Aging and Other Life History Characters
Chapter 11

I) Basic Issues

A) Definition: Life history – the reproductive strategy of an organism

B) What are Life History Characters?

1) Number and size of offspring – female can produce a large number of small offspring OR a small number of large offspring but not a large number of large offspring.

2) Age of first and last reproduction – early and late reproduction may results in more offspring but may be of lower quality.

3) Life span – the longer an individual lives that more offspring they can have, but having offspring shortens life span.

C) Evolution operates to maximize the reproductive output of an organism so: Why do organisms age and die? Why don't all organisms produce a large number of large offspring? Why are all organisms born reproductively capable?

D) Evolutionary Constraints on Life History Characters

1) Phylogenetic – evolutionary history of an organism can put limits on what is likely and what is unlikely to evolve.

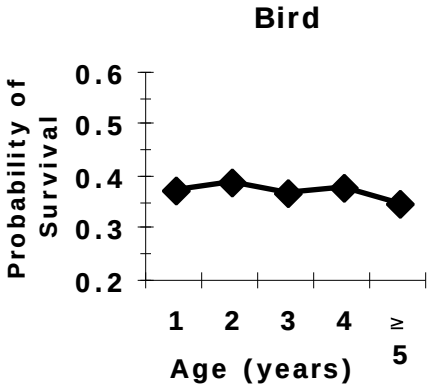
2) Genetic – life history characters are certainly polygenic and may require that a large number of mutations accumulate before significant differences in fitness are seen (i.e., evolve very slowly)

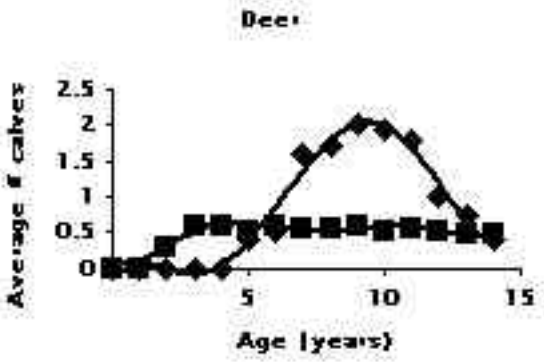
3) Antagonistic pleiotropy – one gene can affect more than one character (pleiotropy) and the specific effects can be antagonistic (e.g., mutation for early reproduction causes early death).

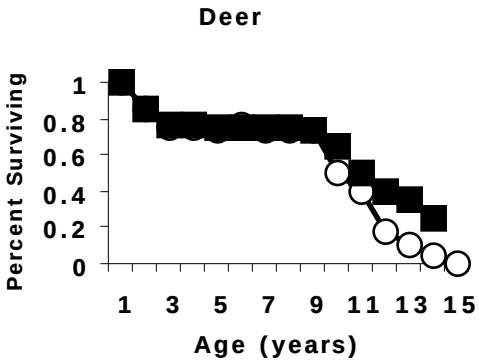
4) Physiological – organisms need energy for growth and reproduction. There is a limited amount of energy that can be collected, so

II) Evolution of Aging and Death

A) Senescence – a late-life decline in an individuals fertility and probability of survival.



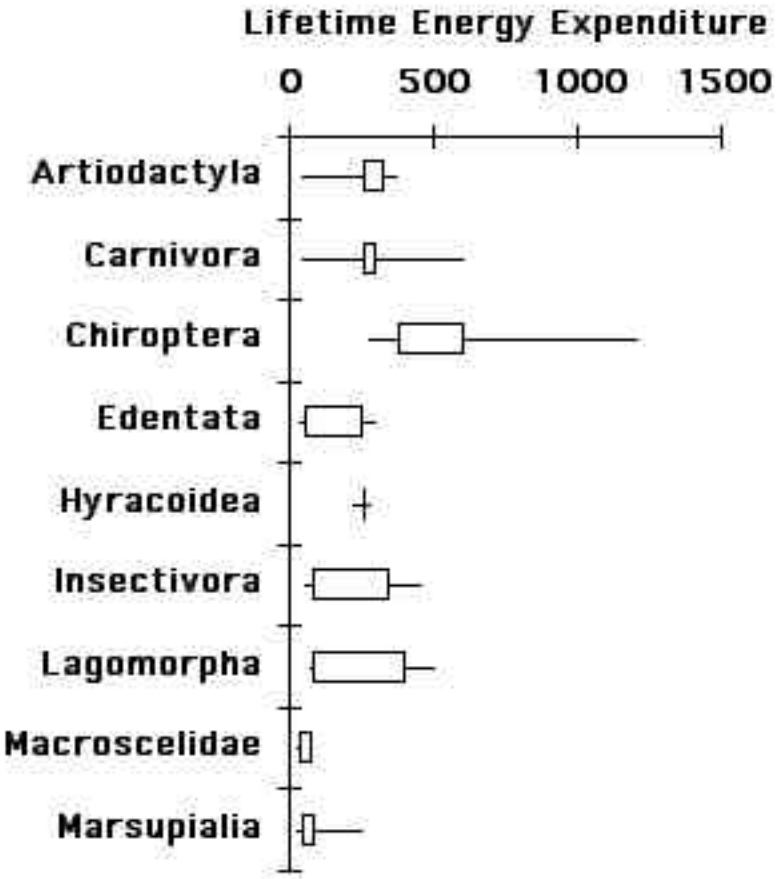




B) Aging reduces an individual's fitness so natural selection should favor genotypes that don't age.

C) Rate-of-Living Theory for Aging

1) Aging is caused by irreparable damage to cells and tissues accumulating over time and therefore should be correlated with metabolic rate.



2) Past, strong, directional natural selection has resulted in an absence of variation for life span and therefore

a) experiments with fruit flies indicate that life span can be extended through artificial selection

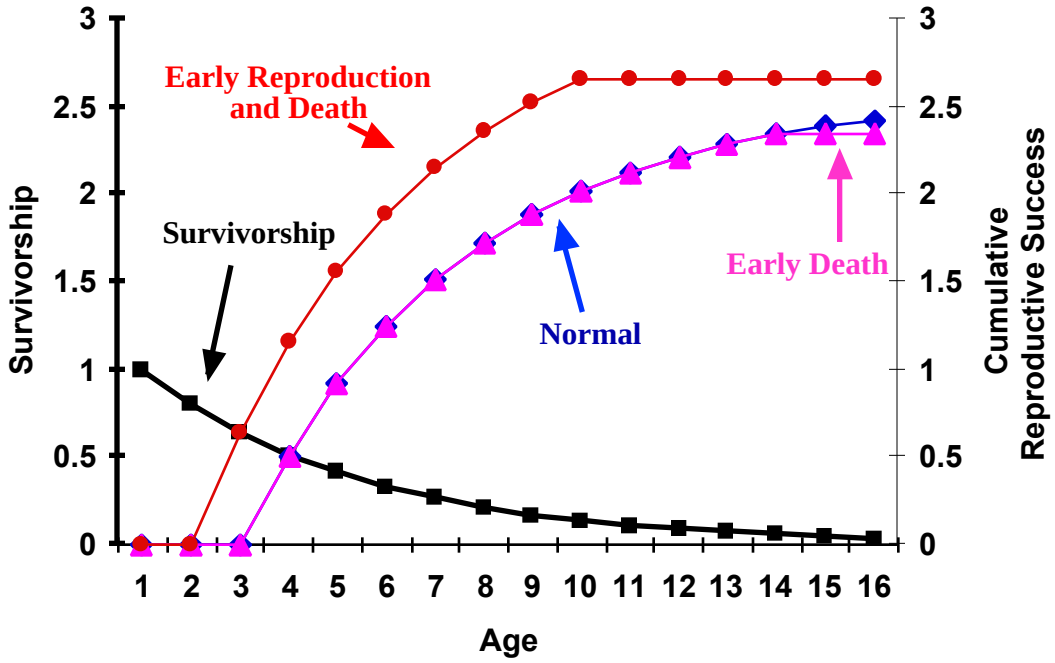
3) Loss of telomeres of chromosomes and tradeoff between controlled cell growth and length of cell life.

D) The Evolutionary Theory of Aging

1) Aging is caused not by accumulation of damage but failure to repair it completely.

a) alleles causing aging are only mildly deleterious and selection late in life is very weak due to only slight difference in fitness

b) there are tradeoffs between repair and reproduction



III) Evolution of Age at Reproduction

A) Advantages and disadvantages to early reproduction

1) Advantage: Increases lifetime reproductive success

2) Disadvantage: in experience may produce low quality offspring. Early reproduction may reduce later reproduction. Early reproduction may shorten lifespan. Usually smaller body size and therefore less able to produce as many or as large or as high quality offspring.

B) Iteroparity – reproduce repeatedly throughout life

1) juvenile mortality is high

2) adult mortality is low – low risk to waiting

3) population growth rate is low – plenty of resources available

4) probability of finding a mate is high

D) Semelparity – reproduce only once

1) juvenile mortality is low

2) adult mortality is high

3) population growth rate is high

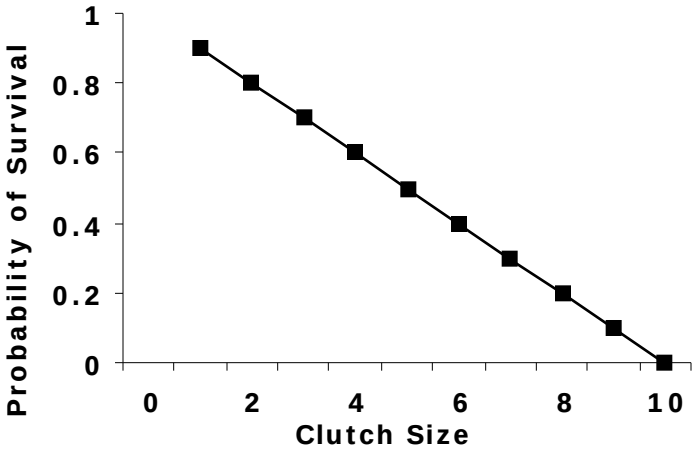
4) probability of finding a mate is low

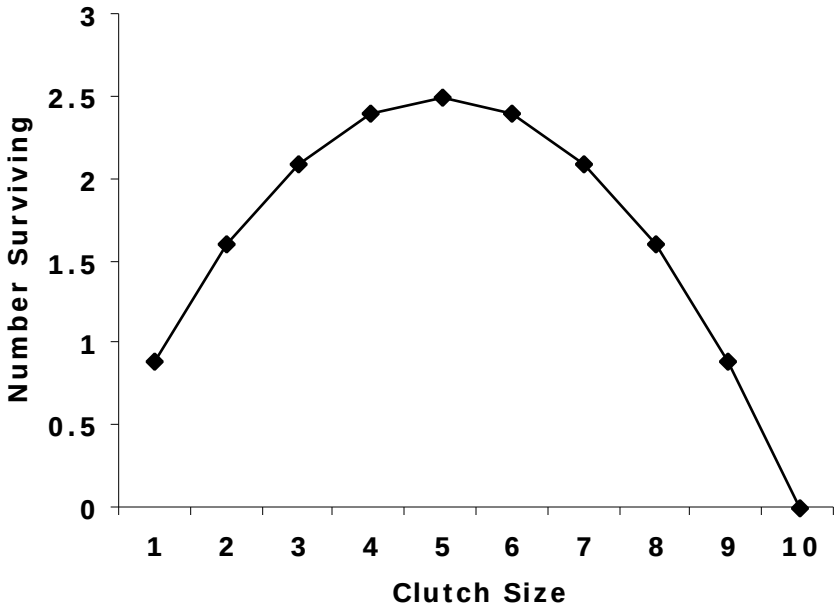
IV) Evolution of the Number and Size of Offspring

The ability to produce a large number of large offspring is not possible given the tradeoff between reproduction and growth and limited resources.

A) Number of Offspring – Lacks Hypothesis: selection will produce the clutch size that results in the largest number of offspring surviving.

1) Limitations to resources results in a negative correlation between survivorship and the number of offspring.





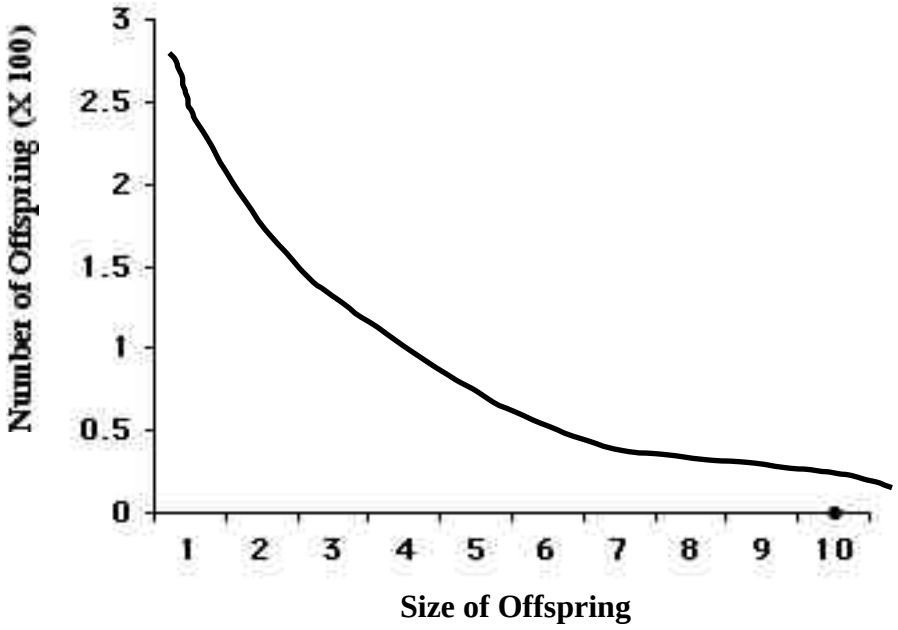
2) Limitations to Lack's hypothesis

a) assumes there is no tradeoff between current adult reproductive success and future

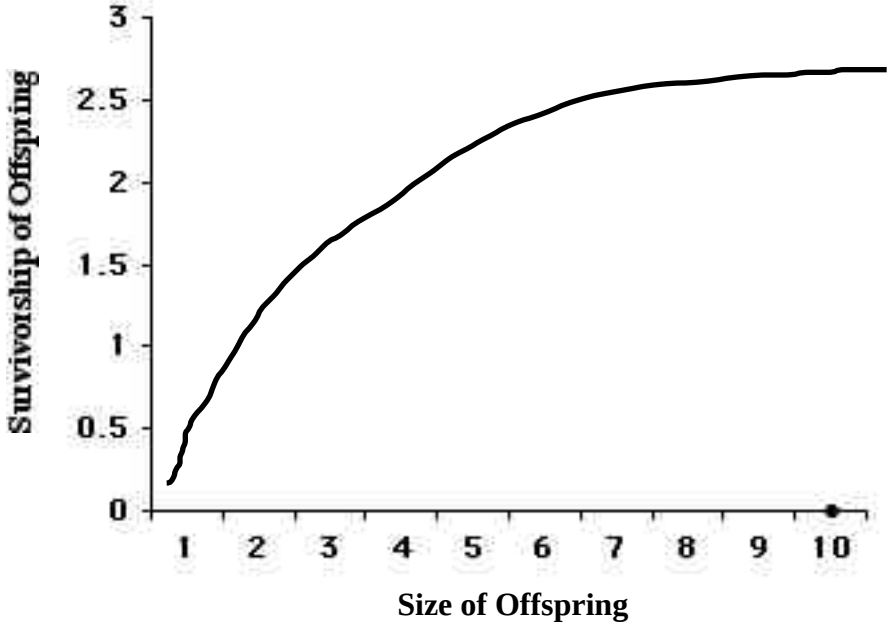
b) assumes there is no correlation (negative) between clutch size offspring experiences and offspring reproductive success.

B) Size of Offspring

1) Size and number – in general, total volume of zygotes is constant per species.



2) Size and survivorship – in general, it is assumed that larger offspring survive better. This relationship is not linear.



V) Conflict of Interest Between Life Histories

Sexual reproduction itself is a life history strategy. Within this strategy there can be a conflict of interest. As with sexual selection, asymmetry among the sexes can result in sex specific modifications.

A) Genetic Conflict Between Mates

1) Conflict:

a) In many organisms there is multiple paternity (i.e., several males father a single brood)(same basic thing happens even when single offspring are sequentially fathered by different males).

b) Females are equally related to all of the offspring.

c) Any one father is only related to the offspring for which he was the father (and unrelated to the others).

2) Strategy:

a) Females invest equally in all offspring

b) Males try to get female to invest preferentially in their offspring at the expense of the others

c) Females try to block male's attempts to bias investment

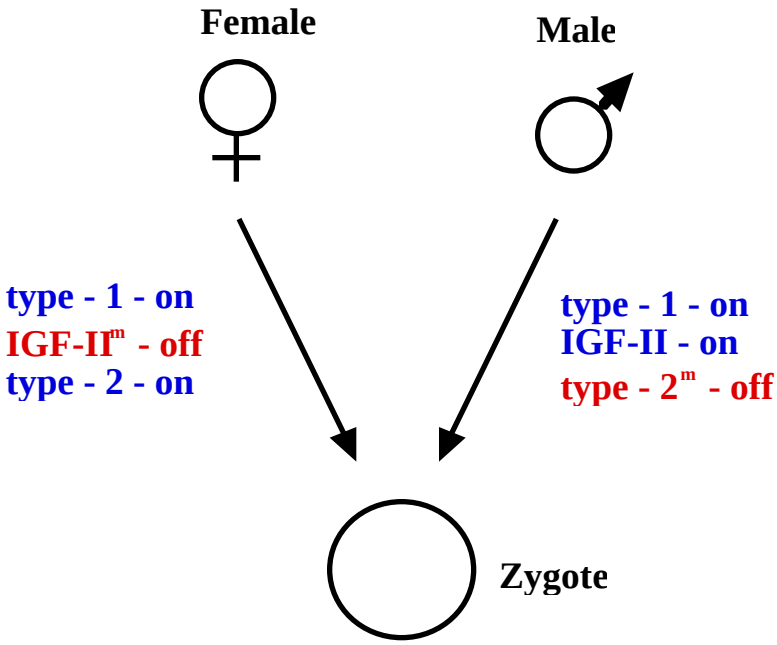
3) Example – Genomic Imprinting and Insulin-like Growth Factor II (IGF-II)

a) Genomic imprinting is a sex specific pattern of DNA methylation that is negatively related to gene expression in the zygote (methylation = no expression).

b) Both males and females methylate their DNA but differently (i.e., in the zygote some male genes are "off" and only the female alleles are expressed and visa versa).

c) IGF-II stimulates cell growth by binding to the "type – 1" receptor on the cell surface

d) A second receptor, "type – 2" also binds IGF-II but DOES NOT stimulate cell growth.



e) Natural selection through males will select for over expressing IGF-II. Less likely to select for females with underexpressing IGF-II since they will want their son's also to do well. Type – 1 receptor is essential for life and is unlikely to be involved. Type – 2 is similar, but there is selection for sex specific expression as a mitigating force.

B) Physiological Conflict Between Mates – Sexual Coevolution

Asymmetry between the sexes can result in sexual selection favoring adaptations that arise in one sex that are detrimental to the other.

1) Conflict:

a) females mate with multiple males therefore, male – male competition for mating.

2) Strategy (chase-away sexual selection):

a) seminal fluid evolves to influence female behavior (tendency to multiple mate, egg-laying rate)

b) independently, however, the seminal fluid is harmful to females.

c) females evolve to be unaffected by seminal fluid

d) males evolve to have stronger seminal fluid

VI) Life History in a Broader Evolutionary Context

A) What maintains genetic variation in life history traits?

Given that life history traits are very closely (i.e., directly) tied to reproductive success, they should be held fairly close to the fitness maximum.

e.g., five genes contribute to the number of offspring that an individual can have. At each locus, there are two alleles – a "0" allele and a "1" allele. Each 0 allele adds nothing to fitness. Each 1 allele adds "one unit" (i.e., 1/10th of fitness – 5 genes, two alleles each maximum absolute fitness is 10 time that of minimum).

	Locus					
	1	2	3	4	5	Relative Fitness
Genotype	00	00	00	00	00	0.0
	11	11	11	11	11	1.0
	11	01	11	00	01	0.6
	01	01	00	01	11	0.5

Natural selection should, over time, fix the population for the 1 allele at all loci – i.e., no genetic variation

a) heritability is lowest for life history traits as opposed to other traits (i.e., behavioral, physiological, or morphological)

b) nonetheless, heritability is not zero for life history traits

i) heterozygote advantage, frequency dependent selection, genotype-environment interactions (including tradeoffs and inter sex conflict)

B) Evolution of novel life history traits – that these are so closely related to fitness means that new, novel life history strategies can evolve and sometime very quickly.

C) Life history traits are not necessarily optimal – can lack necessary variation, time or have fundamental limits.