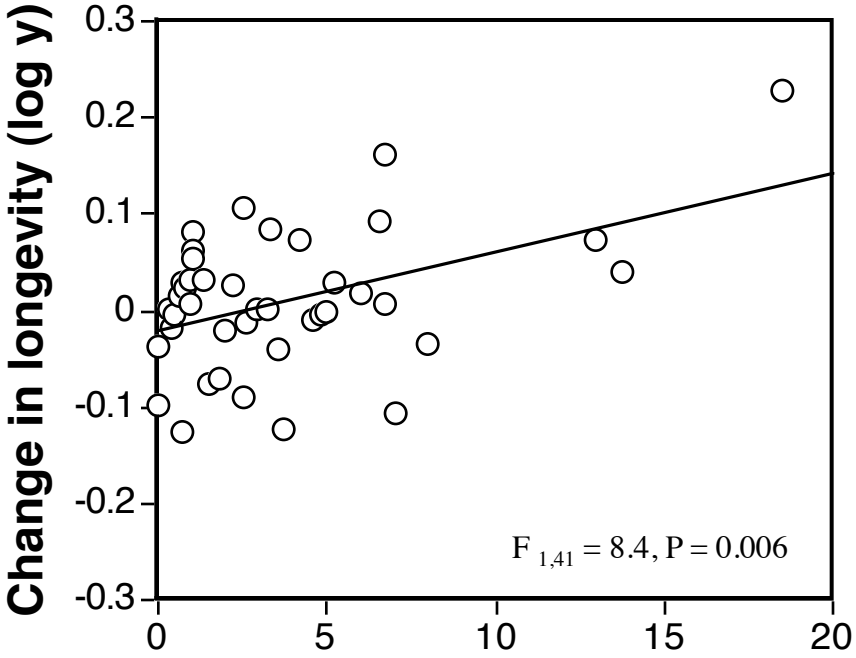
Hibernation and longevity





Latitude and longevity





Multivariate analysis of longevity

(independent contrasts)

Source (controlled*)	df	F	P
Repro. rate (body mass)	1,56	16.9	0.0002
Hibernation (rep. rate)	1,56	14.3	0.013
Body mass (rep. rate)	1,56	5.4	0.025
Cave roosting (rep. rate)	2,56	5.2	0.043

*indicates the independent variable used to generate residual longevities for the contrast analyses, $r^2 = 0.58$

Conclusions

- Bats live 3.5 times as long as other mammals of comparable size.
- From an evolutionary perspective, extrinsic mortality risk could account for the effects of body size, cave roosting, reproductive rate and hibernation on longevity
- From a physiological perspective, the effects of reproductive rate and hibernation on longevity are consistent with allocation of finite resources to the soma.

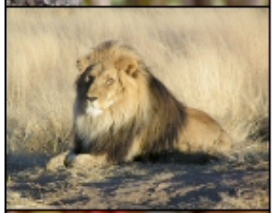
Implications

- Caloric restriction is the only method for experimentally increasing lifespan in mammals
- Calorie restricted (and hibernating!) rodents show
  - Decreased blood glucose
  - Decreased glycolytic enzyme activity
  - Increased gamma globulin levels
  - Increased antioxidant defenses
- Hibernation could act to conserve resources much like caloric restriction

AnAge

The Animal Ageing & Longevity Database

Human Ageing Genomic Resources



Build 10 (18/04/2008): 4,122 entries

Welcome to AnAge, a curated database of ageing and life history in animals, including extensive longevity records. AnAge was primarily developed for comparative biology studies, in particular studies of longevity and ageing, but can also be useful for ecological and conservation studies and as a reference for zoos and field biologists.

Finding Entries in AnAge

To search AnAge please type keywords or phrases relating to the species or common name of the organism you wish to find. Terms at any taxonomic level are acceptable. Note that the search is case insensitive.

Search AnAge

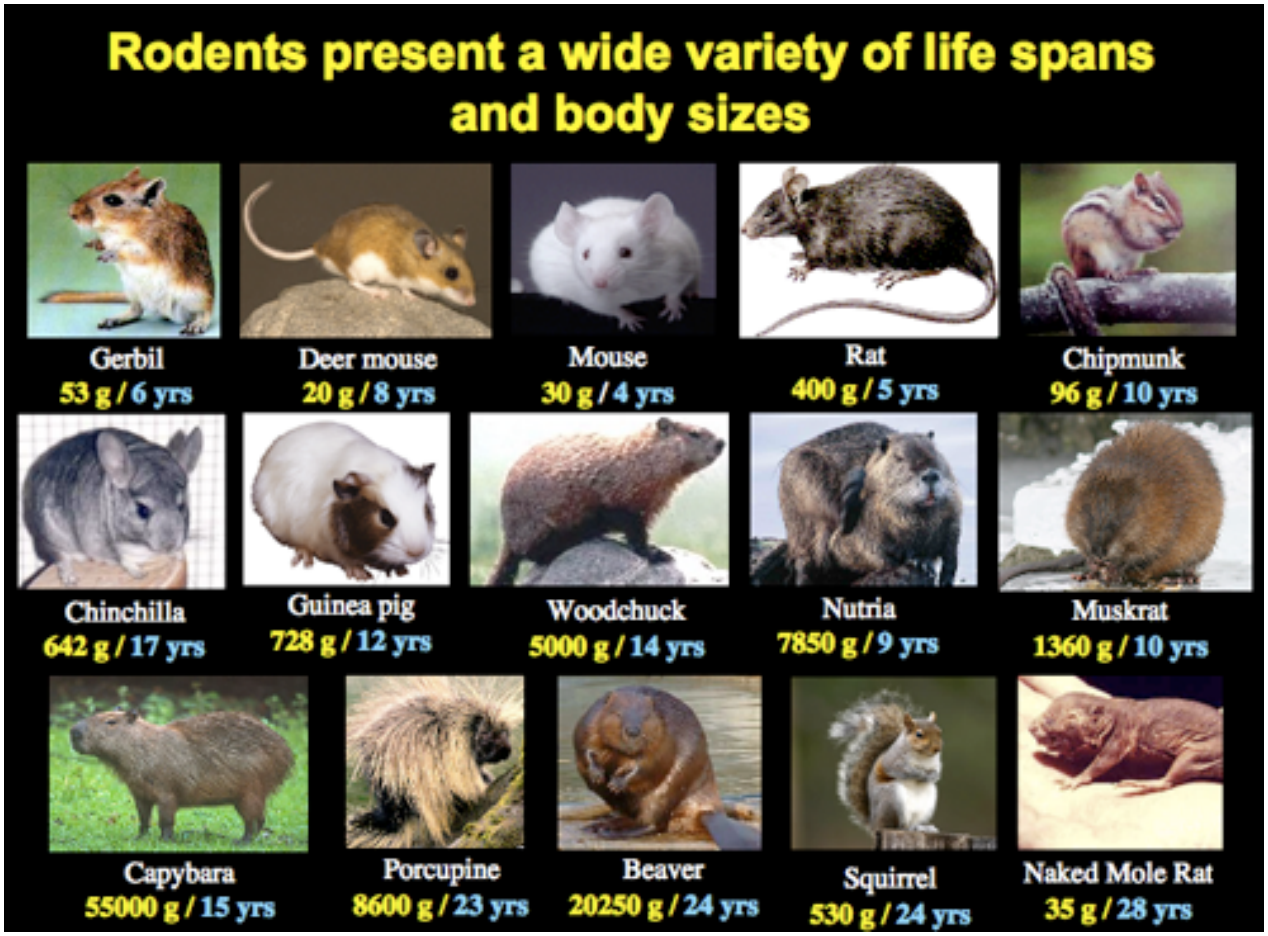
If you already know the HAGRID of the organism you wish to retrieve, just type it below. Please note, however, that HAGRID numbers are not static.

Retrieve HAGRID

Browsing AnAge

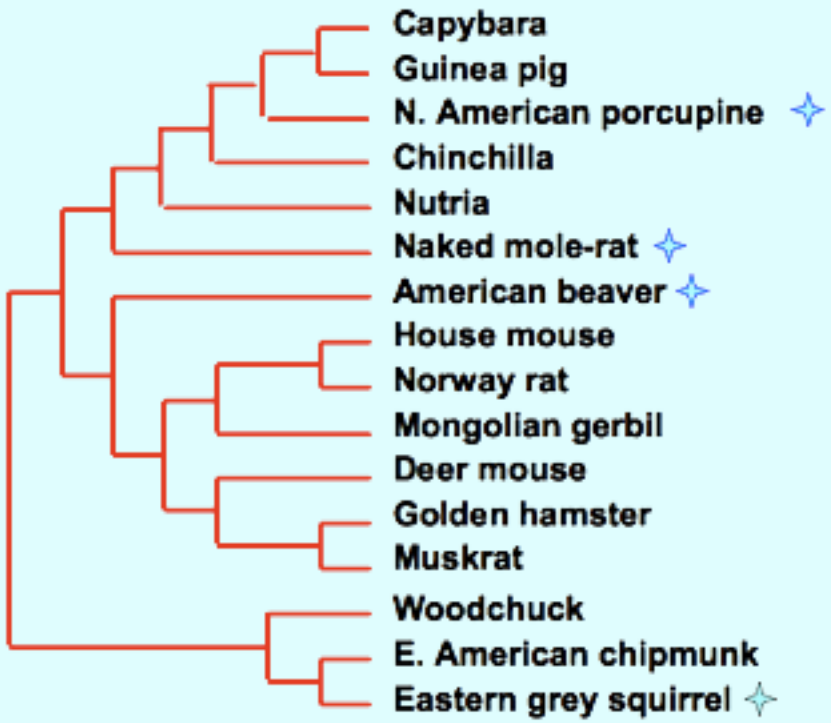
For more freedom of choice users are encouraged to browse through the taxonomy of the database using AnAge's browser.

Comparative biology of aging



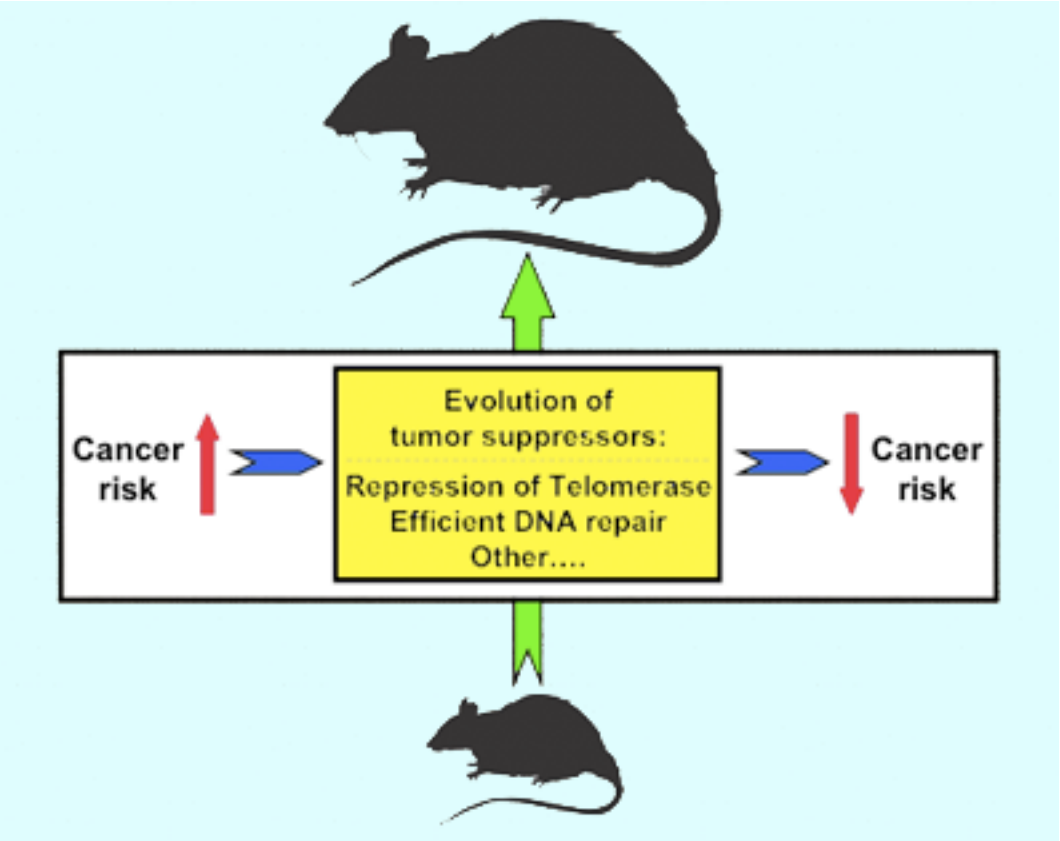
http://www.rochester.edu/College/BIO/labs/Gorbunova/research2.php

Rodent phylogeny



Rodents with maximum lifespan greater than 20 years.

Telomerase activity and body size coevolve



In multicellular organisms, telomerase is required to maintain telomere length in the germline but is dispensable in the soma. Mice, for example, express telomerase in somatic and germline tissues, while humans express telomerase almost exclusively in the germline. As a result, when telomeres of human somatic cells reach a critical length the cells enter irreversible growth arrest called replicative senescence. Replicative senescence is believed to be an anti-cancer mechanism that limits cell proliferation. The difference between mice and humans led to the hypothesis that repression of telomerase in somatic cells has evolved as a tumor-suppressor adaptation in large, long-lived organisms. We tested whether regulation of telomerase activity coevolves with lifespan and body mass using comparative analysis of 15 rodent species with highly diverse lifespans and body masses. Here we show that telomerase activity does not coevolve with lifespan but instead coevolves with body mass: larger rodents repress telomerase activity in somatic cells. These results suggest that large body mass presents a greater risk of cancer than long lifespan, and large animals evolve repression of telomerase activity to mitigate that risk.

Additional Readings

- Kirkwood, T.B.L. and Austad, S.N. 2000 Why do we age? Nature 408:233-238.
- Perez-Campo, R., M. Lopez-Torres, S. Cadenas, C. Rojas and G. Barja 1998 The rate of free radical production as a determinant of the rate of aging: evidence from the comparative approach. Journal of Comparative Physiology B 168:149-158.
- Brunet-Rossinni AK 2004. Reduced free-radical production and extreme longevity in the little brown bat (*Myotis lucifugus*) versus two non-flying mammals. Mechanisms of Aging and Development 125: 11-20.