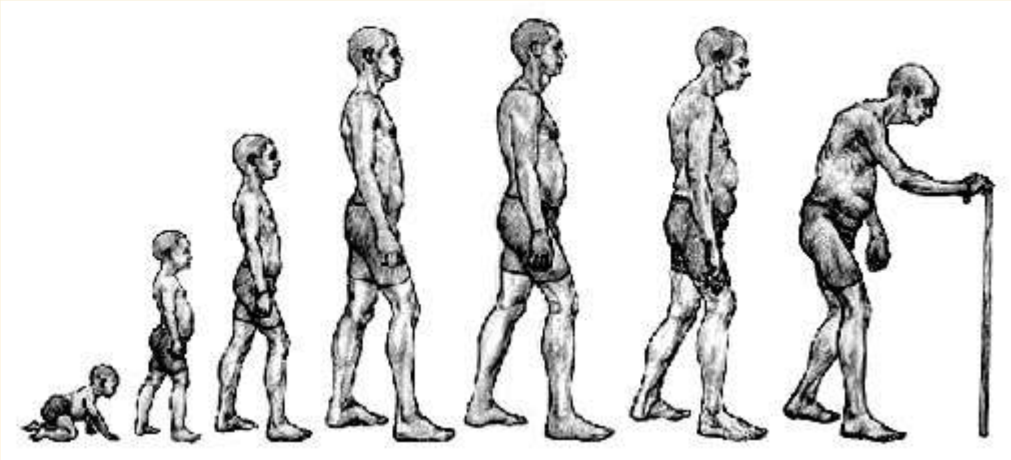
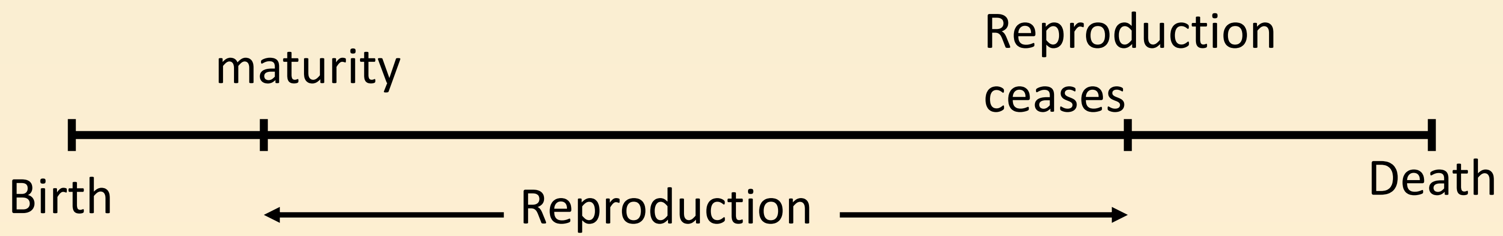
Aging and Life History Characters



Life history theory attempts to answer questions such as the following:

- Why do we age (senesce)?
- Why do some species reproduce only once while other reproduce repeatedly?
- Why do some species have many small offspring while others have only a few relatively large ones?
- Why do some take a long time to reach reproductive maturity, others only a short time?



Life-history Characteristics

- All organisms have been selected to maximize reproductive success over the course of their lifetimes.

- There is, however, tremendous variation in how organisms achieve this.

Life-history Characteristics

- Some organisms produce many offspring once, but live only a short time.

- Others produce a few offspring over the course of a long life.

Some Long Lived Species

Whooping Crane

Spotted Owl

- These have moderate juvenile mortality, low adult mortality, and low fecundity.
- They are endangered.

X-ray of female brown kiwi

- Mature at birth- No!
- Produce high quality offspring frequently- yes!
- Live long-sort of! (20 years)

Some Short Lived Species

Starling

House Finch

- These have high juvenile mortality, moderate adult mortality, and high fecundity.
- They are thriving.

Life-history Characteristics

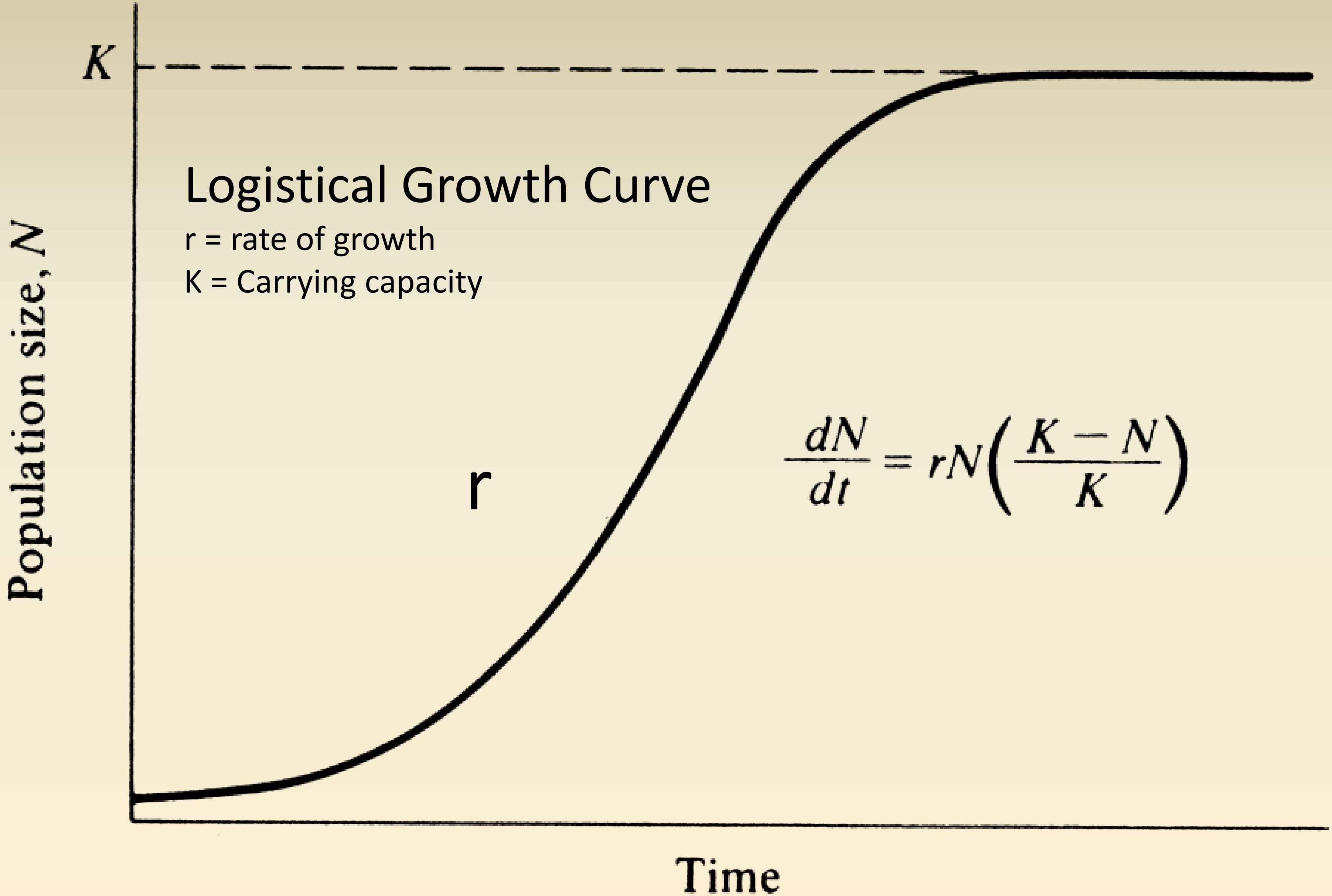
- There is also enormous variation in the size of offspring. Oysters produce 10-50 million tiny eggs whereas whales produce a single large calf.

- What explains the variation we see?

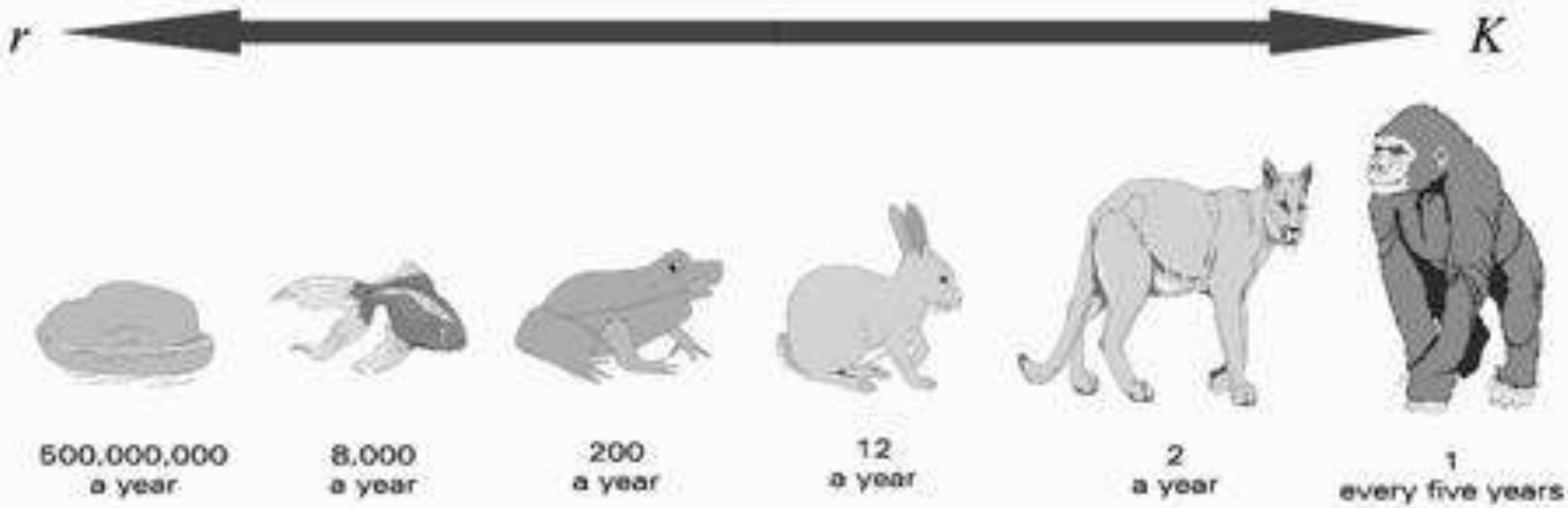
Logistical Growth Curve

r = rate of growth

K = Carrying capacity



The *r*-*K* Scale of Reproductive Strategy: Balancing Egg Output versus Parental Care



Oysters are an example of a very *r*-strategy. They produce 500 million fertilized eggs a year and provide no parental care. The great apes are an example of a very *K*-strategy. They produce one infant every five or six years and provide extensive parental care.

Opportunistic (r selected)	Equilibrium (K selected)
large number of offspring	few offspring
offspring small in size	offspring large in size
short life span	long life span
little or no nurturing by parents	considerable nurtuing by parents
reproduce once or few times	reproduce many times

Life-history Characteristics

- Clearly, there are constraints **and trade-offs** in the strategies that organisms can employ.
- The best strategies are determined by the **availability of energy** and an organisms' prospects of survival.

- Amount of energy an organism can harvest is finite and biological processes take time!

- **trade-offs** between life history traits are unavoidable!

- variation in life-histories are due to differences in the allocation of energy.

- Organisms that find **“optimal balance”** between costs and benefits are favored by natural selection.

Why do organisms age and die?

Senescence (Aging) – late-life decline in fertility and probability of survival.

Reduces fitness of individual.

Why does aging persist?

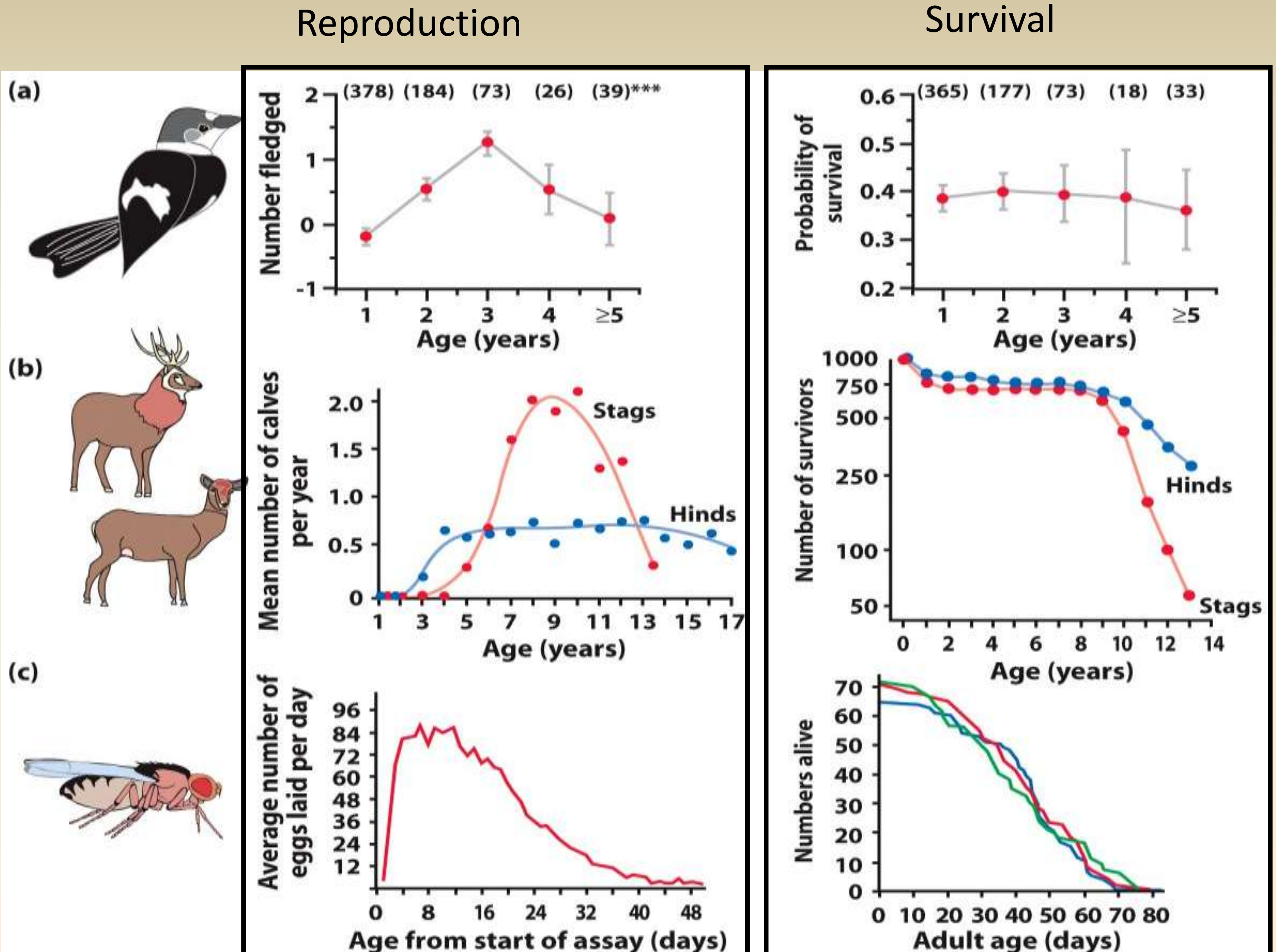
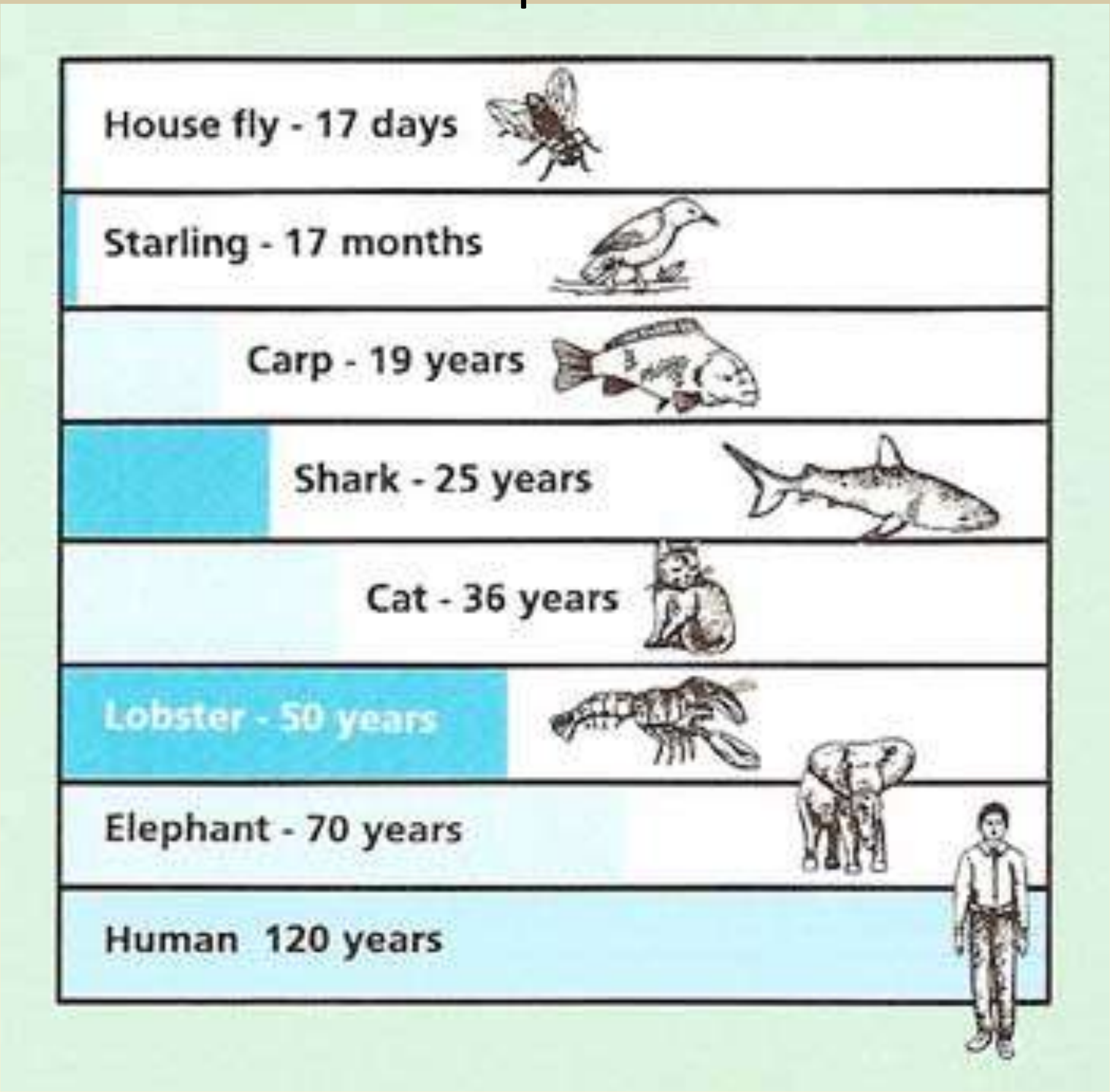


Figure 13-4 Evolutionary Analysis, 4/e

Lifespans


House fly - 17 days
Starling - 17 months
Carp - 19 years
Shark - 25 years
Cat - 36 years
Lobster - 50 years
Elephant - 70 years
Human 120 years

Winner = Tortoises – 180 years

Rate of Living Theory – aging is caused by the accumulation of damage to cells and tissues.

Damage cause by DNA damage, buildup of toxins.

Aging rate should be correlated with metabolic rate.

“Live Fast Die Young”

Predictions of the rate-of-living theory of aging

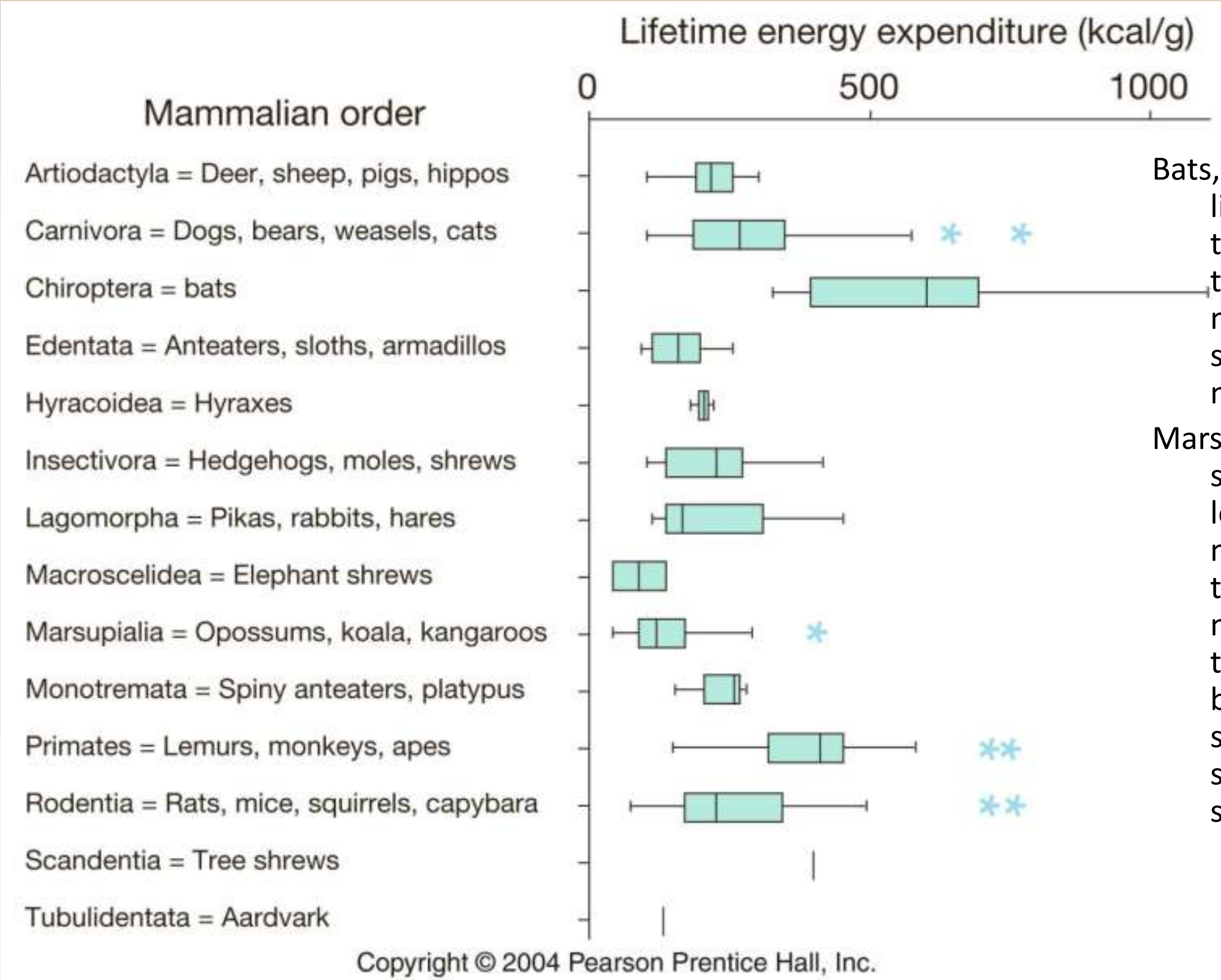
Because cell and tissue damage is caused in part by the by-products of metabolism, the **aging rate should be correlated with the metabolic rate**, or, equivalently, different species (within broad taxonomic groups) should have similar per gram total lifetime energy expenditures

Because organisms have been selected to resist and repair damage to the maximum extent possible, species should not be able to evolve longer life spans

Rate-of-living Hypothesis

- Austad and Fisher (1991) tested prediction 1.
- Calculated amount of energy expended per gram of tissue per lifetime for 164 mammal species. Theory predicts rate should be similar across groups.
- Found range from 39 kcal/g/lifetime in elephant shrews to 1,102 kcal/g/lifetime in a bat.

The data suggest that prediction (1) is not upheld (Austad & Fischer 1991)



Bats, in particular, live almost 3 times longer than other mammals of similar size and metabolic rate

Marsupials have significantly lower metabolic rates than other mammals of the same size, but also have significantly shorter life spans

Rate-of-living Hypothesis

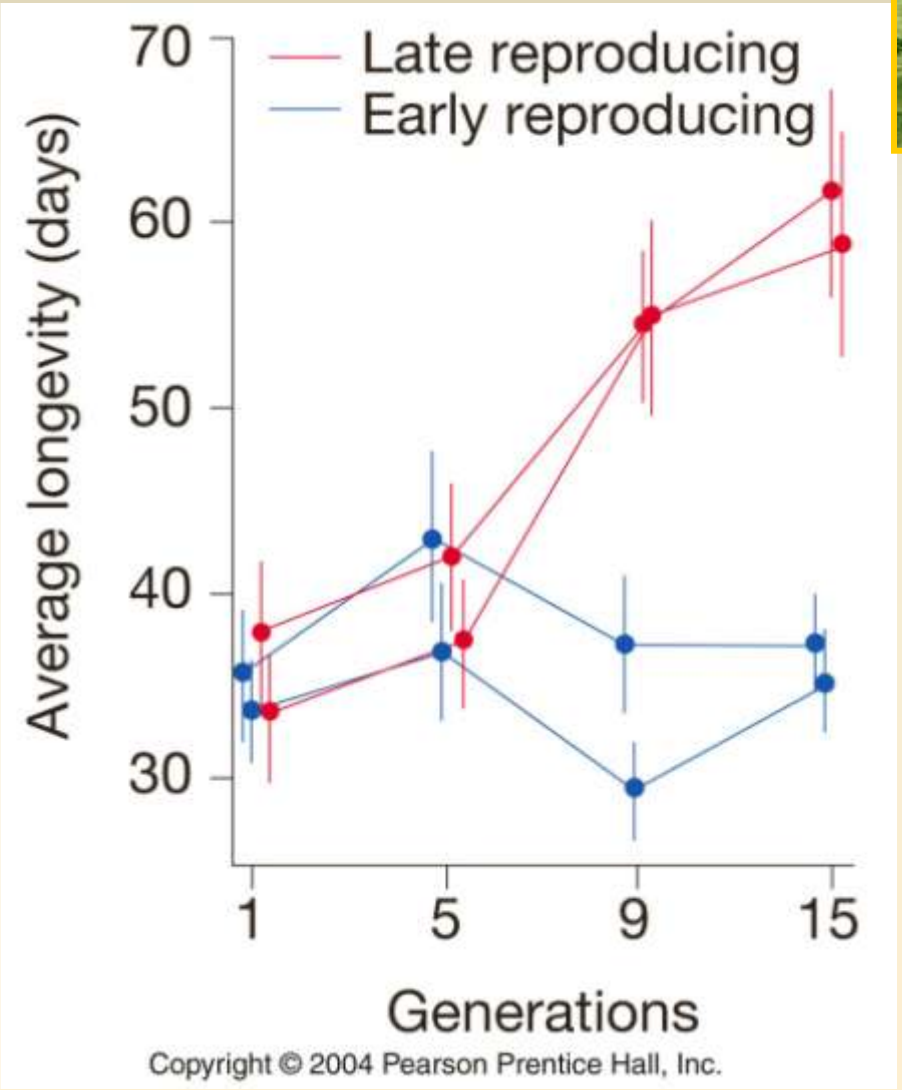
- Also found bats have rates similar to those of many other mammals but life spans that are 3 times as long.

- These patterns don’t fit rate-of-living predictions.

Experiments show that prediction (2) is not upheld (Luckinbill et al. 1984)

Life span of *D. melanogaster* is easily increased by selection in the laboratory.

This means that there is *heritable genetic variation* for life span.



The “telomere” theory of aging

Telomeres are tandemly repeated nucleotide sequences that are placed on the ends of eukaryotic chromosomes by the enzyme telomerase (TTAGGG in humans)

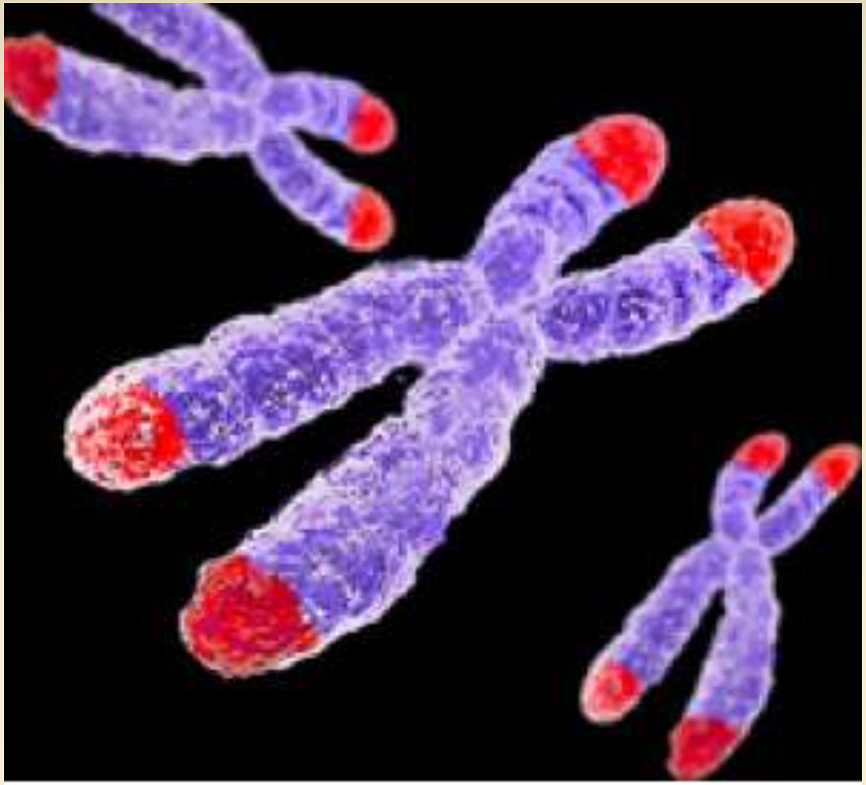
Telomeres are necessary because linear chromosomes shorten with each round of replication. Without them, chromosomes would erode away

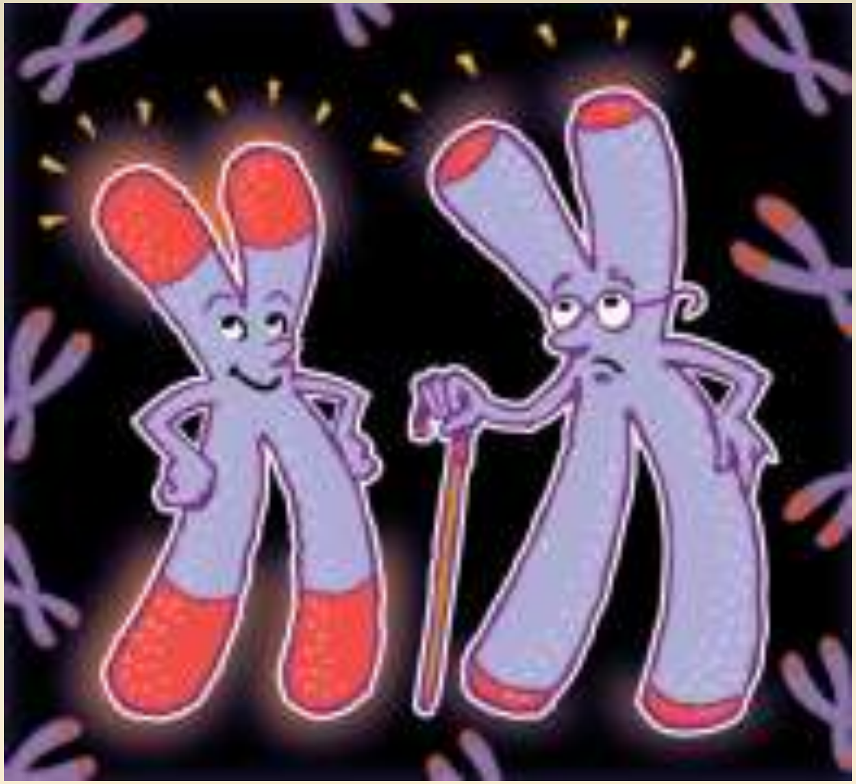
Telomerase is not expressed in most somatic cells

This means that somatic cells can undergo a limited number of mitotic divisions

Under this theory, individuals age because they can no longer replace damaged and worn-out cells

The “telomere” theory of aging





Some evidence from zebra fishes and human populations support this.

Telomere length was associated with longevity.

Looking at broad diversity of mammals. (Gomes et al 2011)

Longer lived mammals tend to have shorter telomeres.

Not associated with notion that longevity of organisms is associated with longevity of their cells.

The evolutionary theory of senescence

Senescence occurs because the "force of selection" declines with advancing age.

W. D. Hamilton 1966. The moulding of senescence by natural selection. J. Theoret. Biol. 12:12-45

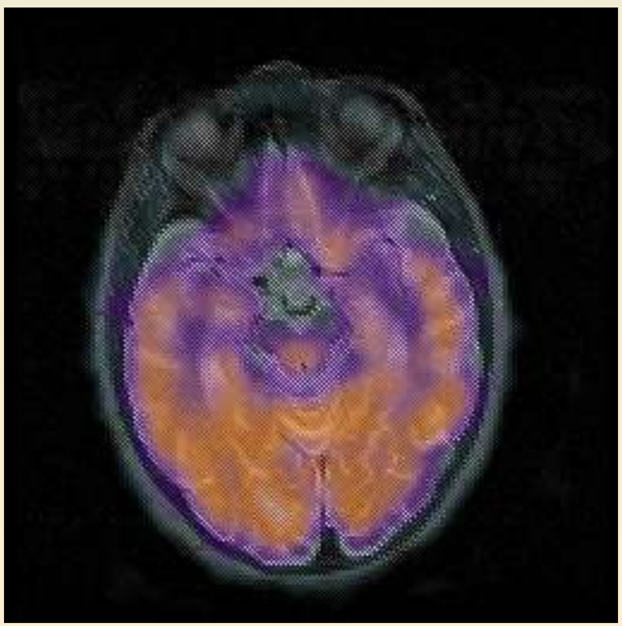
THE INTENSITY OF NATURAL SELECTION DECLINES WITH AGE

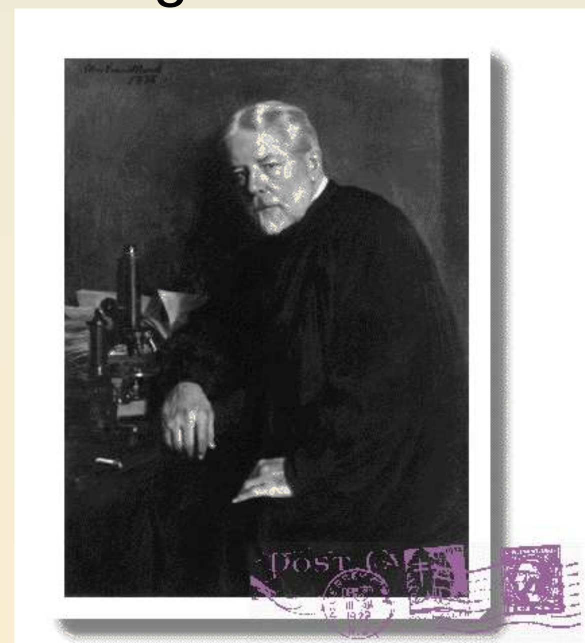
…the forces of natural selection *weakens* with increasing age …. If a genetical disaster… happens late enough in individual life, its consequences may be completely unimportant. Even in such a crude and unqualified form, this dispensation may have a real bearing on the origin of innate deterioration with increasing age.

Medawar, 1952

LATE-ONSET MUTATIONS ARE NOT ELIMINATED BY NATURAL SELECTION

EXAMPLE: Huntington's chorea: disabling disorder of the nervous system caused by a dominant mutation that is not expressed until the age of 35 – 40.





George Sumner Huntington

A verbal argument

1. Death before reproduction = zero fitness
2. Death after reproduction begins = greater than zero fitness
3. Therefore: natural selection will work most effectively against lethal mutations that kill before reproduction begins, but less effectively against lethals that act later in life.
4. If harmful genetic effects are expressed late enough in life, selection against them will be negligible because most individuals carrying the harmful alleles will already have died from other causes (predation, accident, etc.)

Evolutionary Hypothesis for aging

If selection can produce longer life spans why does it not do so?

Under evolutionary hypothesis for aging, organisms age because the body fails to repair cell and tissue damage rather than because it cannot do so.

Evolutionary genetic mechanisms

Mutation accumulation

Peter Medawar (1952) — senescence due to deleterious alleles with effects confined to late ages — **senescence evolves because natural selection is powerless to prevent it**

Antagonistic pleiotropy (trade-offs)

George Williams (1957) — senescence due to alleles with beneficial effects early in life but deleterious pleiotropic effects late in life —**senescence is selectively advantageous**

How many offspring should an individual produce in a year?

In life history decisions a fundamental choice is how many offspring to produce in a year.

The more offspring produced in a year, the less each can be cared for and additional offspring affect the parents prospects for survival.

Clutch size in birds

The question of how many young is optimal has been extensively studied in birds.

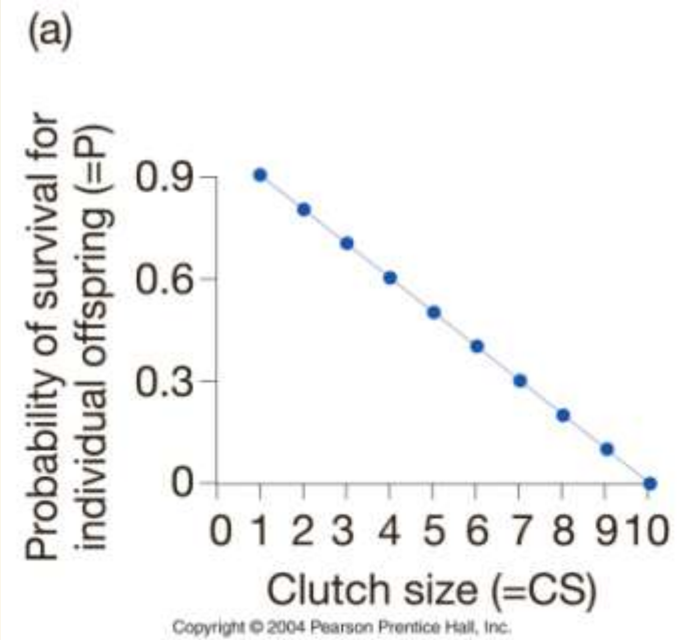
David Lack 1947 suggested that selection would favor the clutch size that produced the most surviving offspring.

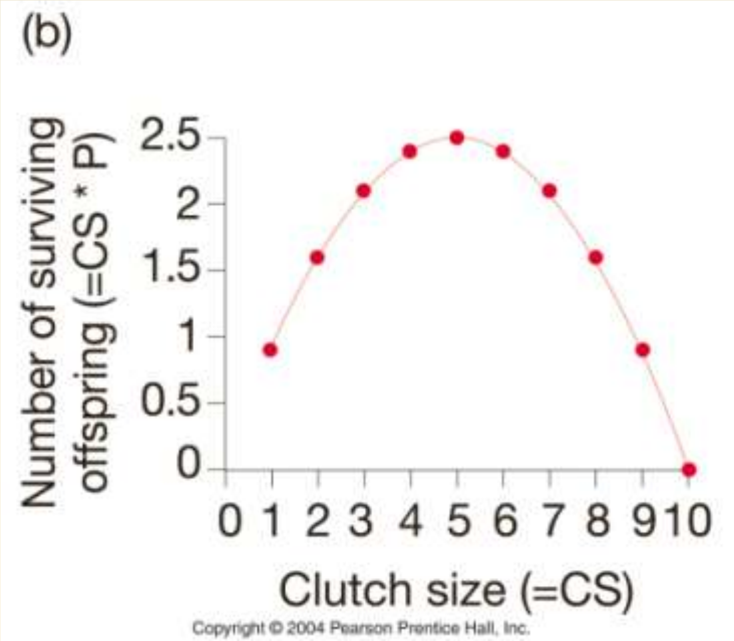
Lack’s hypothesis for the evolution of clutch size

- proposed by David Lack in 1947.

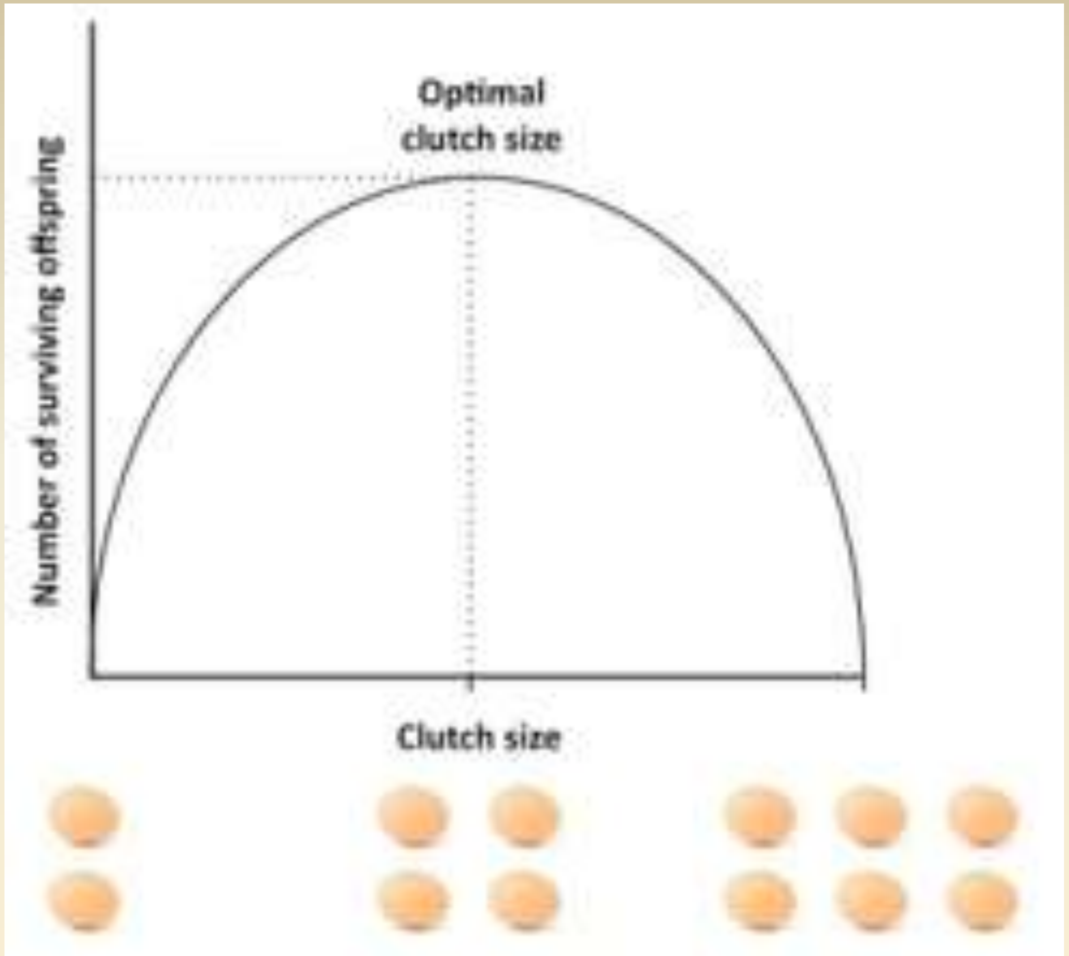
David Lack (1910 – 1973)

A mathematical treatment of Lack's hypothesis (Fig. 12.16)



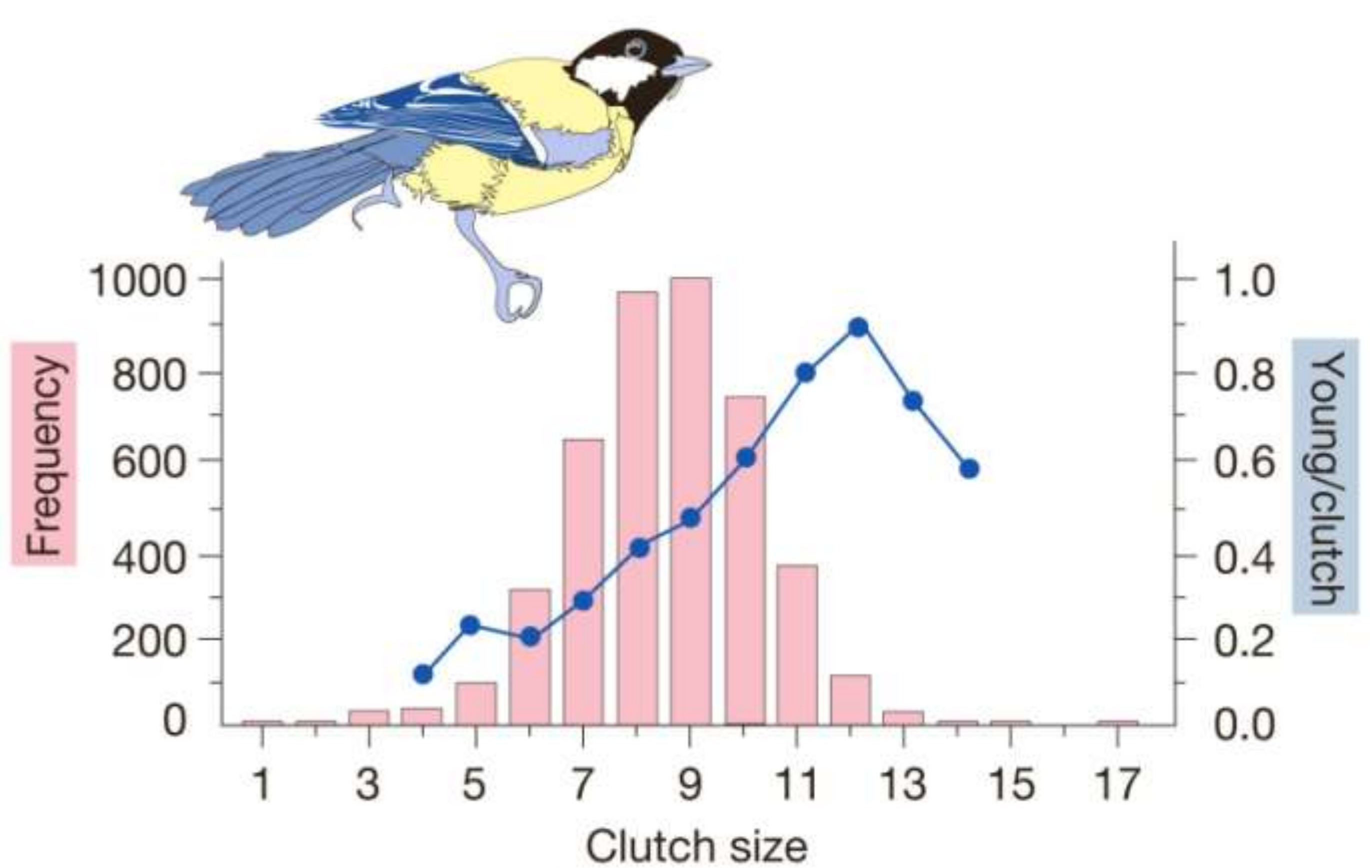


Given the relationship between clutch size and the probability of survival of individual offspring, the clutch size that maximizes the number of surviving offspring is 5



The "Lack clutch" is defined as the clutch size that maximizes the number of fledged (surviving) offspring, assuming that offspring mortality is a function of clutch size. The trade-off between clutch size and offspring survival leads to an intermediate optimum in reproductive effort.

Most birds lay smaller clutches than predicted by Lack's hypothesis



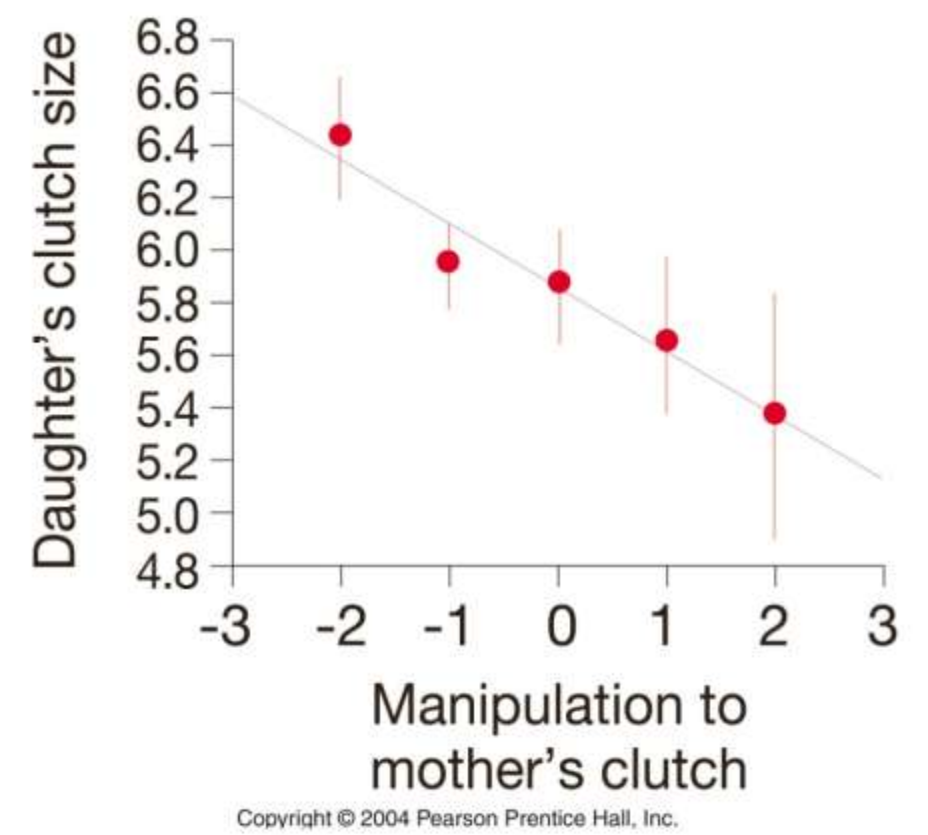
Clutch size and number of young per clutch in great tits (Boyce and Perrins 1987) (Fig. 12.17)

Average clutch size was less than the most productive clutch size
Smaller clutch sizes could have had more

Reasons why birds may not behave according to Lack's hypothesis

Lack's hypothesis assumes that there is no trade-off between reproduction in one year and the next

Lack's hypothesis assumes that the only effect of clutch size on the offspring is through their survivorship



Clutch size of mothers affects clutch size of daughters in collared flycatchers (Schluter & Gustafsson 1993) (Fig. 12.18)

Biological Invasions

Snow Campion – *Silene latifolia*

Traditional explanation

When *Silene latifolia* arrived in New World it left all its enemies and pathogens behind.

Evolution of Life History explanation (Blair and Wolf 2004)

1. Common Garden Experiment in U.S.

American plants germinated earlier, grew faster, made more flowers, and survived longer than European plants.

With few enemies, there was a adaptive shift in energy budget, skimped on defense to invest more heavily in reproduction.

2. Common Garden Experiment in Europe

American plants were easy pickings for predators, more susceptible to smut fungus

End