Variation in natural populations

1) How much phenotypic variation is present in natural populations?

2) What is the genetic basis of continuous variation?

3) Genetic covariance

4) Genetic and non-genetic polymorphisms

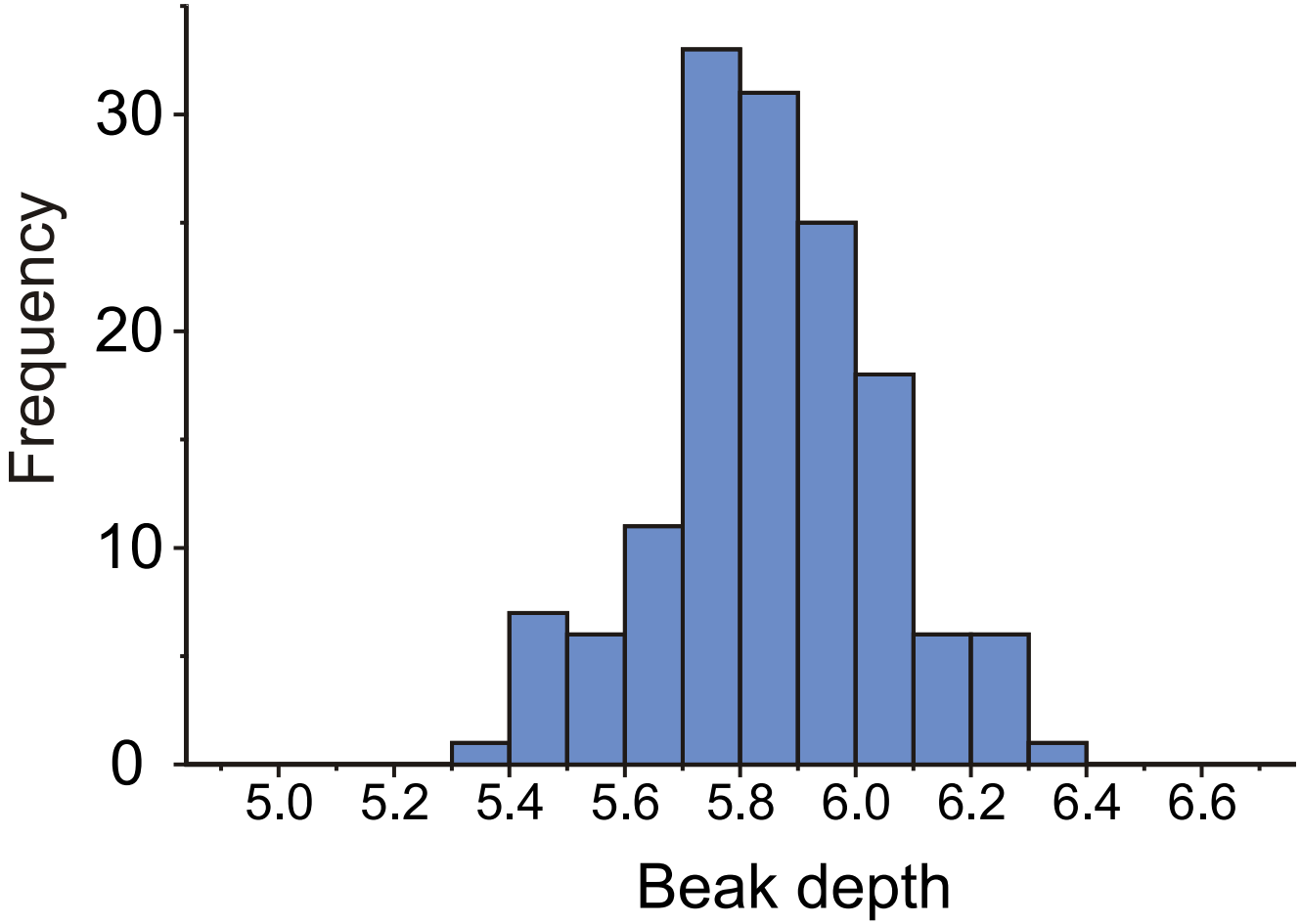
5) Supergenes in natural populations

6) What maintains genetic variation in natural populations?

7) Example exam questions

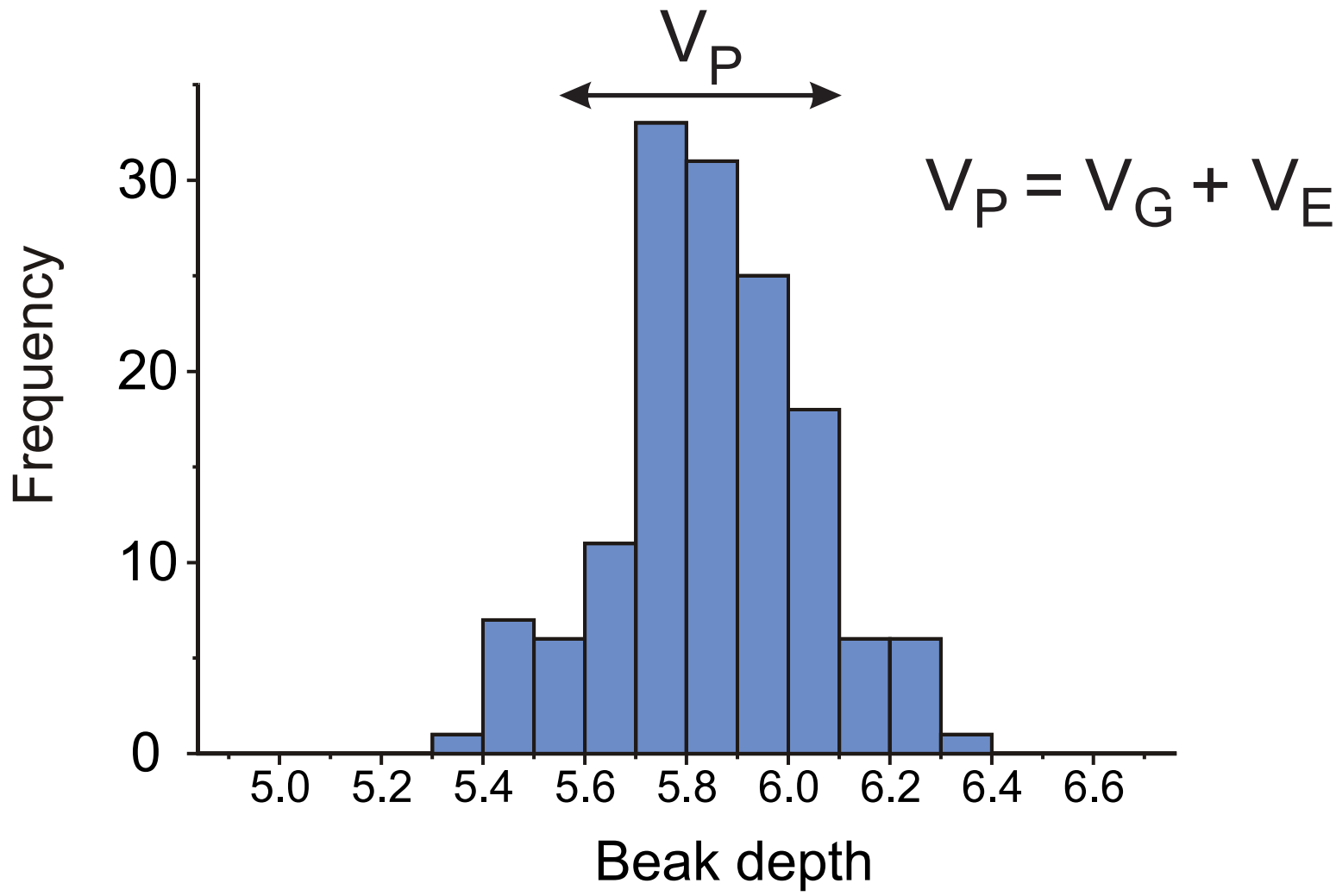
1) How much phenotypic variation is present?

Coefficient of variation $100(\sigma/\bar{x})$ is 2 to 4% for most birds
but is greater in many other organisms



2) What is the genetic basis of continuous variation?

Continuous phenotypic variance has two main components



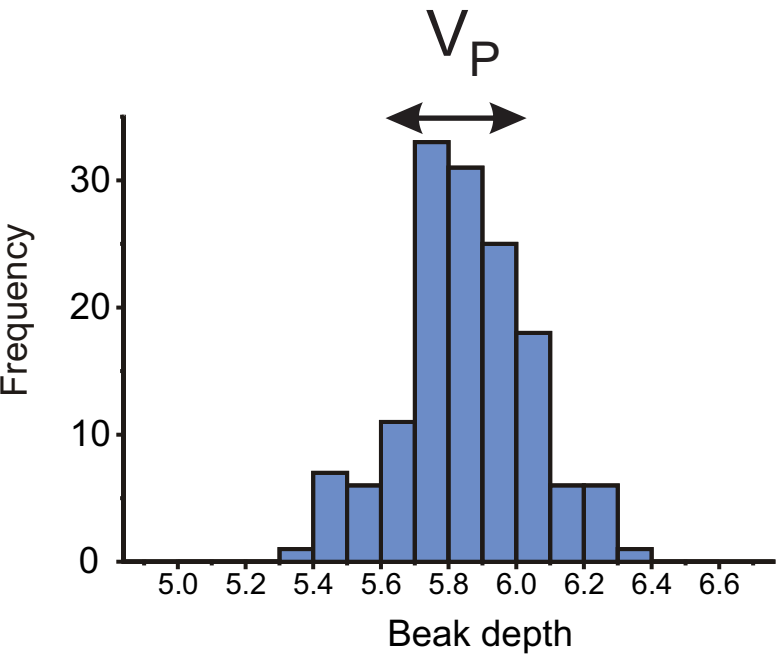
2) What is the genetic basis of continuous variation?

Quantitative genetic model of continuous variation

$$V_P = V_G + V_E$$

Total phenotypic variance among individuals in the population (measured directly)

"Environmental" variance, which means everything else: true environmental variance, but also developmental noise, non-additive genetic variance

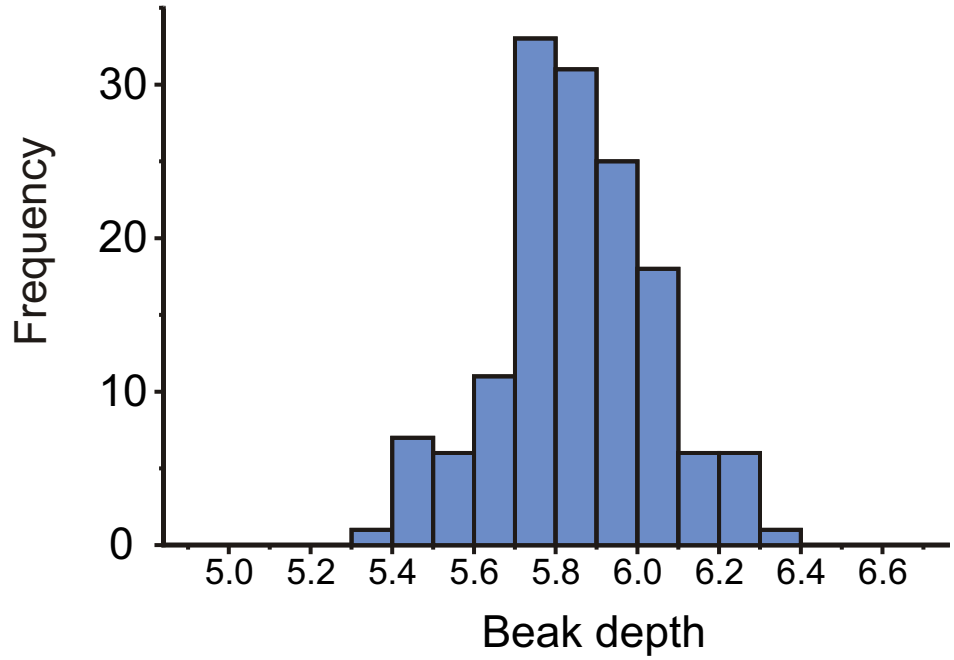


Additive genetic variance among individuals.
Additive = the genetic variance component determining the resemblance of offspring to their parents.

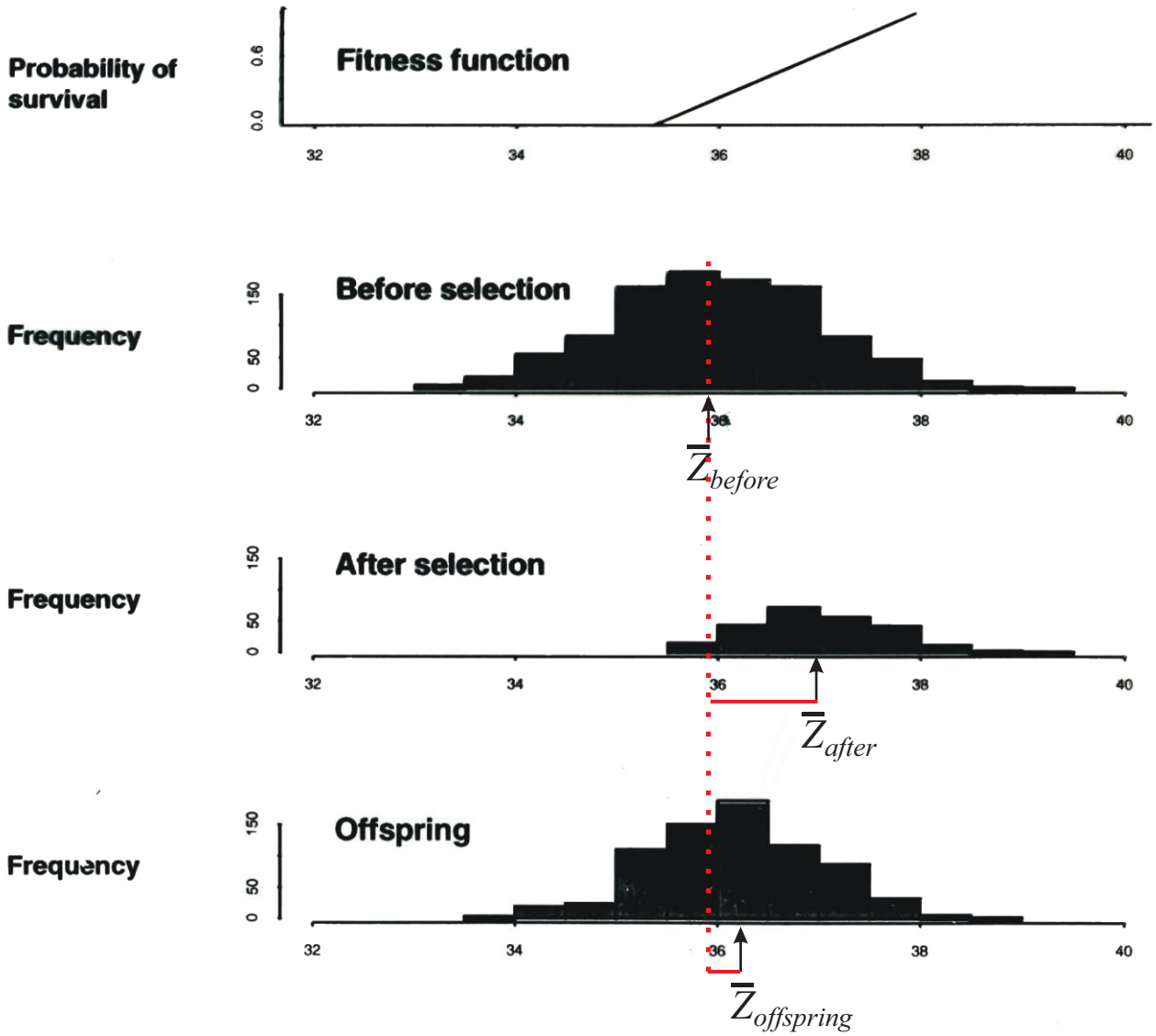
2) What is the genetic basis of continuous variation?

Heritability: the fraction of total phenotypic variance that is additive genetic

$$h^2 = \frac{V_G}{V_P}$$



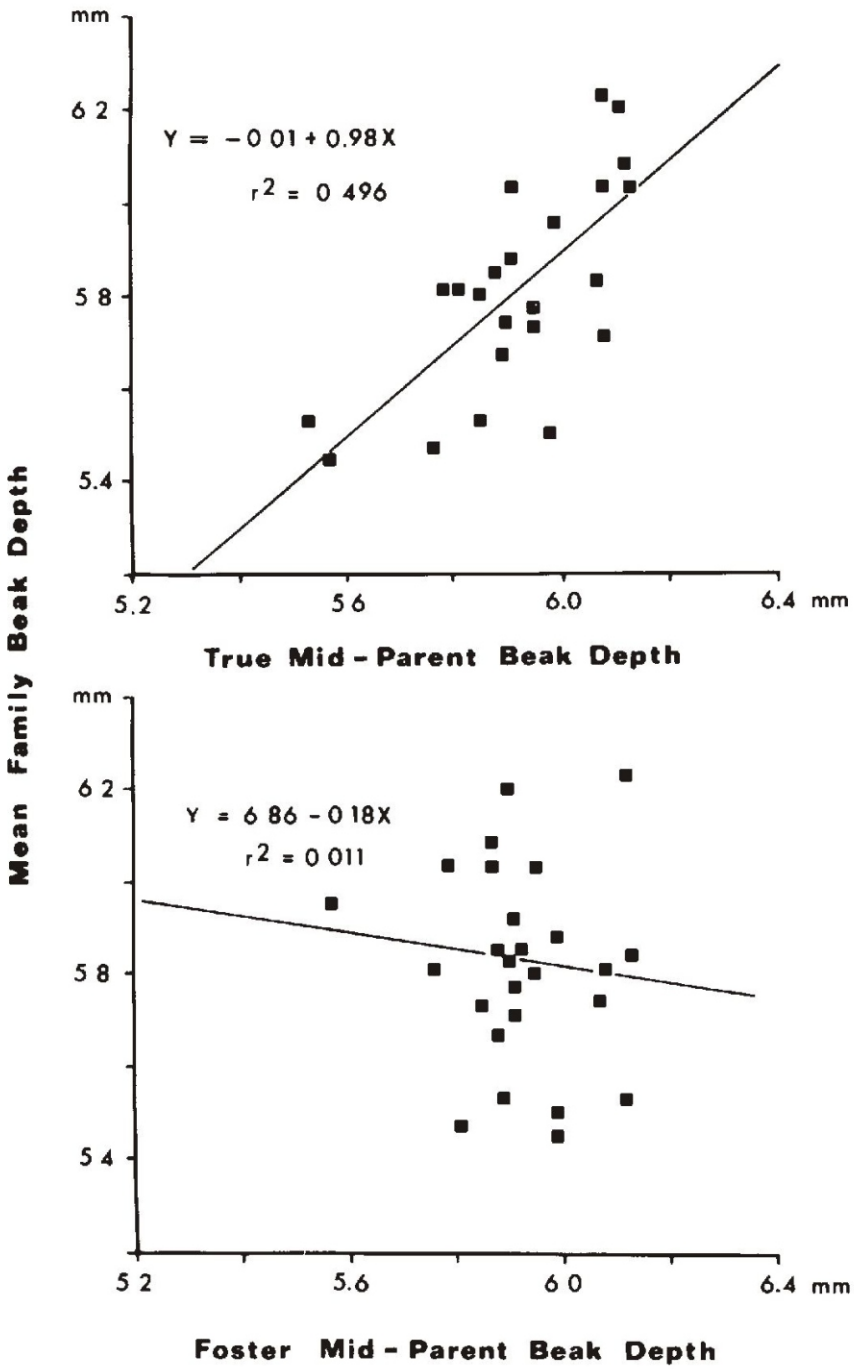
Recall: example of directional natural selection



$$S = \overline{Z}_{after} - \overline{Z}_{before} = 1$$

$$\Delta\overline{Z}_{offspring} = h^2 S = 0.2$$

Cross-fostering experiment on Mandarte Island song sparrows



Beak depths (mm) of offspring compared with the beak depth of their true parents and their foster parents.

"mid-parent" is the average of male and female parent measurements

Smith and Dhondt (1980) Evolution

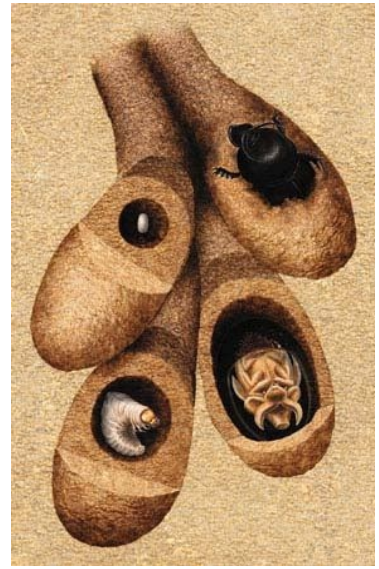
2) What is the genetic basis of continuous variation?

Example of a non-genetic source of variation

Maternal effects – the influence of maternal phenotype on the phenotypes of her offspring

Apparent "heritability" of daughters' pronotum width in *O.taurus*	h^2	SE
Heritability of offspring pronotum width estimated using resemblance to father	0.020	0.069
Heritability of offspring pronotum width estimated using resemblance to mother	0.279	0.186

"Dung beetles belonging to the genus Onthophagus *provision offspring before hatching. During reproduction, females remove portions of dung and pack them into the blind end of tunnels excavated beneath the dung pad. A single egg is deposited into an egg chamber, which is then sealed; one egg and its associated dung provision constitutes a brood mass and represents the entire resource base that is available to a larvae during development."*



Hunt and Simmons (2002) PNAS

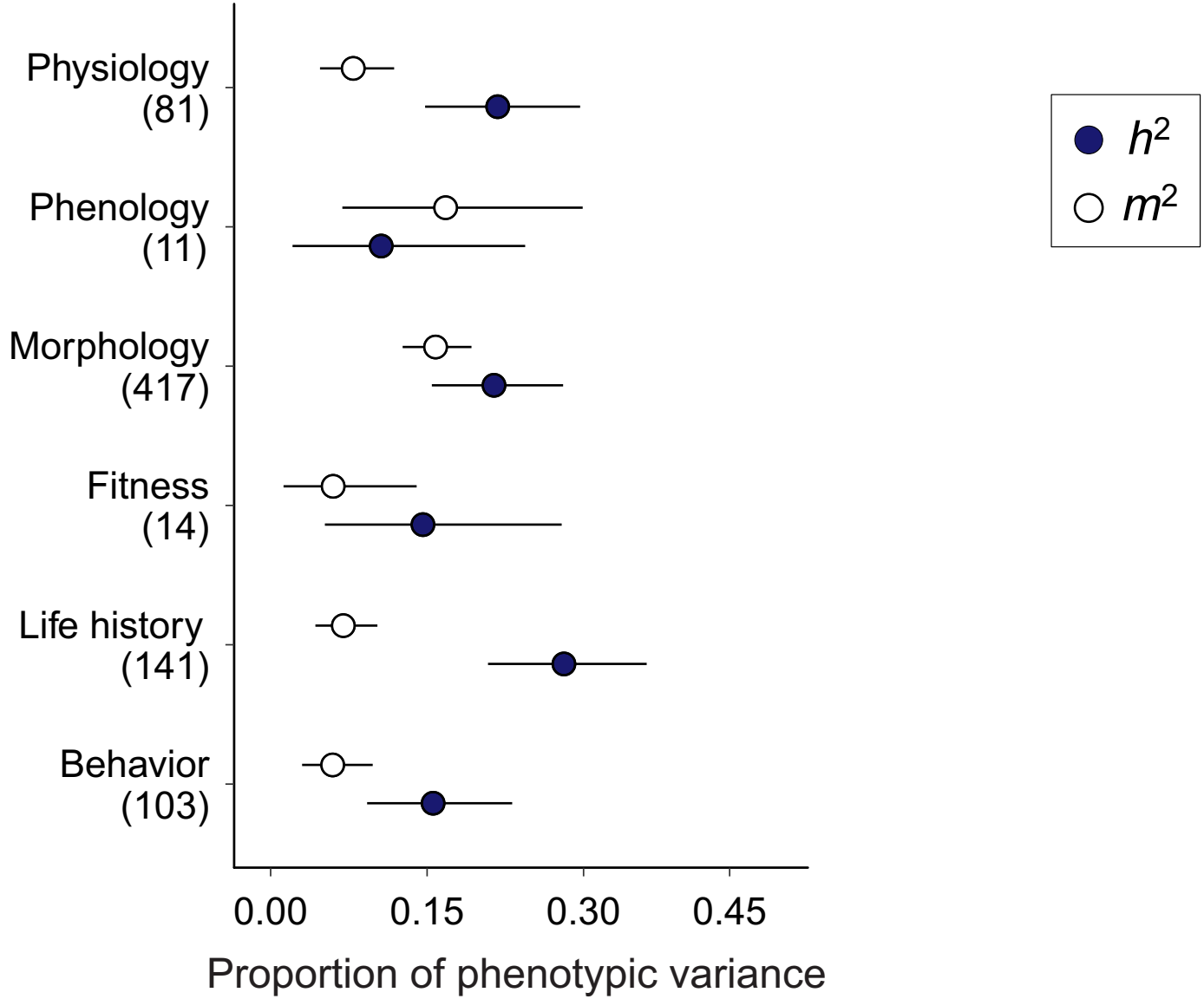
2) What is the genetic basis of continuous variation?

Most continuously-varying traits appear to be heritable

Meta-analysis of 770 estimates of h^2 and m^2 from 116 studies, 64 species.

Additive genetic effects accounted for an average of h^2=0.22 of the phenotypic variation (95% CI: 0.17–0.27).

Maternal effects accounted for 0.11 of all phenotypic variance (95% CI: 0.09–0.13).

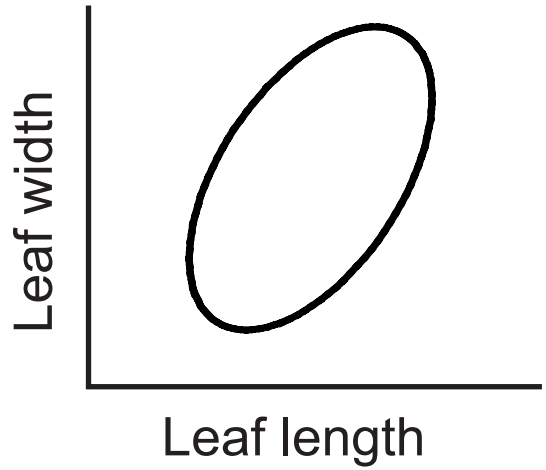


Moore et al (2019) *Ecology Letters*

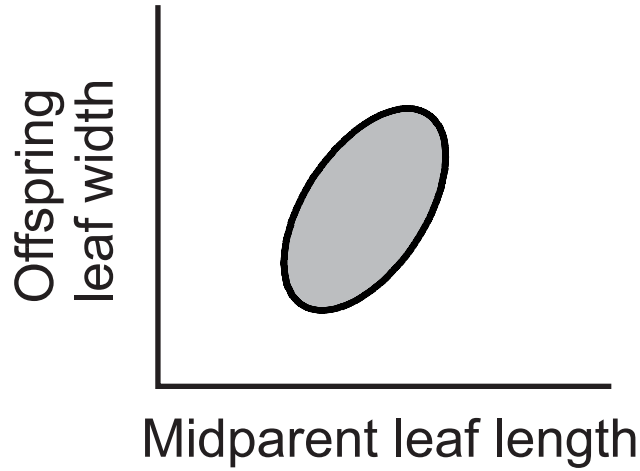
3) Genetic covariance between traits

Evolutionary significance of genetic covariance

Phenotypic covariance



Genetic covariance



wild radish

Main cause of genetic covariance is thought to be pleiotropy

Conner and Via (1993) Evolution

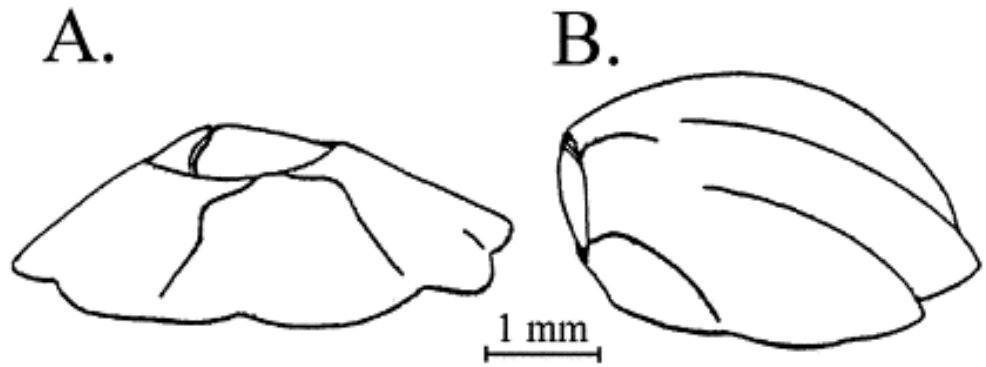
4) Genetic basis of polymorphisms

Polymorphism: discontinuous variation within a population

If individual herbivorous tadpoles of the spadefoot toad *Scaphiopus multiplicatus*, eat a fairy shrimp, they transform into a large carnivore and even a cannibal

Pfennig (1992) Evolution

Examples of mainly non-genetic polymorphisms

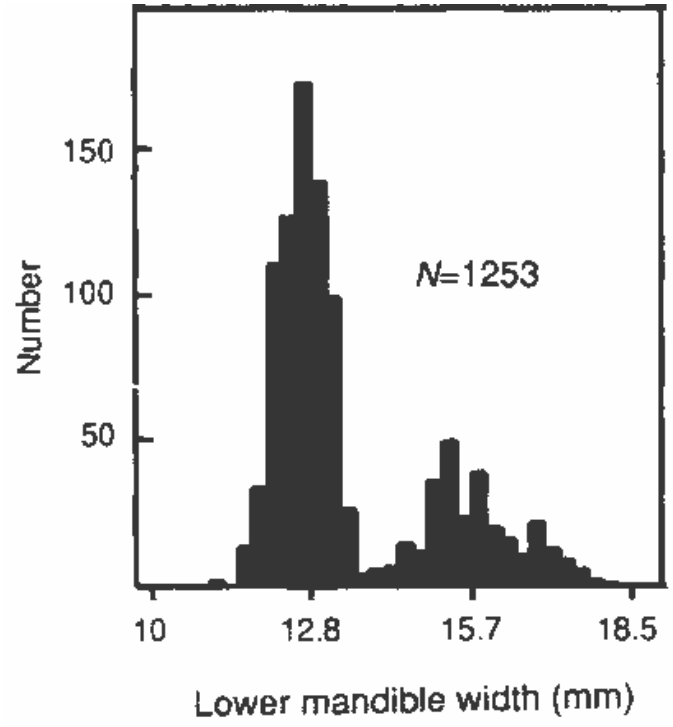


The two morphs of *Chthamalus anisopoma*
(A) The conical morph; (B) the bent morph

Lively (1986) Ecology

4) Genetic basis of polymorphisms

Examples of mainly genetic polymorphisms

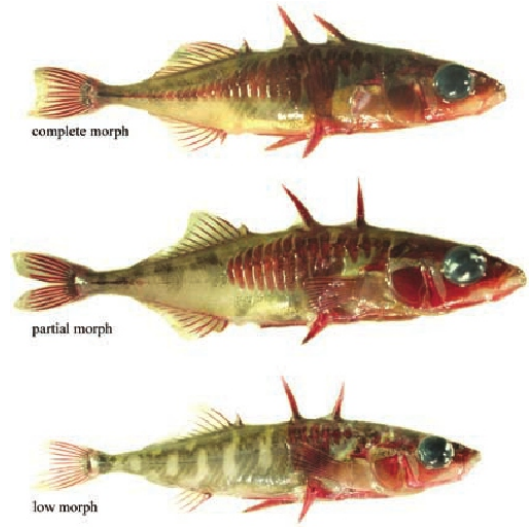


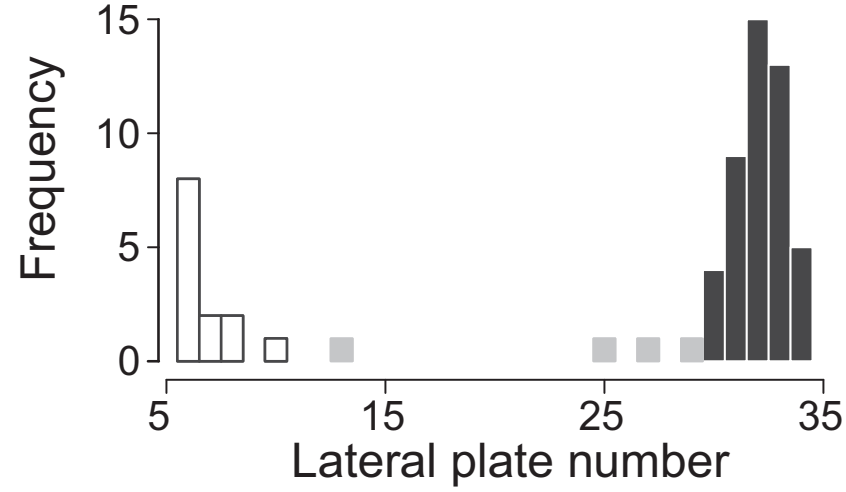
The black-bellied seedcracker exhibits a non-sex related polymorphism in bill size caused by a single locus having two alleles, “small” is dominant over “large” (gene not yet known).

Smith (1993) Nature

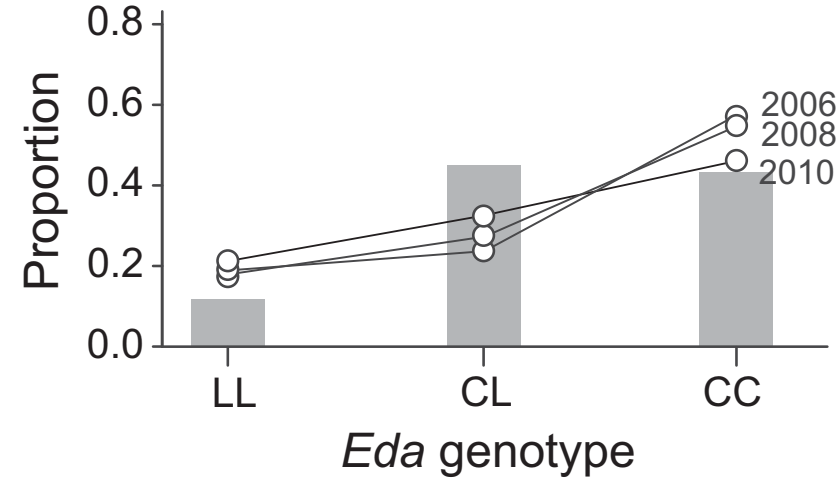
4) Genetic basis of polymorphisms

Examples of mainly genetic polymorphisms





The threespine stickleback in Kennedy Lake Vancouver Island, exhibits a polymorphism in bony lateral plates mainly determined by the gene *Ectodysplasin* (*Eda).*



Marchinko et al (2014) Current Biology

4) Supergenes in natural populations

Some complex phenotypic polymorphisms are determined by variation at a *supergene*: a group of linked genes inherited together

A supergene underlies a polymorphism in male ruffs with three morphs: dark “independents” white “satellites” and female mimicking “faeders” (left to right).

Pennisi et al (2017) Science (Photo by C. Küpper & D. Lank)

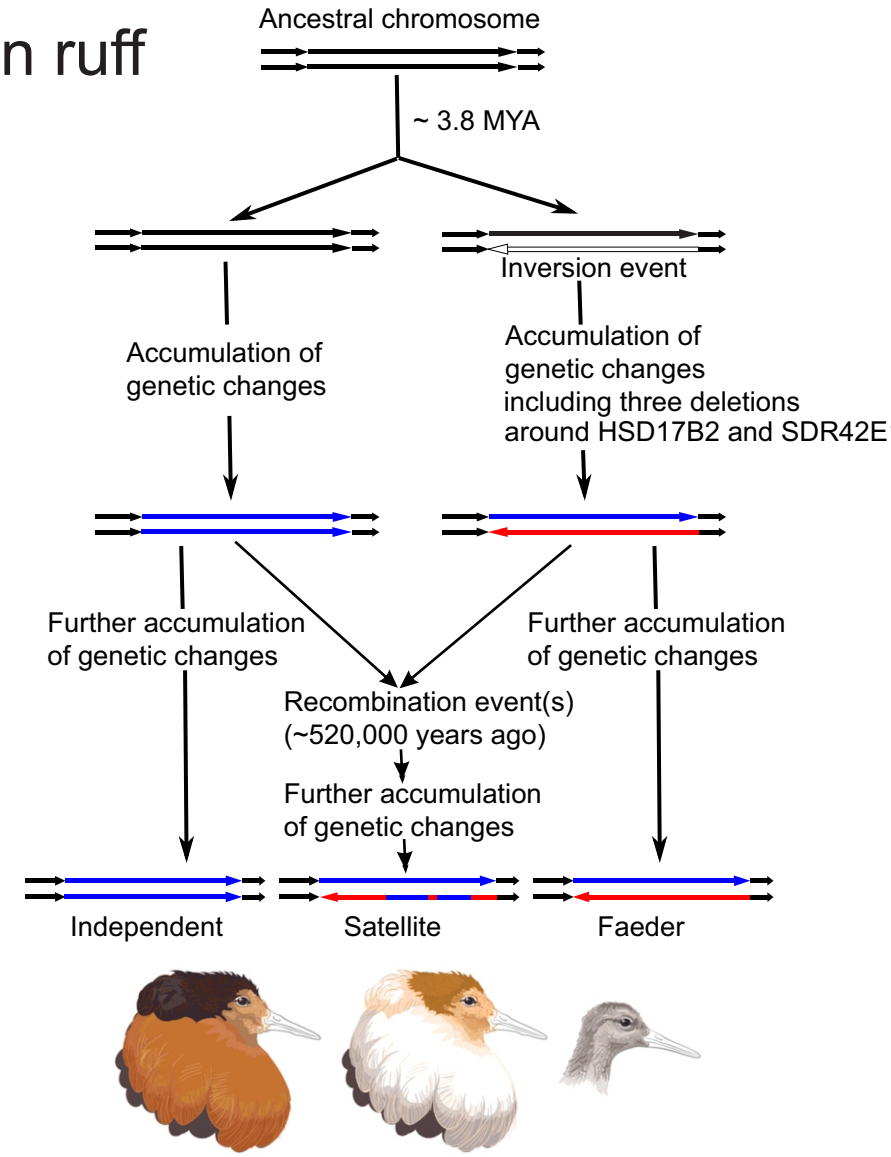
4) Supergenes in natural populations

Reconstruction of supergene evolution in ruff

Examples usually involve a similar mechanism to prevent the breakup of linked genes by recombination (crossing over).

Linked genes are held together on a chromosomal inversion, which largely prevents crossing-over between opposites in the inverted region, allowing groups of alleles that function together to remain associated.

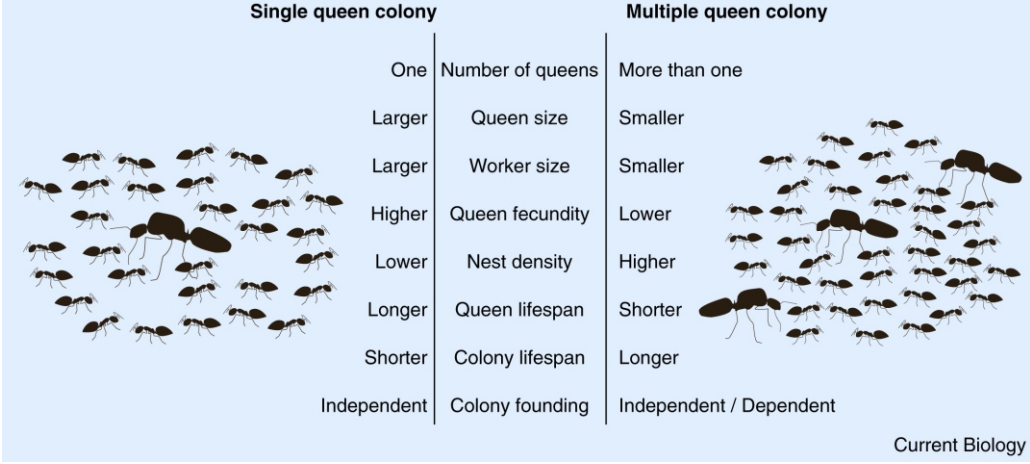
In this way a complex of traits can be inherited together as a simple genetic polymorphism.



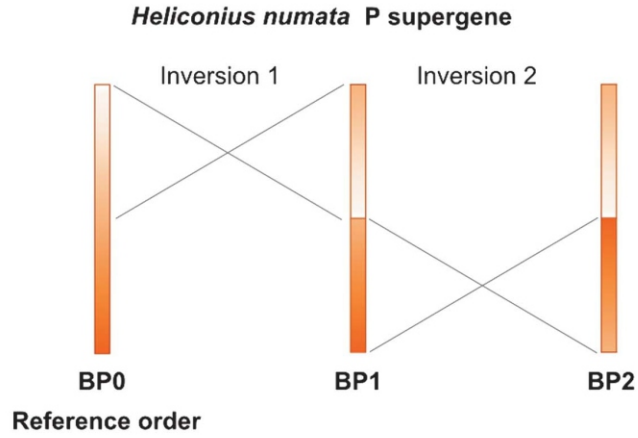
Lamichhaney et al. (2016) Nature Genetics; (Image from: Taylor & Campagna (2016) Science)

4) Supergenes in natural populations

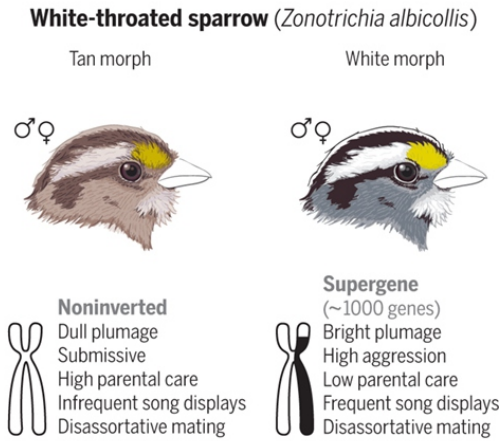
Social polymophism determined by independently-evolved inversions in fire ant and alpine silver ant



Color and pattern polymorphism in *Heliconius numata*



Color/behavior polymorphism in white throated sparrow



H. numata morphs

Species mimicked (models)

Libbrecht & Kronauer (2014) Current Biology; Taylor & Campagna (2016) Science; Joron et al (2011) Nature.

5) What maintains genetic variation in natural populations?

Hypotheses

I) Mutation-selection balance

ii) Balancing selection (net advantage of heterozygotes)

iii) Divergent natural selection with gene flow

iv) Frequency-dependent selection

6) Example exam questions on this section

What is the difference between heritability and maternal effects? Give an example of each.

Distinguish briefly: phenotypic correlation vs genetic correlation.

Distinguish briefly: gene and supergene.

Provide an example of an case in which a genetic correlation is thought to have been important to an evolutionary outcome.

Some polymorphisms involving a complex of traits have been found to be determined by supergenes. How are supergenes maintained intact rather than broken up by recombination?

Give an example of a complex polymorphism maintained by variation at a supergene.