ECOLOGY:

The relationship between organisms and their environment

The relationship between organisms and other organisms

The "Environment" is a general term referring to but not limited to:

- Topography
- Climate
- Chemistry of air, water, and soil
- Photoperiod
- Sympatric organisms of the same species
- Sympatric organisms of different species

Three kinds of ecology:

Autecology:
interaction between a single organism and its environment

Population ecology:
interaction between conspecifics in the same population

Community ecology:
interaction between different species in a local ecosystem

Life history: the unique series and timing of events from an organism's birth through the end of its reproductive life, including:

- Feeding
- Growth
- Dispersal
- Mating
- Production of independent offspring
- Vital interactions with other organisms

The life history of any given species usually maximizes fitness, and evolves under the influence of environmental conditions and constraints, including but not limited to:

- Habitat
- Climate
- Air/water/soil chemistry
- Available resources
- Predators and/or prey
- Parasites and/or hosts
- Daily, seasonal, and/or annual cycles

Variation in life histories may result from genetic variation…

..or it may result from **phenotypic plasticity:** the ability for a single genotype to produce several different phenotypes under the influence of environmental conditions

Plants that are shorter at high altitudes than at low altitudes

Rocky shore marine snails have thicker shells where water turbulence is higher

Some insects take on the colors of the foods they eat

Both biology and life history determine where an organism can live

Example: Evergreen trees (conifers) are more tolerant to cold and frost than deciduous trees (most angiosperms).

Therefore, evergreen conifers tend to live at higher altitudes than deciduous trees: altitudinal zonation

And, evergreen conifers can live at higher latitudes than deciduous trees: latitudinal zonation

Zonation of intertidal organisms:

Marine organisms live higher or lower in the intertidal zone depending on their own particular needs and tolerances to temperature, salinity, light levels, food availability, and dessication

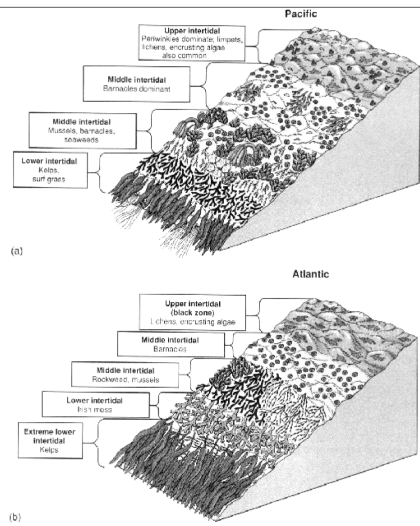
Upper intertidal:
snails, green algae

Upper-mid intertidal:
barnacles

Lower-mid intertidal:
mussels, brown algae

Lower intertidal:
brown and red algae

Subtidal:
red algae, echinoderms



Life history evolution

Consider reproduction. What’s the difference between bristlecone pine and Pacific salmon?

Life history evolution

Bristlecone pine
Reproduce many times during 1000+ year lifetime

Pacific salmon
Spawn once, then die

	Gulls	**Ducks**
Body	Shorter necks Longer legs Longer wings Hooked bill Webbed feet	Longer necks Shorter legs Shorter wings Flat bill Webbed feet
Diet	Mainly scavengers some mollusks, fish	Mainly vegetarian some mollusks, fish
Habitat	Seashores	Mainly freshwater
Clutch Size	Usually 4	Up to 12
Plumage	Sexes identical	Males are flashier
Nesting	In large colonies	Individually
Juveniles	Are fed by parents Take years to mature	Feed themselves Mature more rapidly

What can selection act on?

$l(x)$ Probability of surviving to age x

$m(x)$ Fecundity at age x

What does selection favor?

Roughly speaking, natural selection favors leaving the maximum number of surviving offspring

= maximum number of copies of genes left to the next generation

Expressing reproductive strategies in "Life tables"

Pacific salmon

Age, x	$l(x)$	$m(x)$
1	0.01	0
2	0.001	0
3	0.0001	0
4	0.00001	100,000
5	0	0

Bristlecone pine

Age, x	$l(x)$	$m(x)$
100	0.0005	1,000
200	0.0004	1,000
300	0.0003	1,000
400	0.0002	1,000
…	…	…

Lifetime reproductive success for a genotype

LRS = Expected number of offspring produced over the lifespan (year by year)

$= l(1)\ m(1) + l(2)\ m(2) + l(3)\ m(3) + \ldots$

Lifetime reproductive success for a genotype

$$\text{LRS} = l(1)\ m(1) + l(2)\ m(2) + l(3)\ m(3) + \ldots$$

Age, x	$l(x)$	$m(x)$	$l(x)\ m(x)$
1	0.9	0	0
2	0.5	1	0.5
3	0.1	2	0.2
4	0.05	10	0.5
5	0	0	0
		LRS	1.2

So, what prevents infinite LRS from evolving?

Age, *x*	*l*(*x*)	*m*(*x*)
1	1.0	∞
2	1.0	∞
3	1.0	∞
4	1.0	∞
…	…	…

1) Deleterious mutations
2) Tradeoffs

Different deleterious mutations have their effects at different ages

Hemophilia:
Often kills before puberty

Huntington's disease:
Onset is in 30s or 40s

Mutations that kill late in life are more weakly selected against than those that kill early

Age, *x*	*l*(*x*)	*m*(*x*)
1	0.5	1
2	0.25	2
3	0.1	3

LRS = 1.3

Mutations that kill late in life are more weakly selected against than those that kill early

Age, *x*	*l*(*x*)	*m*(*x*)
1	0.5	1
2	0.25	2
3	0.1	3

LRS = 1.3

Age, *x*	*l*(*x*)	*m*(*x*)
1	0.5	1
2	0.25	2
3	0	0

LRS = 1.0

A mutation that kills before age 3 reduces LRS by 0.3

Mutations that kill late in life are more weakly selected against than those that kill early

Age, x	$l(x)$	$m(x)$
1	0.5	1
2	0.25	2
3	0.1	3

LRS = 1.3

Age, x	$l(x)$	$m(x)$
1	0.5	1
2	0.25	2
3	0	0

LRS = 1.0

Age, x	$l(x)$	$m(x)$
1	0.5	1
2	0	0
3	0	0

LRS = 0.5

A mutation that kills before age 2 reduces LRS by 0.8

What prevents infinite LRS from evolving?

1) Deleterious mutations
2) Tradeoffs

Tradeoffs (1): To maximize fitness, should you:

Survive better or *reproduce more*?

Energy → **Survival** / Reproduction

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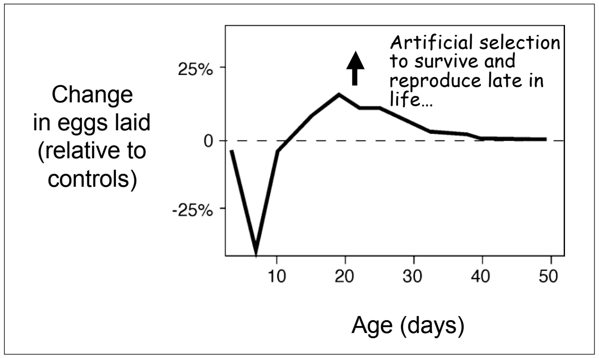
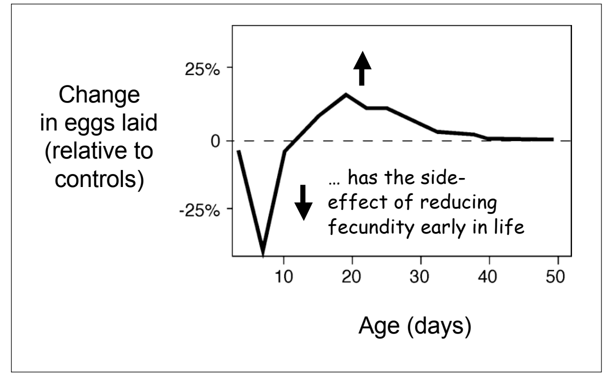
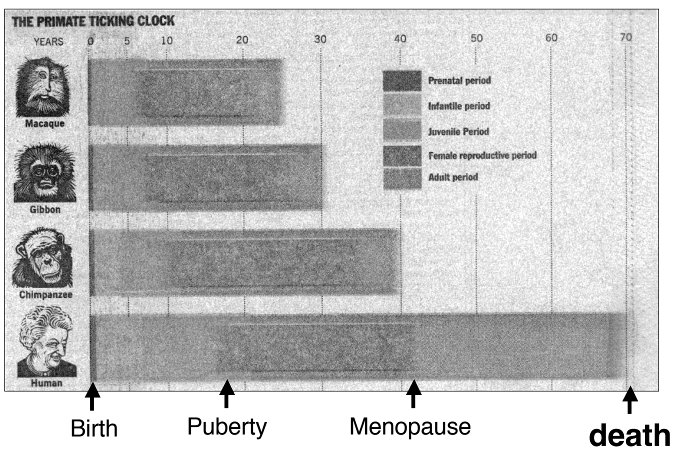
An example of tradeoffs: artificial selection experiment on *Drosophila*



An example of tradeoffs: artificial selection experiment on *Drosophila*

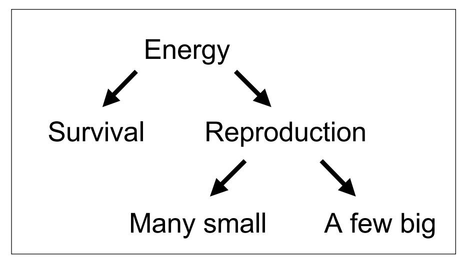


Human life history and menopause; Is fitness enhanced by "grandmothering"?



Tradeoffs (2):

Many small or a few big kids?



Example of lots of small kids

Oak tree

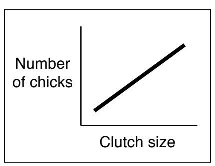
Can produce > 10^6 acorns,
each < 0.00001% of its mass

Example of a (very!) few big kids

Brown Kiwi

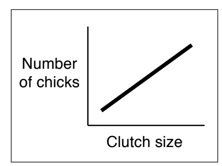
The single egg weighs about
1/3 of the mother's body weight

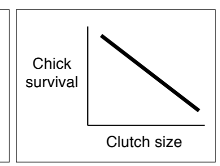
Tradeoff between fecundity and offspring survival



Given a certain amount of reproductive effort, making more offspring …

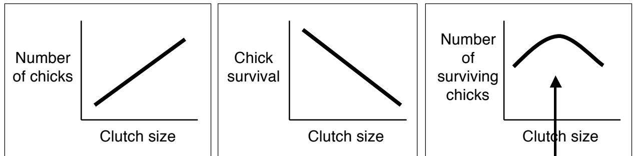
Tradeoff between fecundity and offspring survival



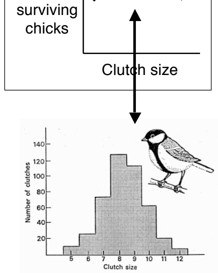


… produces smaller offspring that are less likely to live

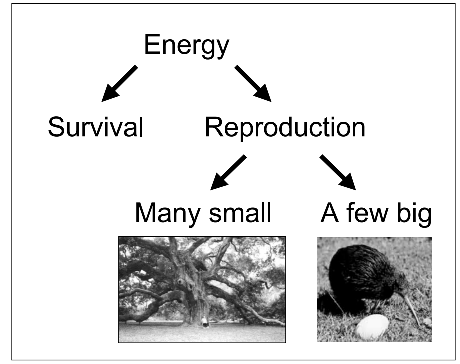
Tradeoff between fecundity and offspring survival



Natural selection then favors maximizing the number of surviving offspring



Tradeoffs



<u>A population is a contiguous group of individuals of the same species</u>

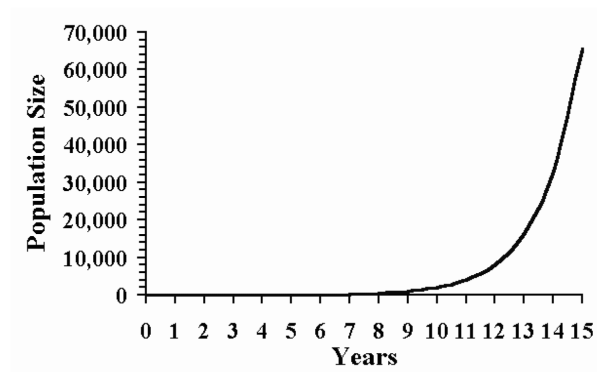
How do populations grow?

If nothing were to limit reproduction, and if all offspring were to survive, population growth would depend solely on the numbers of births and deaths (per individual) in the population

$$\frac{\Delta N}{\Delta T} = (b - d) N$$

<u>Exponential growth equation:</u> The change in the number of individuals (ΔN) after a certain time has elapsed (ΔT) is equal to the number of births per individual minus the number of deaths per individual (b - d) , times the current population size (N).

Thus, populations grow when $b > d$, and shrink when $b < d$, and the net change between generations depends on the population size, N.



An example of exponential population growth

Can populations grow exponentially forever?
- Consider the effect of population size

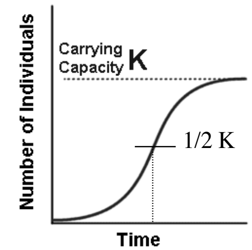
The rate of increase **r** (essentially equal to b - d) is limited by the carrying capacity **K** of the environment

So that

$$\frac{\Delta N}{\Delta T} = r\left(\frac{K - N}{K}\right) N$$

Logistic growth equation: the change in the number of individuals (ΔN) after a certain time has elapsed (ΔT) is equal to the (maximum) rate of increase (r), times the carrying capacity limit (K-N)/K, times the number of individuals currently in the population (N).

Thus, large populations grow more slowly when they are near their carrying capacity, as (K-N)/K will approach zero.



Logistic population growth:
The rate of growth speeds up as it approaches 1/2 K, and slows down as it exceeds 1/2 K

Thus, we can estimate the time at which population growth will reach its maximum rate.

1/2 K is also known as the maximum sustainable yield; this value can be used for problems such as determining how many game animals can be hunted or caught, or how much of a wild resource can be eaten or harvested, without endangering the population.

$$\frac{\Delta N}{\Delta T} = r\left(\frac{K - N}{K}\right) N$$

The life histories of organisms depend on population growth rates.

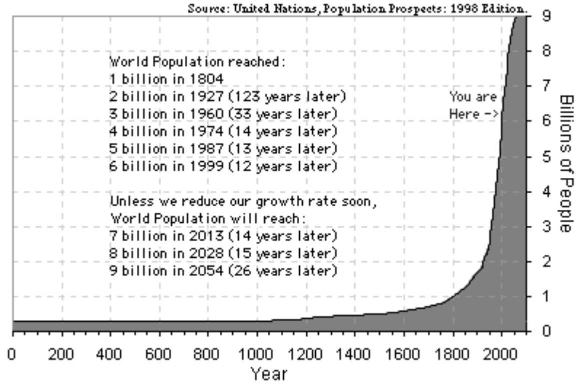
In less stable environments, K is rarely reached; a species would be selected to maximize fitness by maximizing its population growth rate, since resources are abundant. We call these r-selected species.

In more stable environments where K is reached and maintained, a species would be selected to maximize fitness by being more competitive and efficient in its environment, since resources are limited. We call these K-selected species.

r-selection (e.g. insects)	K-selection (e.g. large mammals)
Variable mortality rates	Constant mortality rates
Variable population size below K	Constant population size close to K
Competition variable and usually low	Competition constant and usually high
Rapid development	Slow development
Early reproduction	Delayed reproduction
Small body size	Large body size
Many offspring	Fewer offspring
Shorter lifespans	Longer lifespans
High productivity	High efficiency

What about ducks and gulls? Seashores are more stable environments than temperate inland habitats; thus, it is a reasonable hypothesis that gulls are more K-selected, while ducks are more r-selected.

	Gulls (K-selected)	Ducks (r-selected)
Body	Shorter necks Longer legs Longer wings Hooked bill Webbed feet	Longer necks Shorter legs Shorter wings Flat bill Webbed feet
Diet	Mainly scavengers some mollusks, fish	Mainly vegetarian some mollusks, fish
Habitat	Seashores	Mainly freshwater
Clutch Size	Usually 4	Up to 12
Plumage	Sexes identical	Males are flashier
Nesting	In large colonies	Individually
Juveniles	Are fed by parents Take years to mature	Feed themselves Mature more rapidly



Since the agricultural and industrial revolutions, human beings have undergone exponential population growth; this has largely been the result of food surpluses and advances in medicine that have reduced the death rate (and increased **r**). Humans have not yet reached the carrying capacity of Earth, but soon will.

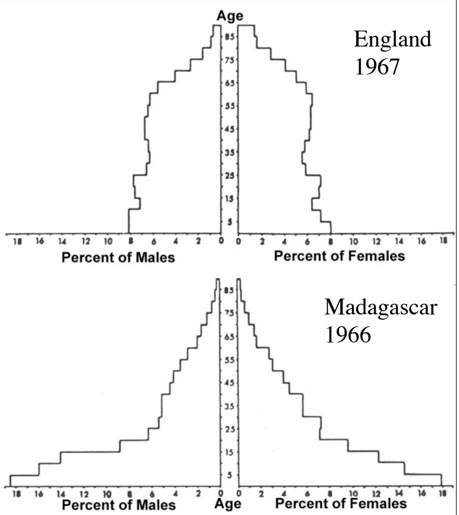
Demography

The N, r, and K of a population are closely related to mortality and survivorship, which also determine the age structure within a population.

Compare human population structures of England and Madagascar in the late 60's.

In England, birth and death rates are approximately equal, and the population is not expected to grow. All age classes are approximately equal in size (in number of individuals).

In Madagascar, the birth rate greatly exceeds the death rate. There is a large young class advancing towards reproductive age, and the population size will continue to go up.



Many density dependent factors regulate population sizes

Relationships between predators and prey;
Relationships between parasites (or pathogens) and their hosts
Relationships between codependent species (mutualism)

The sizes of predator (parasite) populations are regulated by the sizes of prey (host) populations; likewise, the sizes of prey (host) populations are regulated by the sizes of predator (parasite) populations.

Population sizes of predators and prey often fluctuate in coupled cycles as a result of this relationship.

Historical fluctuations in lynx and snowshoe hare populations.