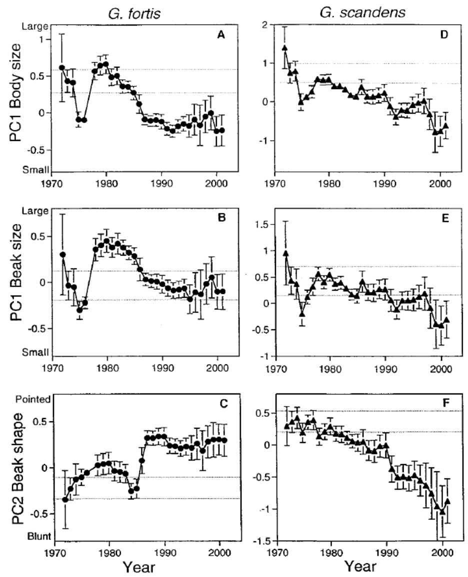
responses of quantitative traits to selection



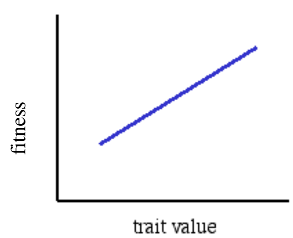
Grant and Grant 2002 Science 496:707

Directional Selection

one phenotypic extreme has higher fitness

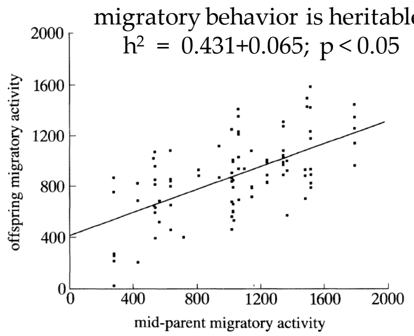
mean shifts towards one phenotypic extreme

variance declines



directional selection on migratory behavior in the blackcap warbler

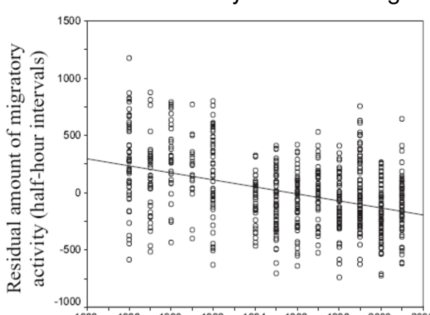
global change in temperature:
- earlier onset of spring
- delayed onset of autumn



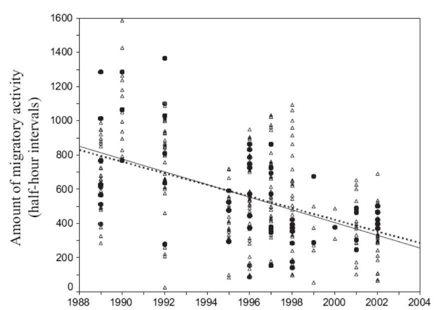
Pulido and Berthold 2010 PNAS 107:7341

migratory behavior has declined significantly in the past 23 years

birds collected each year as nestlings

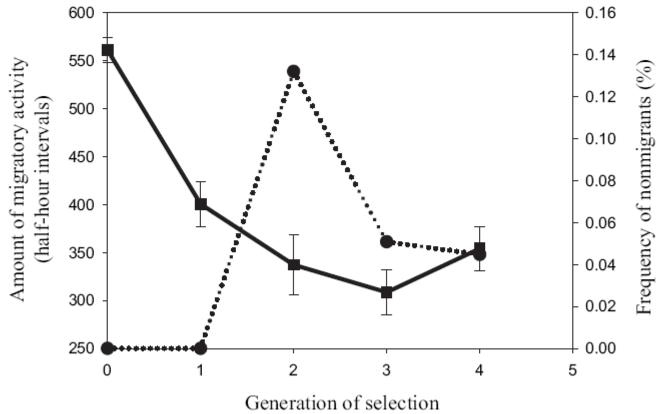


field collected parents and their aviary-reared offspring



Pulido and Berthold 2010 PNAS 107:7341

selection for reduced migratory activity produced significant changes in behavior



Pulido and Berthold 2010 PNAS 107:7341

how much does a population change in one generation of selection?

recall with a single gene,

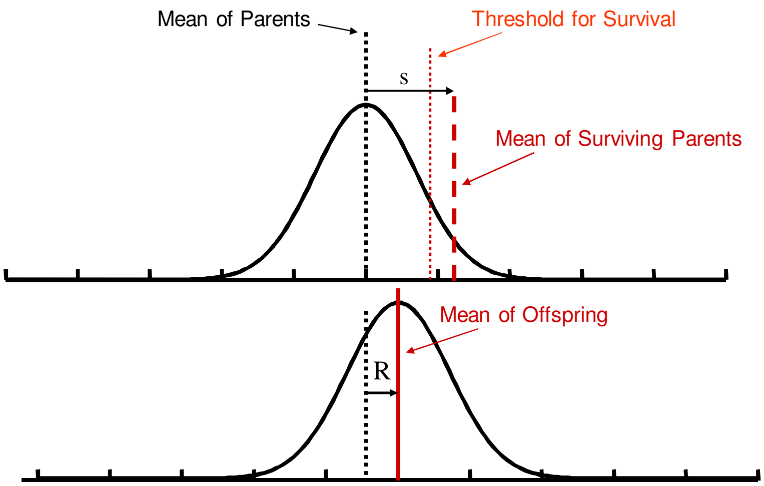
$$\Delta\text{pheno} = \Delta Q \dashrightarrow \Delta q = \frac{-sq^2(1+q)}{1-sq^2}$$

change in phenotype distribution = strength of selection, genetic variation

for a quantitative trait,

$R = h^2 s$ "breeder's equation"

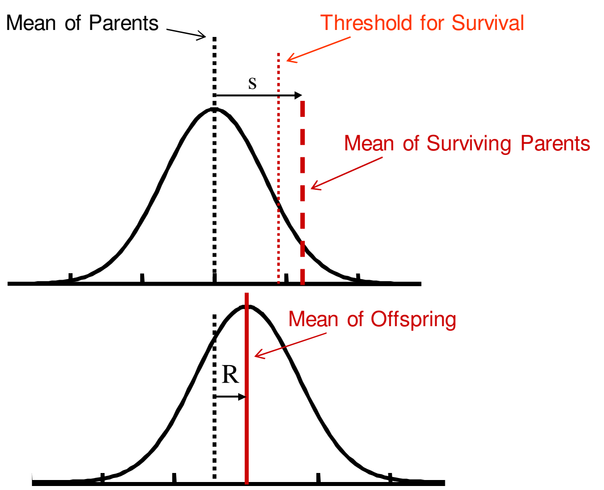
Response to selection = heritability x strength of selection



$$R = h^2 s$$ "breeder's equation"

ΔOffspring = h^2 ΔParents

predicting the response to selection



$$R = h^2 s$$ "breeder's equation"

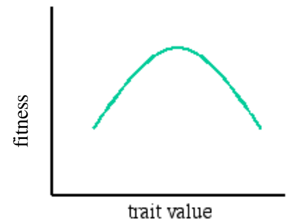
ΔOffspring = h^2 ΔParents

Stabilizing Selection

favors intermediate phenotypes

doesn't change the mean phenotype

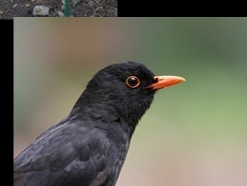
reduces variance



Stabilizing selection on bill color in the European Blackbird, *Turdus merula*

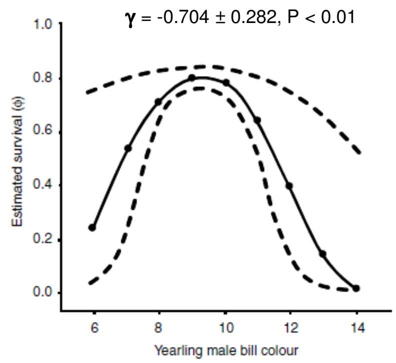
pale bill color

orange bill color



Gregoire et al 2004 J Evol Biol 17:1152

measured bill color in 55 ♂ blackbirds, monitored survival for 5 years



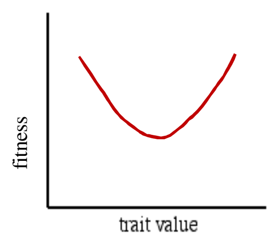
lower foraging ability
poor immunocompetence

outcompeted by more orange males for space or resources

costs of intraspecific competition, predation

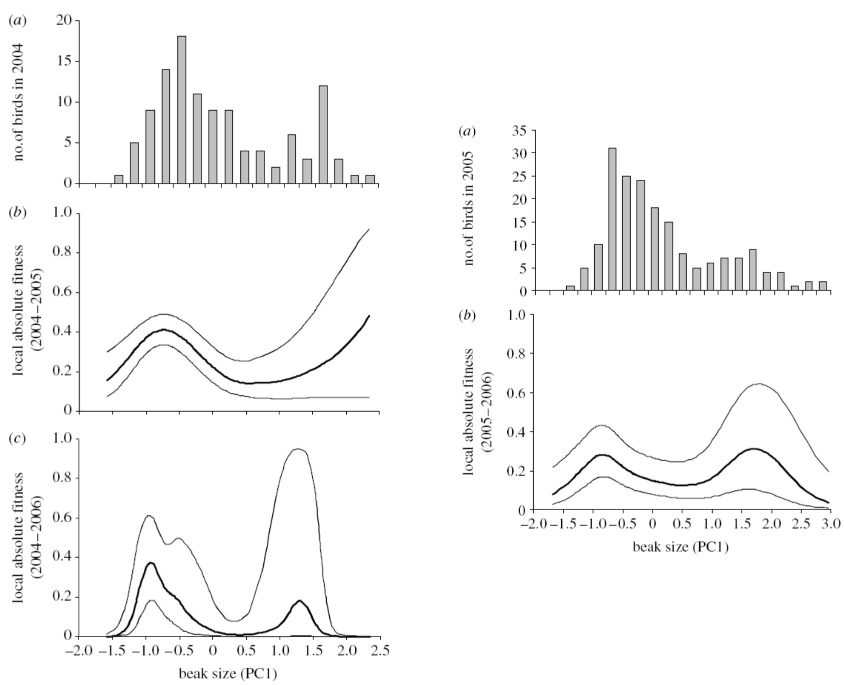
Disruptive Selection

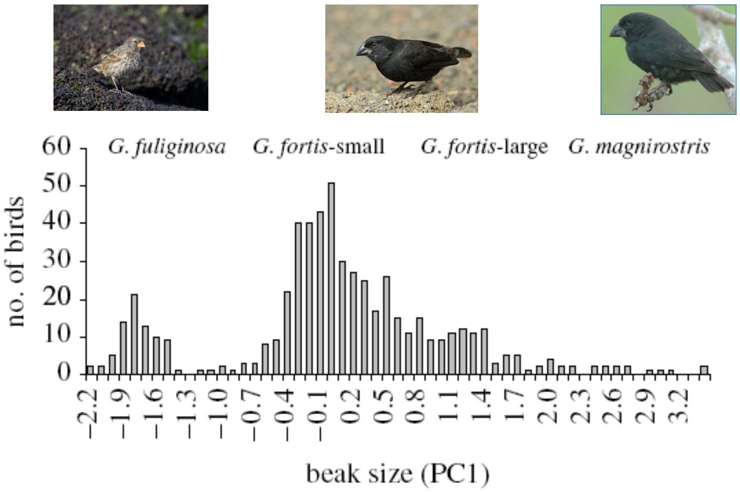
- favors the phenotypic extremes
- population mean may not change
- increases variance
- may lead to divergent populations*



Disruptive selection in the medium ground finches
of Santa Cruz Island

Hendry et al 2009 Proc Roy Soc B 276:753





What maintains additive genetic variance in fitness traits?

mutation-selection balance

variable selection

disruptive selection/frequency-dependent selection

non-equilibrium with respect to selection
(stabilizing, directional)

antagonistic pleiotropy/genetic correlations

Evolution of correlated characters

selection acts on individuals, not traits

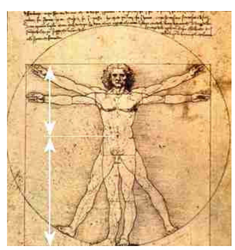
pleiotropy (one gene, many traits)
polygeny (many genes, one trait) → many loci, many traits

↓

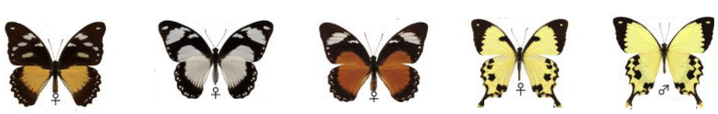
genetic correlations

Genetic correlations may arise from:

pleiotropy



linkage disequilibrium



Evolution of correlated characters

selection on any trait may be
- direct (changes due to phenotypic/genotypic variation in the trait)
- indirect (changes due to genetic covariation with other traits)

the magnitude and direction of direct selection may differ from overall selection because of indirect effects

a trait may change solely because of selection on some other trait
-- ***correlated response to selection***

a trait may fail to change (despite measurable selection) because of opposing selection on some other, correlated trait
--- ***constraints on trait evolution***

correlation as constraint: evolution in Soay sheep

light phenotype is homozygous recessive
(single replacement substitution changing G→T at coding position 869 in the tyrosinase-related protein 1 (TYRP1) gene

correlation as constraint: evolution in Soay sheep

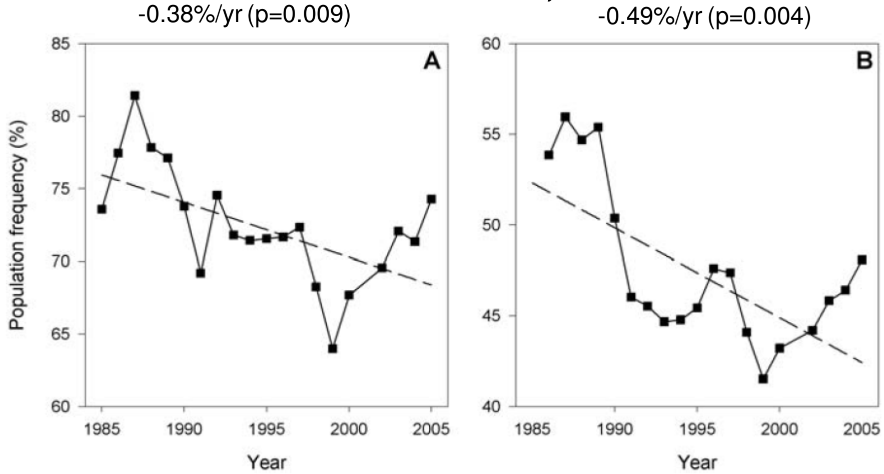
dark sheep are larger than light sheep

large sheep have higher survival and great reproductive success

predict: dark sheep should increase in the population

f(dark sheep) has declined -0.38%/yr (p=0.009)

f(dark allele) has declined -0.49%/yr (p=0.004)



Why are dark sheep declining in frequency?

1) the correlation between coat color and body size is a consequence of environmentally induced, rather than genetic, covariance between traits

- *selection on body size does not result in a parallel response for coat color*

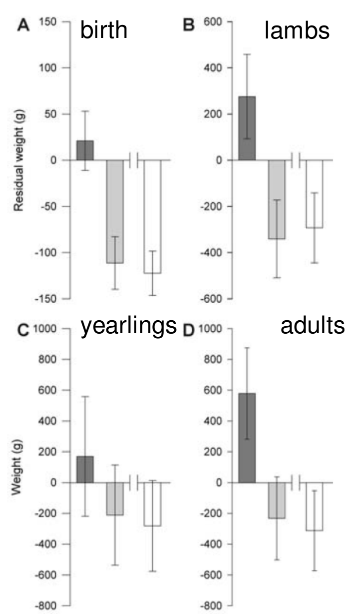
2) coat color and body size are genetically correlated, but there is also a negative genetic correlation between body size and other fitness related loci in the vicinity of the *TYRP1* gene

- *dark sheep are larger but less fit than light sheep*

homozygous dark sheep are significantly larger than light sheep

homozygous dark sheep are larger than heterozygous dark sheep, but the difference is not always significant

- *the association between color and body size is due to a genetic correlation, not an environmental correlation*



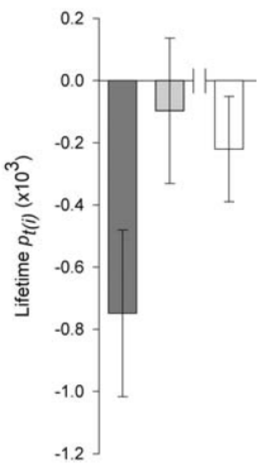
dark color is correlated with a gene that increases body size.

<u>but</u> also with a gene that lowers survival

• *no direct selection on coat color*

the fitness cost associated with dark color outweighs the benefits of being larger

• *evolution of coat color is constrained*



significant genetic association between TYRP1 and lifetime fitness [$F_{2,1336} = 4.03$, $p = 0.020$, $n = 1355$]

additive genetic variance (V_A) represents the heritable component of the phenotype

selection will change the genetic variation in a quantitative trait in a manner similar to one with simpler genetics

heritability can be estimated from breeding studies

heritability is a property of a population

traits may not evolve independently because of genetic correlations due to pleiotropy or linkage disequilibirum

a trait may change as a consequence of direct selection, or as a correlated response to selection on a different trait

a trait undergoing selection may fail to change because of a constraint operating through a genetically correlated character