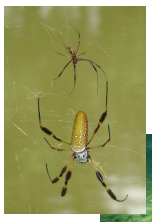
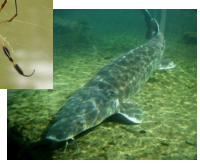
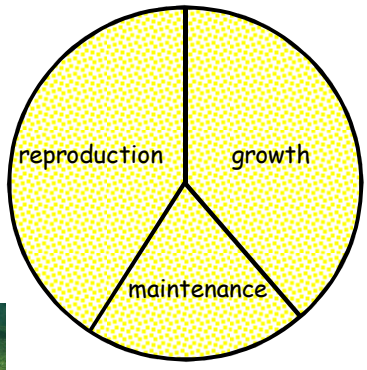
## Evolution of Life History Characters

how do organisms allocate resources (time, effort, energy) between self and offspring (survival and reproduction) ?

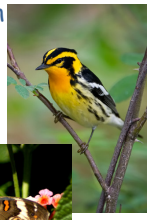
indeterminant growth

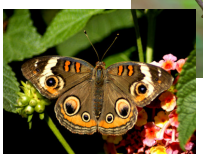







determinant growth



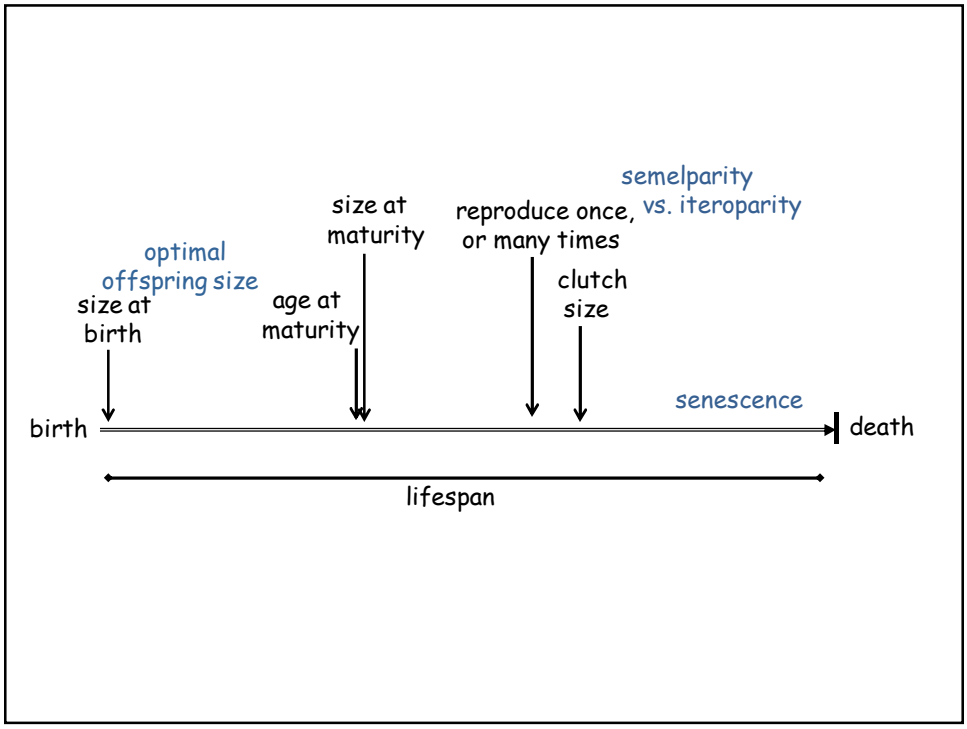


## Outline

what are life history traits?

trade-offs between life history traits

senescence


semelparity
vs. iteroparity
size at
maturity
reproduce once,
or many times
optimal
offspring size
clutch
size
size at
birth
age at
maturity
senescence
birth
death
lifespan

*At what age and size should an individual become mature?*

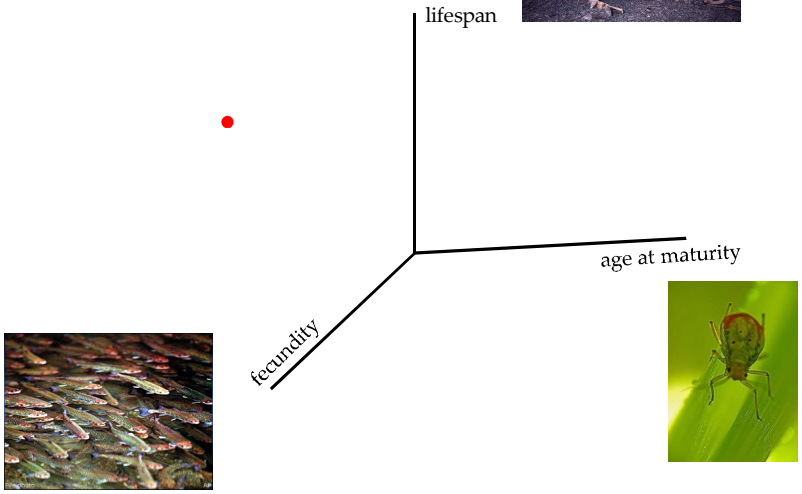
*Should it reproduce once or many times?*

*How many offspring should it produce at one time?*

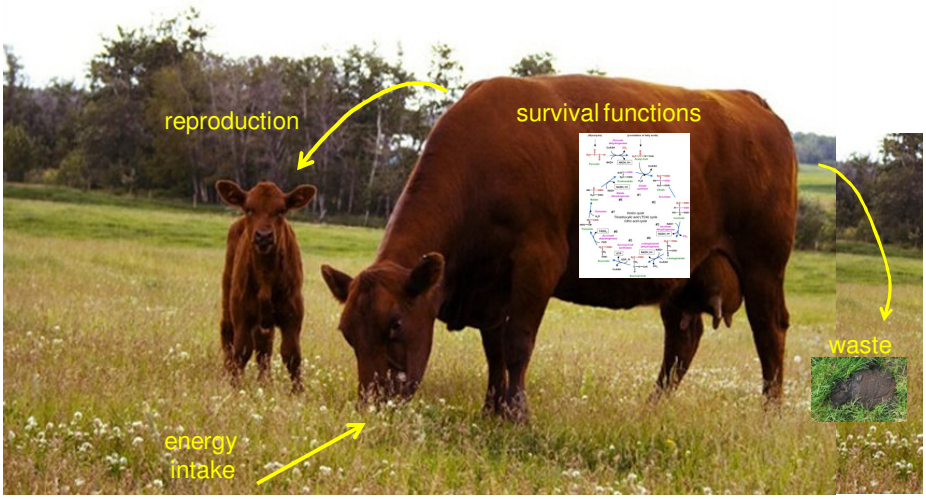
*What size should offspring be?*

selection will act to

- maximize survival
- maximize fecundity
- minimize age at maturity



physiological trade-offs arise from finite resources




frequently observed trade-offs between
life history characters

age at maturity, lifespan (-)

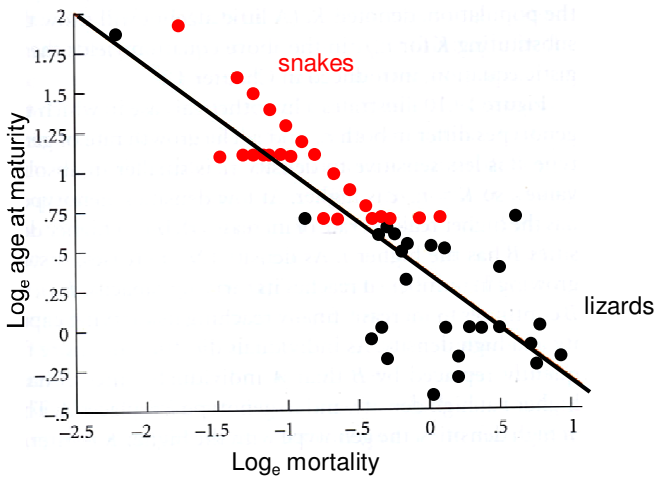
growth rate, size at maturity (+)

offspring size, clutch size (-)

clutch size, number of clutches (-)

lifespan, number of clutches (+)

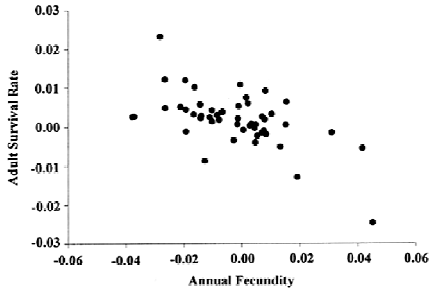
## age at maturity is negatively correlated with lifespan



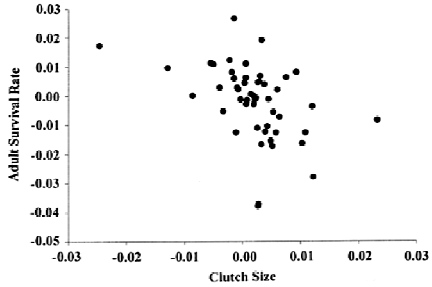

Shine and Charnov 1992

## reproductive effort reduces adult survival in birds

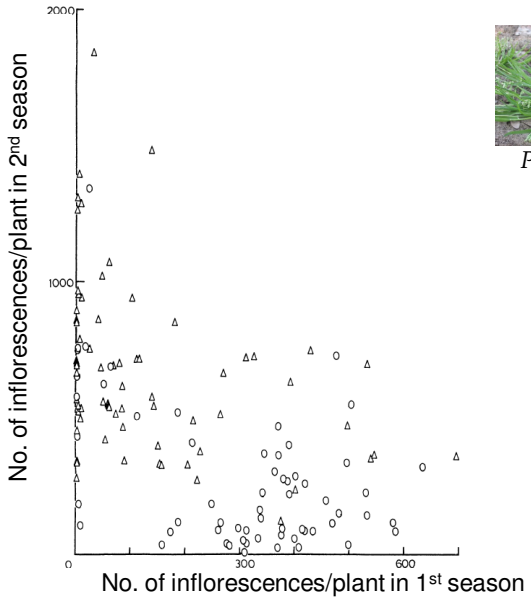
b = -0.25, p < 0.001




b = -0.83, p < 0.001



## current reproduction is negatively correlated with future reproduction

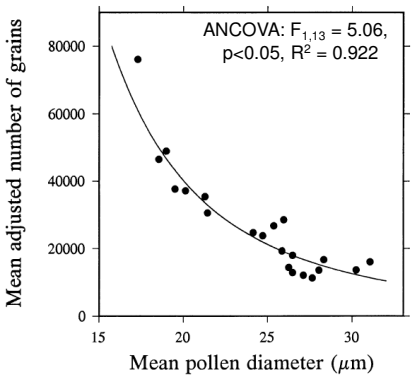



*Poa annua*

Law et al 1979

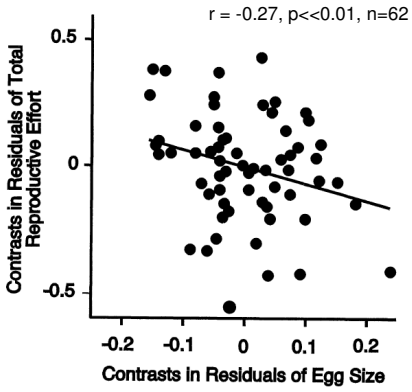
## the number of offspring constrains their size

*legumes*




Vonhof & Harder 1995

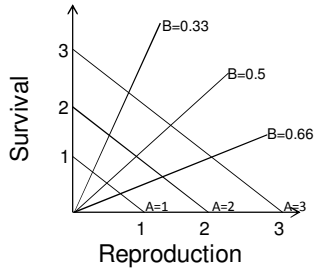
*copepods*

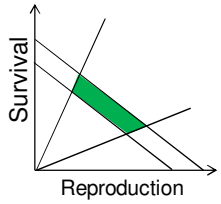


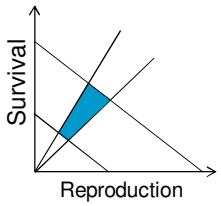

Caley et al 2001

## why don't we always see an expected trade-off?

- resource acquisition vs. resource allocation




A = acquired energy

B = allocation to reproduction

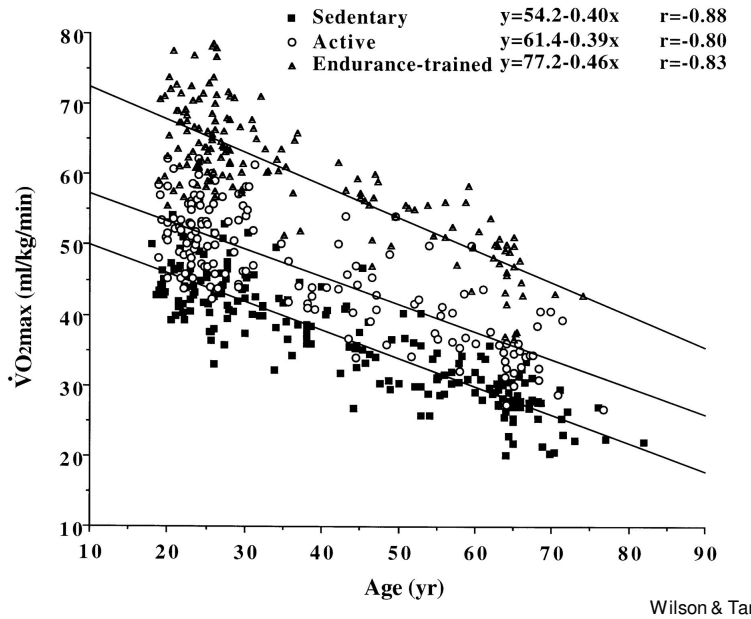
Van Noordwijk and de Jong 1986

## Evolution of senescence

Senescence: greater susceptibility to injuries, disease and death as one grows older

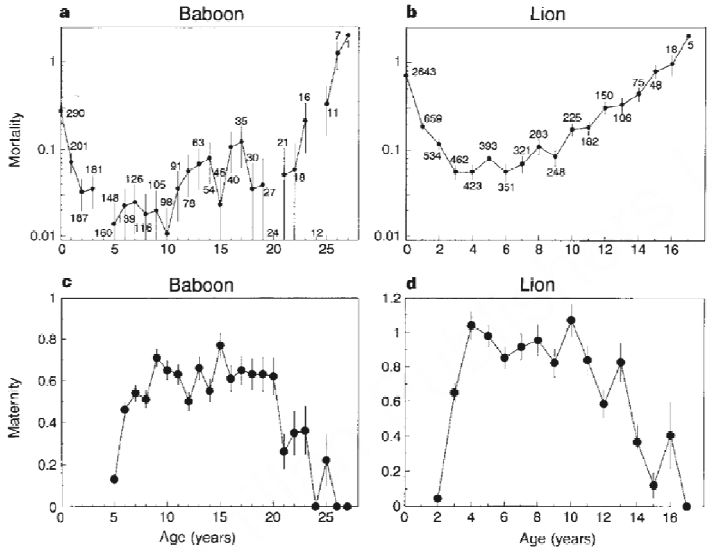
- neural degeneration
- reduced kidney filtration
- decreased respiratory capacity

Decline in cardiovascular function with age




Wilson & Tanaka 2000

# Evolution of senescence




Packer et al 1997 Nature 392:807

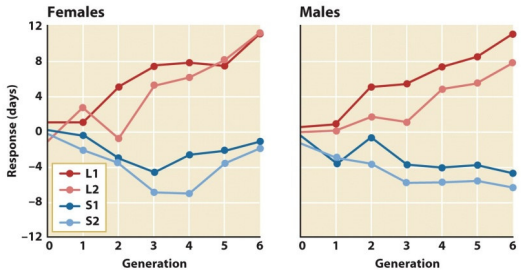
hypotheses for senescence

rate of living hypothesis

"senescence is unavoidable"

"I just want you to know that no matter what you do, you're still gonna die just like everybody else"
-- Rose, Moonstruck

predicts: little/no remaining additive variance in the rate of senescence



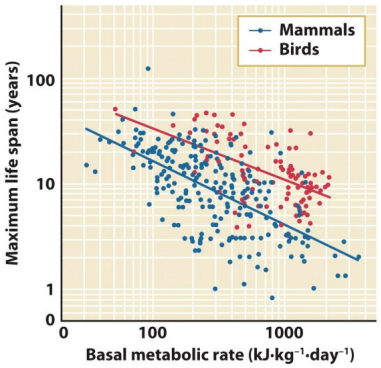

hypotheses for senescence

rate of living hypothesis

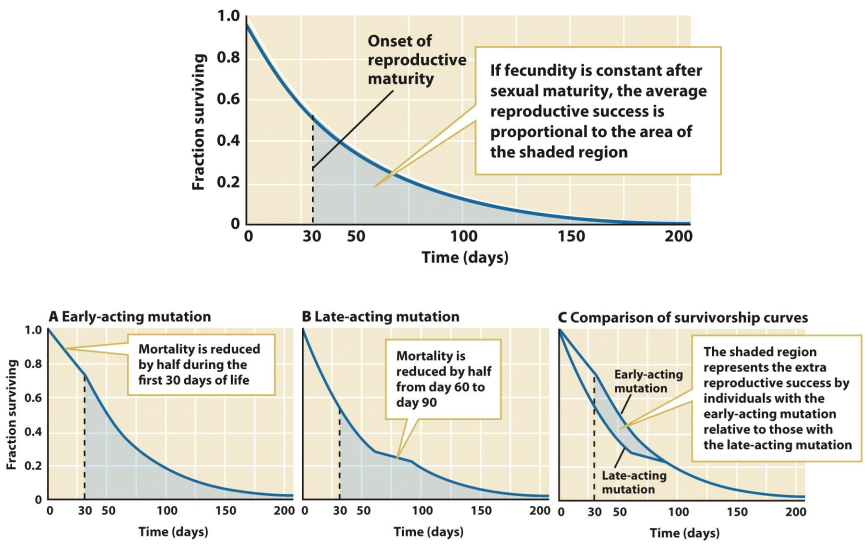
"senescence is unavoidable"

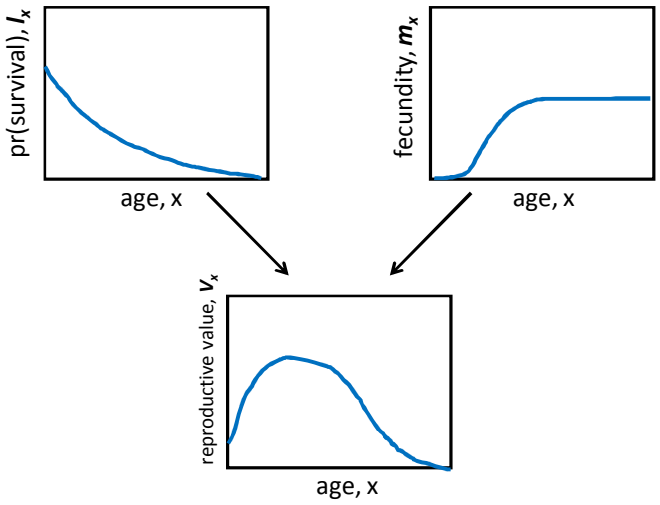
"I just want you to know that no matter what you do, you're still gonna die just like everybody else"
-- Rose, Moonstruck

predicts: strong negative correlation between metabolic rate and lifespan

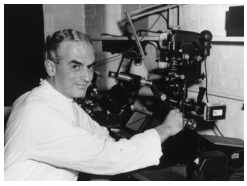


## an evolutionary view of senescence



## Mutation Accumulation hypothesis

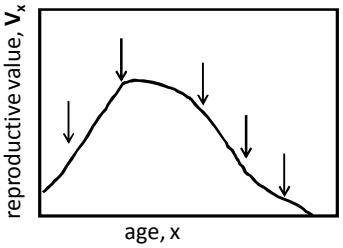


Medawar (1946):
"What is important from our point of view is that the contribution that each age-class makes to the ancestry of the future decreases with age."

reduced selection on older age classes

new, deleterious mutations build up in the genome
- early acting mutations are removed by selection
- late-acting ones are shielded from selection
  - if post-reproductive

## Mutation Accumulation hypothesis




effect of deleterious mutations on fitness depends on the age at which they are expressed

weight by $V_x$


mutations accumulate later in life because little detrimental effect on fitness

selection on interacting loci to shift time of expression

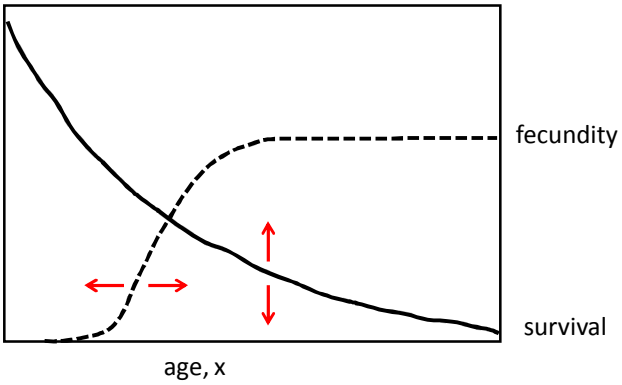
## Antagonistic Pleiotropy

Williams (1957)

"Selection of a gene that confers an advantage at one age and a disadvantage at another will depend not only on the magnitudes of the effects themselves, but also on the times of the effects. An advantage during the period of maximum reproductive probability would increase the total reproductive probability more than a proportionately similar disadvantage later on would decrease it."

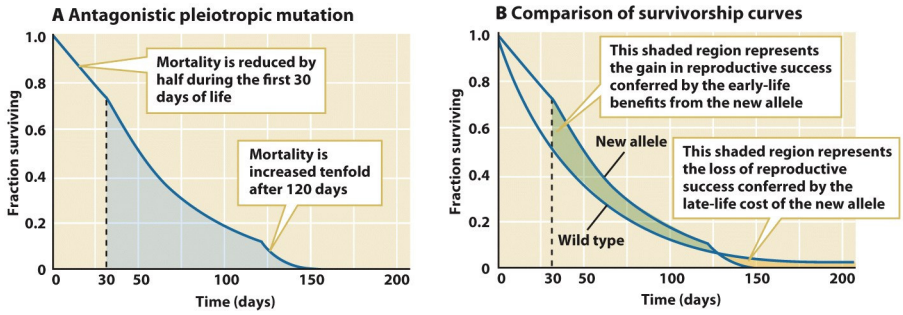
## Antagonistic Pleiotropy hypothesis

trade-offs between early- and late- age effects



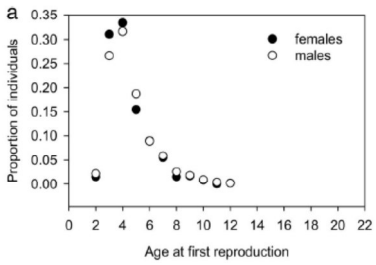
| mutation → survival | onset of reproduction | effect on fitness | |
|---|---|---|---|
| ↓ | --- | negative | |
| ↑ | --- | positive | no pleiotropy |
| --- | → | negative | |
| --- | ← | positive | |
| ↑ | ← | positive | no trade-off |
| ↓ | → | negative | |
| ↑ | → | | trade-off |
| ↓ | ← | favored because of effects on fitness | |

## Antagonistic pleiotropy hypothesis



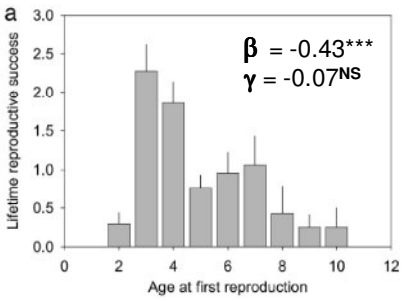
evidence for antagonistic pleiotropy
in mute swans

data: 1,147 birds over 36 years
529 birds, dead by 2005, no reprod > 2000





Charmantier et al 2006 PNAS



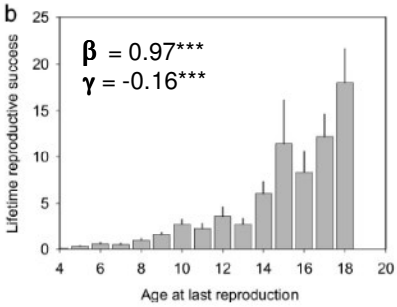
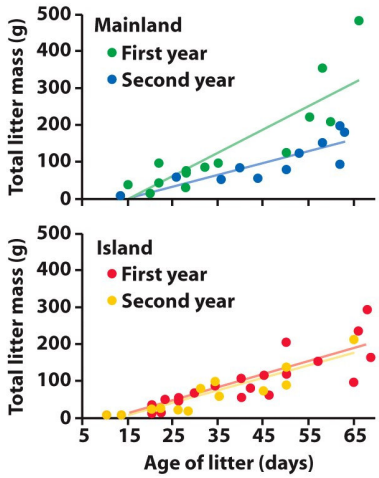



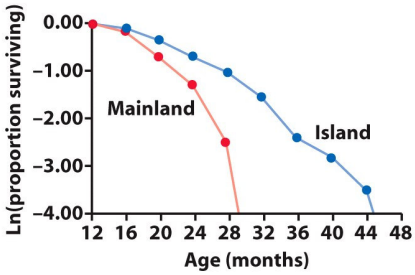

**Table 3. Phenotypic and genetic correlation between AFR and ALR**

| Situation tested | No. of birds | Phenotypic correlation ± SE | Genetic correlation ± SE |
|---|---|---|---|
| All breeding swans dead by 2005 | 648 | 0.193 ± 0.051*** | 0.555 ± 0.291* |
| All breeding swans dead by 2005, and with ALR > AFR | 469 | 0.118 ± 0.060* | 0.560 ± 0.404 |
| All breeding swans dead by 2005, and with age at death > ALR | 272 | 0.191 | 0.495 |

Charmantier et al 2006 PNAS

senescence and extrinsic mortality




Austad 1993

trade-off between investment in reproduction
and investment in repair

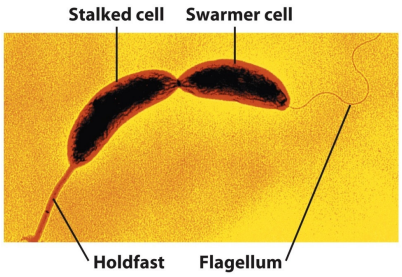
somatic cells vs. germline cells

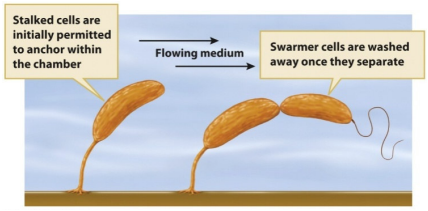
transcriptional and translational machinery

growth rate

"disposable soma"

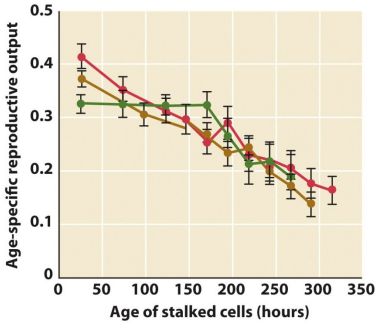
## a test of the reproduction-repair trade-off in bacteria




*Caulobacter crescentus*

starts as free-swimming swarmer
matures → stalked cell




Life history traits are those which are concerned with "decisions" about allocation of resources to maintenance, growth or reproduction

Life history traits often show trade-offs or correlations -- e.g., increased size of offspring may be related to a decreased number of offspring -- these trade-offs represent constraints on the evolution of life history characters

Iteroparity (multiple clutches) evolves when the relative survival rate of adults is high compared to juveniles. Low adult survival favors maximum investment in reproduction (semelparity).

Senescence evolves because selection on deleterious mutations changes as a function of age; mutations that enhance early reproduction (even to the detriment of lifespan) will be favored by selection