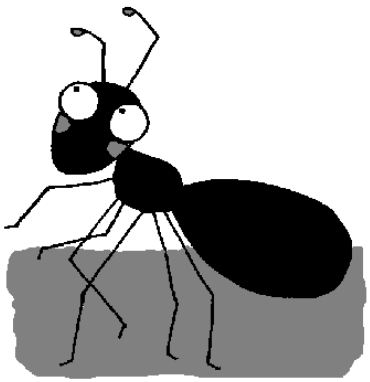
The Evolution of Life Span

Why do we live as long as we do?



Traits That Correlate with Longevity

- Can evolution theory help explain these correlations?

  - Fecundity, # of offspring (inversely correlated)

  - Metabolic rate (inversely correlated)

  - Body weight, brain weight

  - Length of growth period, prolonged adolescence
    Brain Size

Evolution Basics

Natural Selection -The process by which the individual with the greatest fitness is selected from a population of genetically variable individuals of one species.

Fitness = reproductive success

Individuals with the best reproductive success have more offspring. And so on, and so on, until the adaptation (gene) that led to greater reproductive success is present throughout the species.

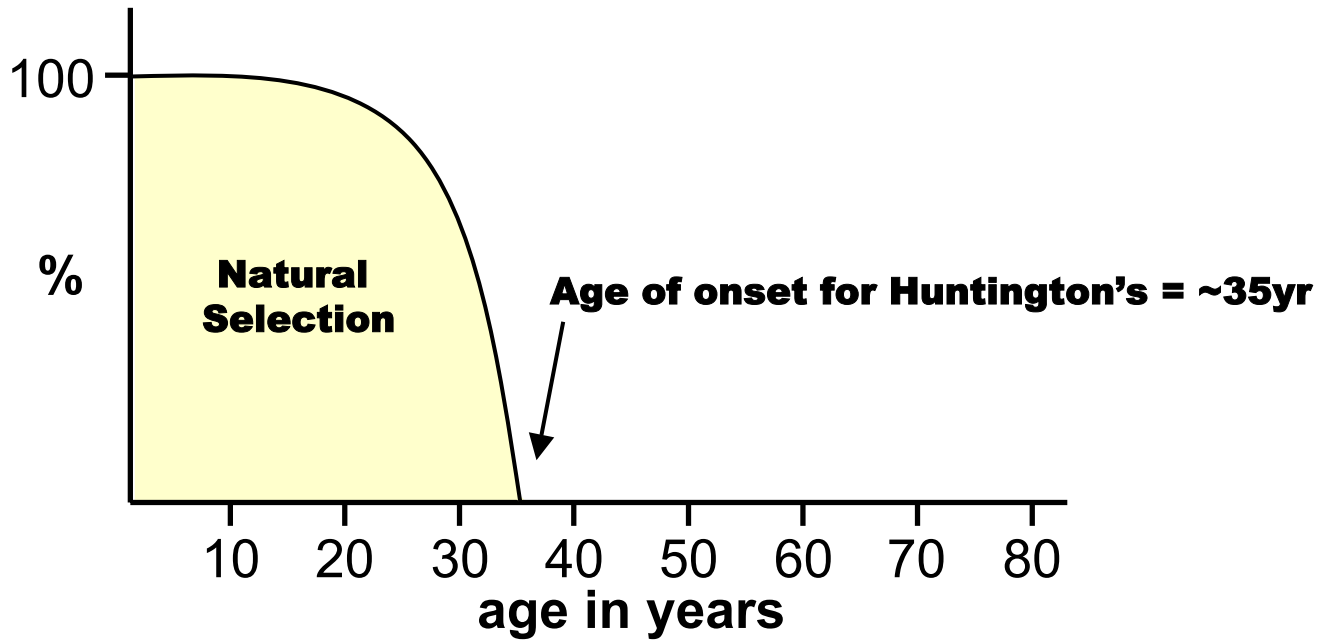
Evolution (natural selection) will only act on genes (traits) that lead to greater reproductive success.

Evolutionary Theory of Life Span

Haldane and Medawar, 1940's

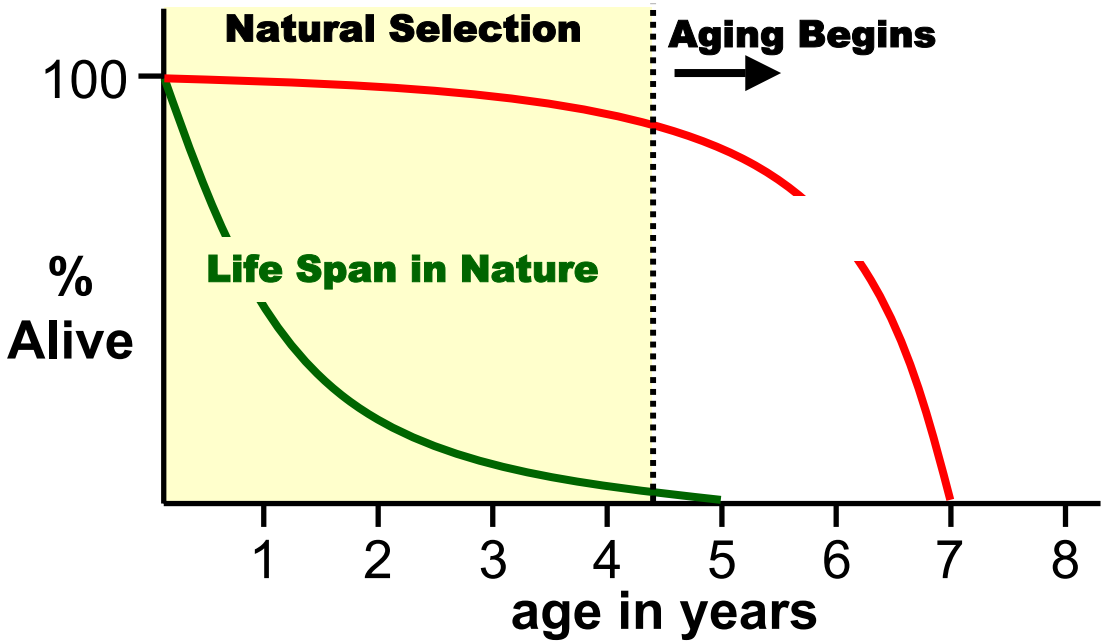
- **Huntington's Disease**, a dominant lethal mutation

How does Huntington's stay in the population if it results in lethality?



***Idea:* Aging results from a decline in the force of natural selection.**

Aging in Nature



- Most organisms do not age in the natural envirnoment.

- What factors might determine life span in nature, and consequently the age at which the force of natural selection declines?

Environmental Selection

Life span is proportional to the rate of extrinsic mortality.

If mortality is high an organism will die from predation or other hazards before it grows old.

-Therefore there is no reason to evolve a long life span.

Evolutionary Theories of Aging

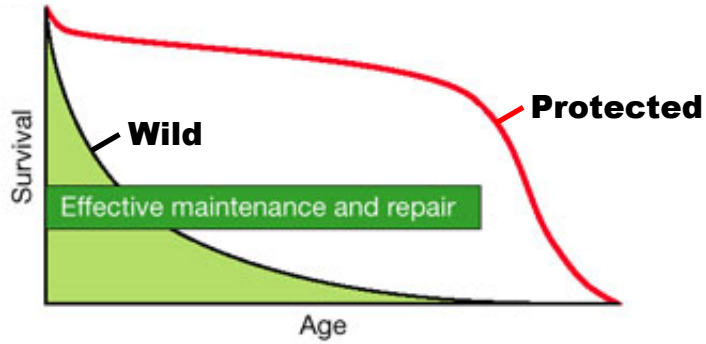
Disposable Soma - Somatic cells are maintained only to ensure continued reproductive success, following reproduction the soma is disposable. (life span theory)

Antagonistic Pleiotropy - Genes that are beneficial at younger ages are deleterious at older ages.

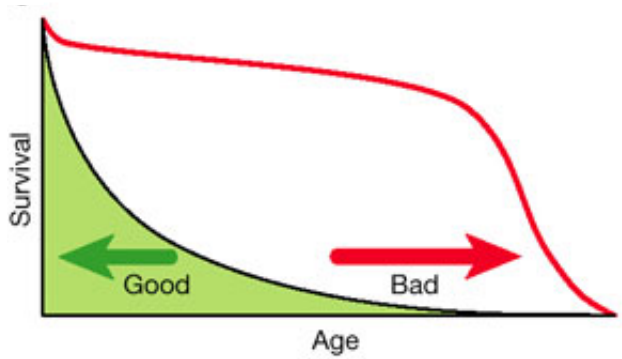
Mutation Accumulation - Mutations that affect health at older ages are not selected against (no strong evidence).

Evolutionary Theories of Aging

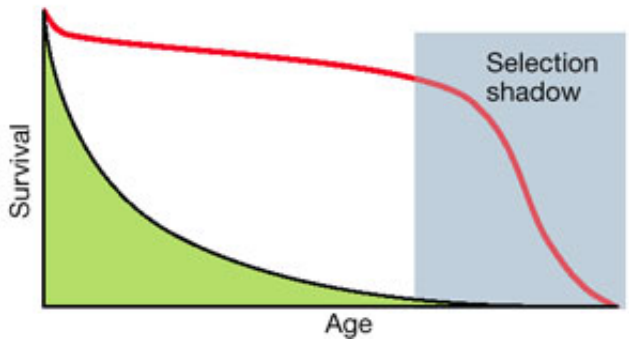
Disposable Soma



Antagonistic Pleiotropy



Mutation Accumulation



***Nature* 408, 233-38 (2000)**

Opossums and Life Span

- ultimate prey, ~ 80% die from predation
- typically reproduce once
- age very rapidly

-***Hypothesis:*** ***The presence of predators limits life span, natural selection favors somatic maintenance for only as long as an average opossum can be expected to live.***

How do we test this hypothesis?

Steve Austad, U. of Idaho

Sapelo Island Opossums

- no predators (out in daytime)
- longer average life span
- reproduce twice (fewer offspring/litter)

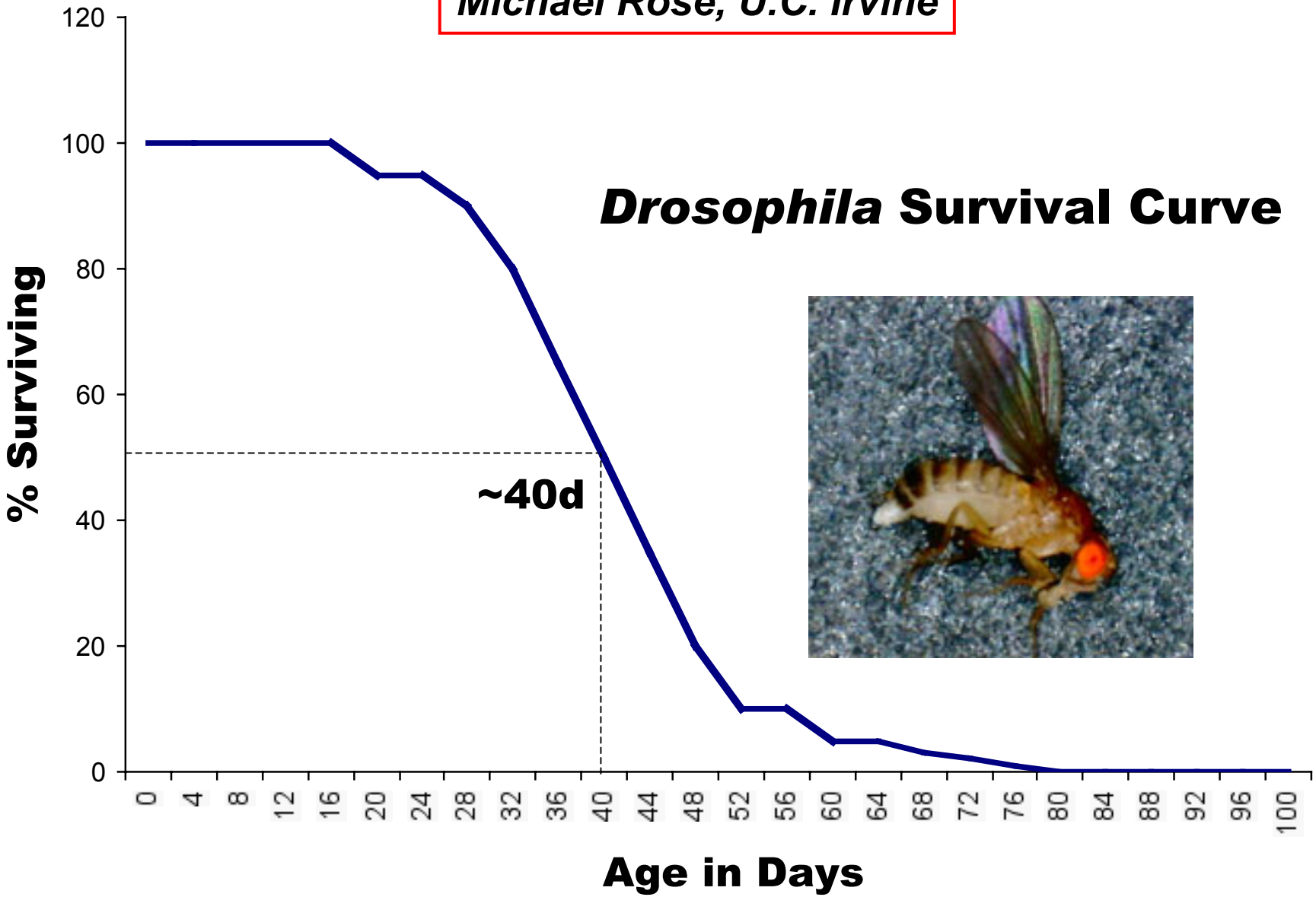
? ***Are these changes due to a lack of predators, or a physiological change that delays the aging process?***

Physiological Change - Sapelo island opossums not only live longer, they age slower than mainland animals.

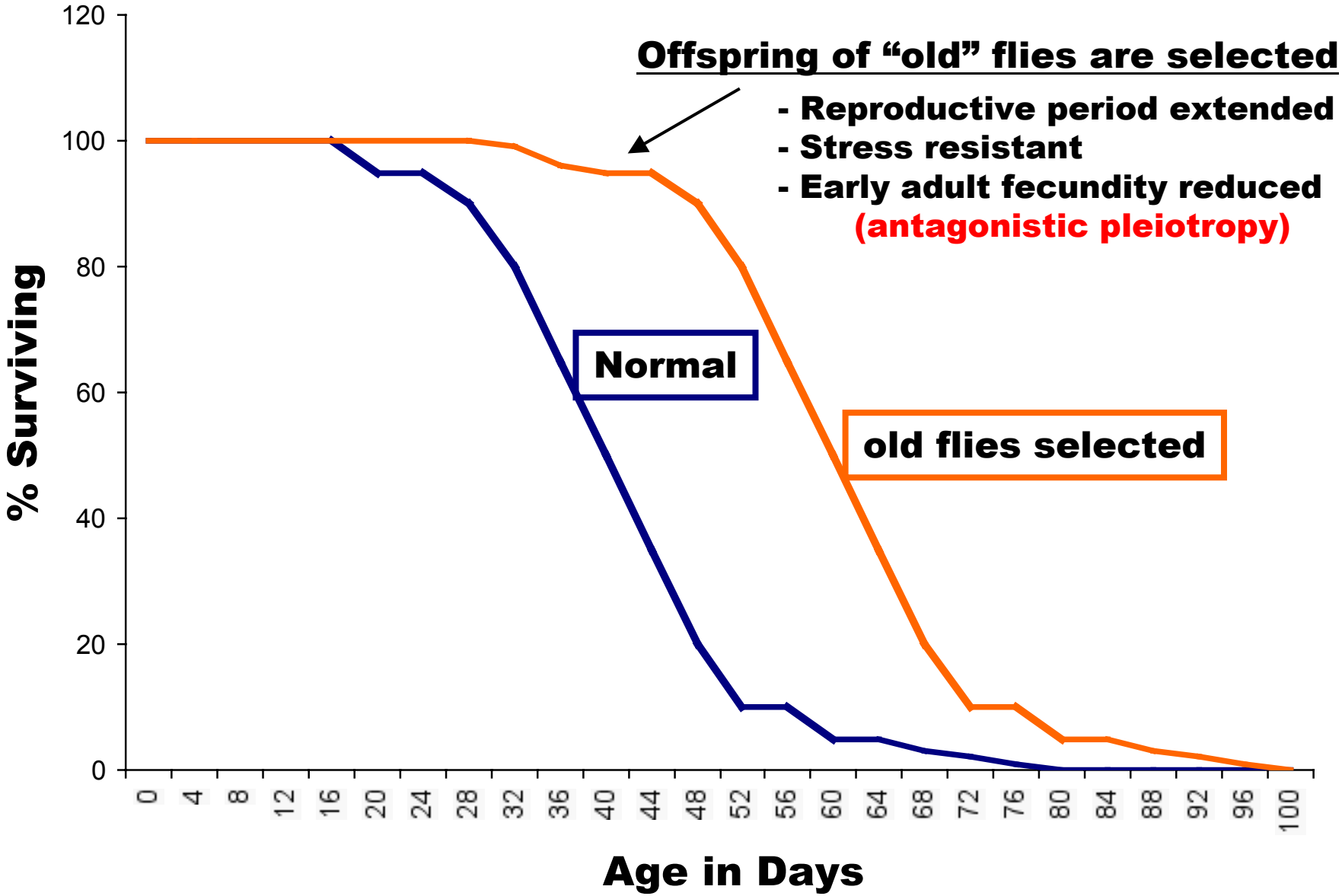
-Sapelo Island opossums have less molecular damage than mainland opossums. (collagen X-linking)

Evolution in the Laboratory

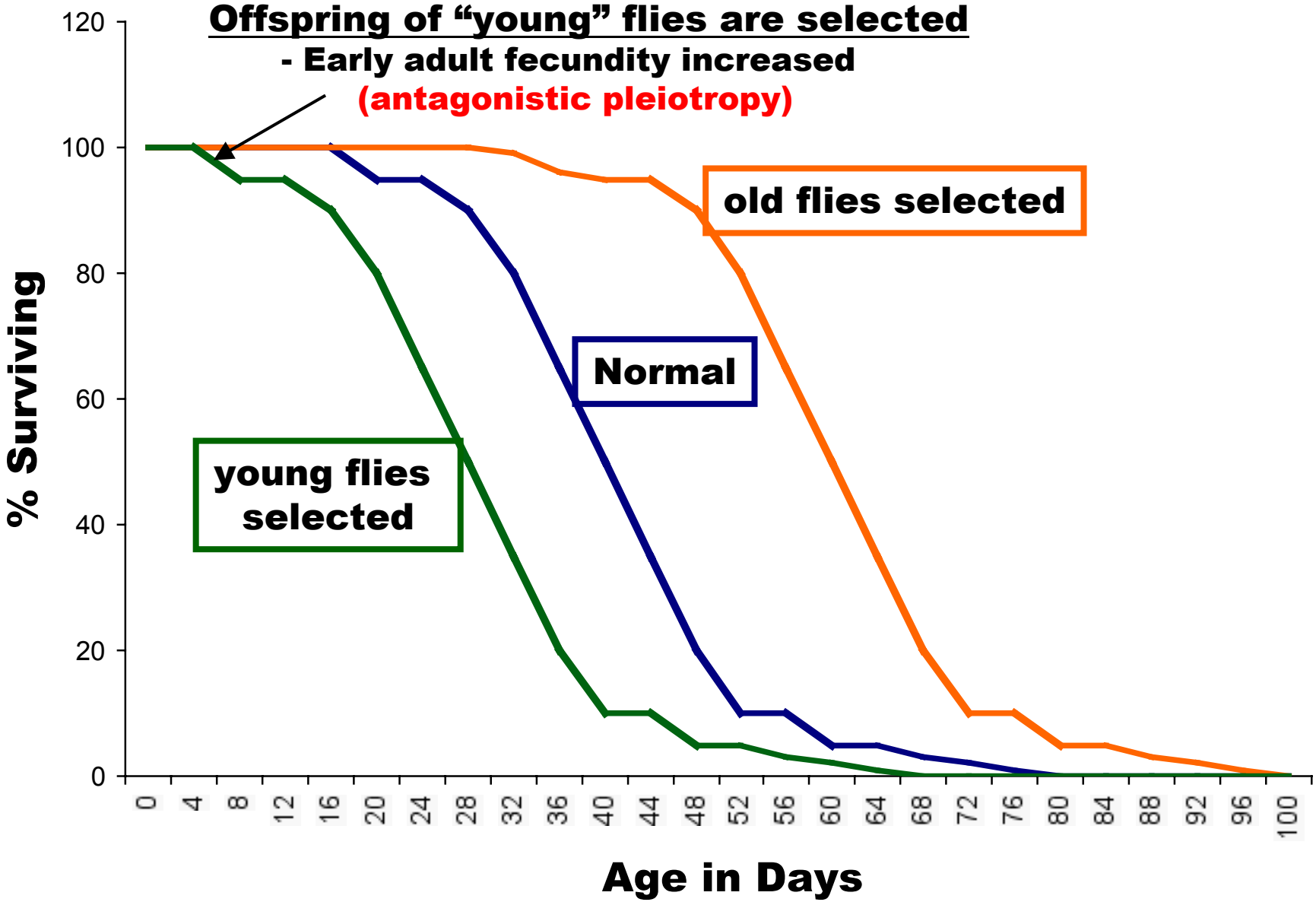
Michael Rose, U.C. Irvine



Evolution in the Laboratory



Evolution in the Laboratory



Summary of Drosophila Selection

1) Selection at age of reproduction can alter the lifespan of *Drosophila* (lifespan has been doubled by this technique).

2) Increase in lifespan has a cost, reduced fecundity (reproduction). (antagonistic pleiotropy)

3) Long-lived flies are stress resistant (heat shock, oxidants).

Exceptions to the Rule

Some organisms evolve unique adaptations that allow the subsequent evolution of exceptional life span.

Rats and Bats: **Rats live for ~3 years, Bats live for ~30 years**

Bats evolved a mechanism (flight) that reduced extrinsic mortality and allowed for the subsequent evolution of a long life span.

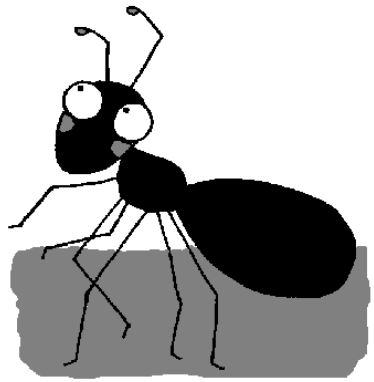
What other adaptations might lead to prolonged life span?

Exceptional Life Span in Eusocial Insects

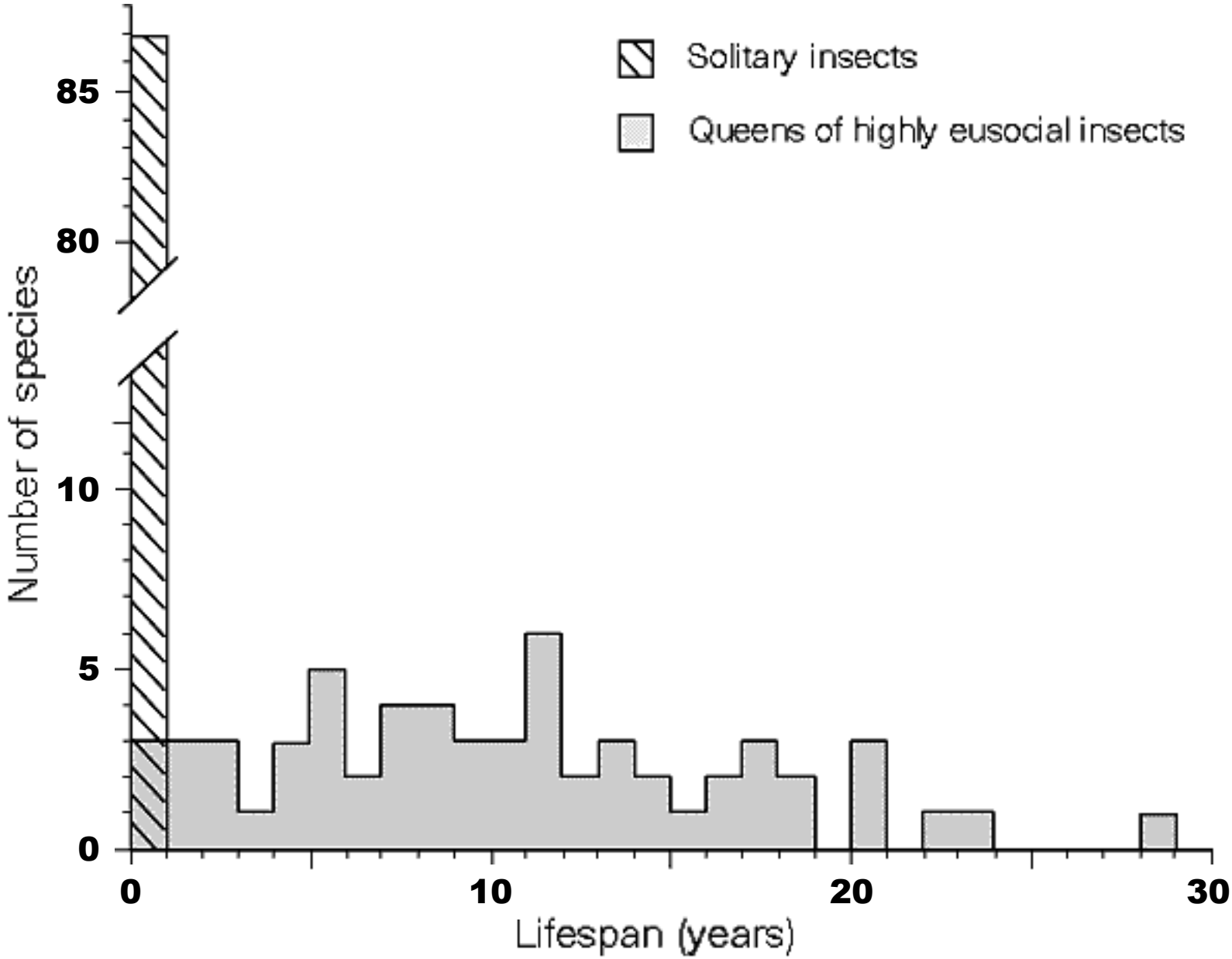
Queen Bees and Queen Ants have exceptional life spans!

- **Small size**
- **Many offspring**

Why do they live so long?

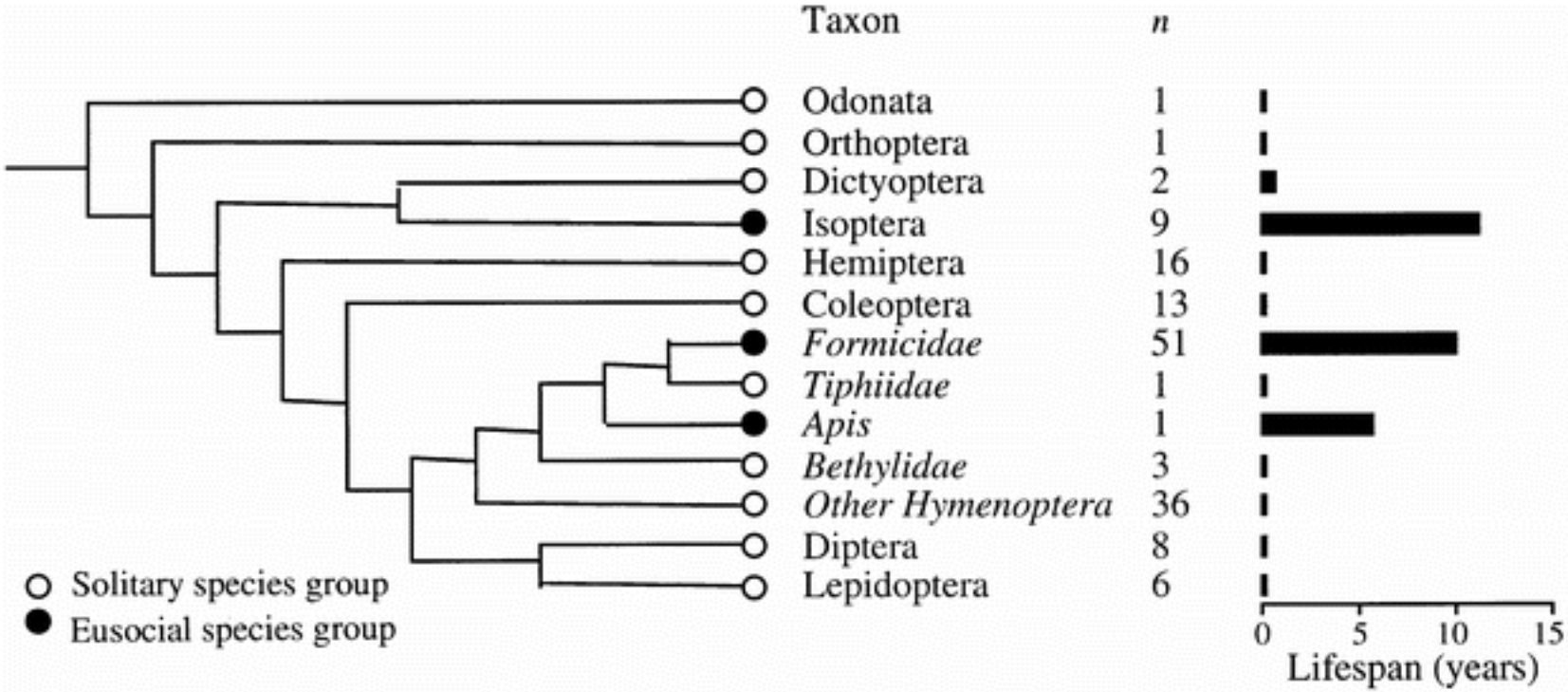


- Protected from the environment, therefore extrinsic mortality is low!



Keller L, Genoud M: **Extraordinary lifespans in ants: A test of evolutionary theories of ageing**. *Nature (London)* 1997, **389**:958-960

Exceptional Life Span is due to Social Organization



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What does this tell us about aging?

-Size does not (always) matter!

-Reproduction / metabolism does not control life span.

- Some queen ants produce their body weight in offspring each day

-Life Span results from selective pressures.

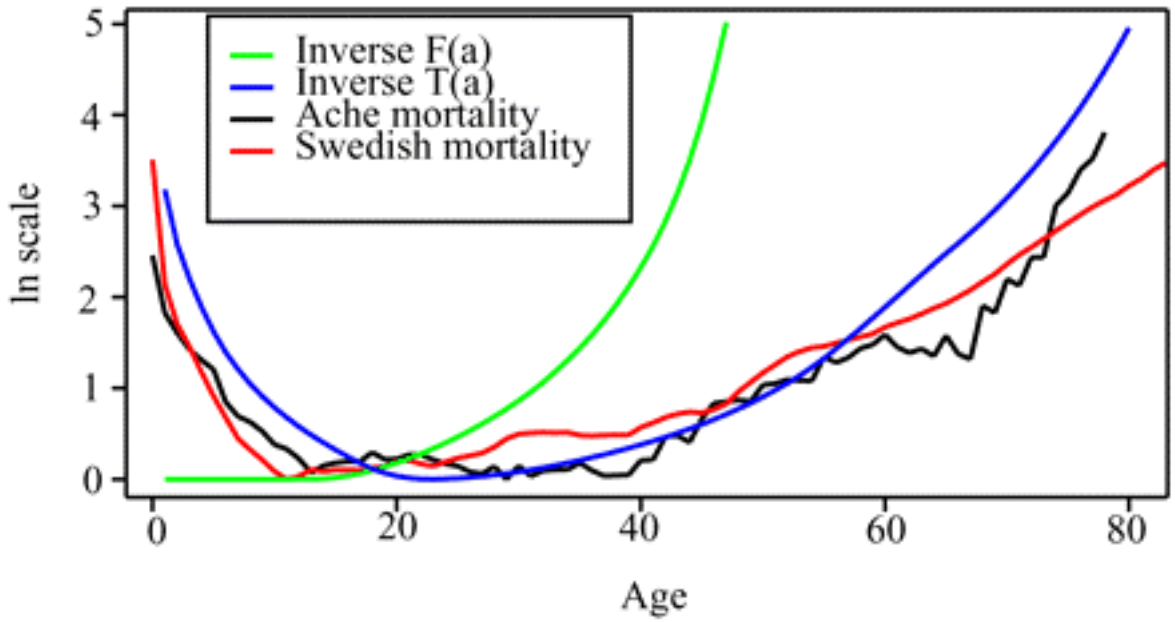
What about Humans?

-Unlike most animals, humans and some related primates age in a natural environment.

-Menopause is also unique to humans. How can nature select for a process that limits reproduction?

-How does parental care influence the evolution of human life span?

Age specific mortality in humans



Evolutionary models that integrate parental investment can more accurately predict age-specific mortality rates.

Life Span versus Aging

Aging - can not be selected for, results from an absence of natural selection.

Life Span - results from a balance between two major selective forces.

Environmental Selection - predators, natural hazards

Social Selection - parental investment, sexual behavior

Main Ideas

1. Life span results from selective pressure.

2. Life span is inversely proportional to extrinsic mortality.

3. Aging results from a lack of natural selection with age.