A Much-Too-Brief Presentation on A Few Aspects of Quantitative Evolutionary Genetics, *continued. . .*

by

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in kind of a rush

Some Basic Definitions

- *Variance*—Sum of the squared differences of each observation and the arithmetic mean for the population, divided by the population size minus one
- *Standard deviation*—Square root of the variance

Some Basic Definitions

- V_P = *phenotypic variance*: variance in some measured phenotypic trait
- V_G = *genetic variance*: variation in a population due to differing genotypes
- V_E = *environmental variance:* variation in a population due to differing environments
- $V_P = V_G + V_E$

Some Basic Definitions

- *broad-sense heritability*: proportion of phenotypic variance that is genetic
- *broad-sense heritability* = $V_G / (V_G + V_E)$
- V_A = *additive genetic variance:* variance caused by genes with additive Mendelian effects
- V_D = *dominance genetic variance:* variance caused by genes showing Mendelian dominance
- $V_G = V_A + V_D$

Example: Scarlet tiger moths (*Panaxia dominula*), intensively studied by the British geneticist E. B. Ford.

At Cothill, England, scarlet tiger moths show three phenotypes: white-spotted (*dominula*), intermediate (*medionigra*), and little-spotted (*bimacula*).

This sets up a case of *additive genetic variance,* because the number of spots on the front wing is governed by one gene with two alleles showing incomplete dominance. In other words, the number of copies of each allele that a moth has determines the number of spots it has.

Yet More Basic Definitions

- *narrow-sense heritability*: proportion of phenotypic variance that is *additive* genetic variance
- *narrow-sense heritability* = $h^2 = V_A / (V_G + V_E)$
- *selection differential* = S = difference between the mean value for the entire population and the mean for the population subset that's selected for
- *response to selection* = R = difference between the mean value for the entire population of offspring and the mean for the offspring produced under selection
- $R = h^2S$ (the "breeder's equation")

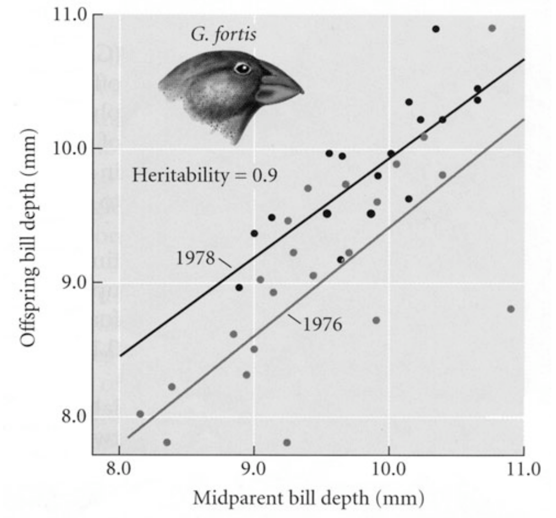
$R = h^2S$

- This equation is important because it predicts a population's response to selection
  - If h^2 is very low, then very little of the variance results from additive genetic causes, and selection won't cause much change
  - If h^2 is high, then most of the variance results from additive genetic causes, and selection has the potential to change the population a great deal

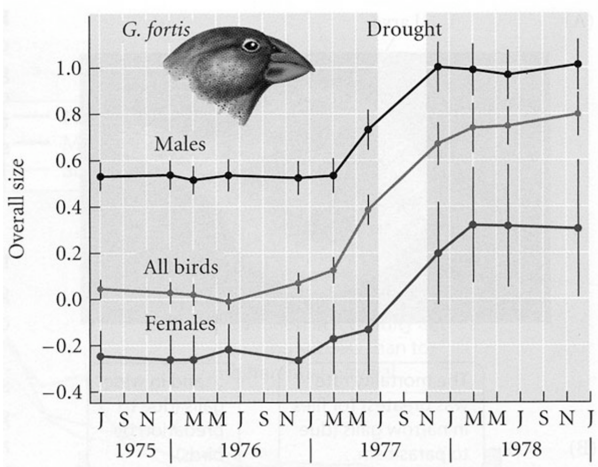
Case study: *Geospiza fortis*

- Peter Grant (1986) studied the population of *Geospiza fortis*, the medium ground finch, on the Galápagos island of Daphne Major
  - He used banding to keep track of parents and offspring, and measured the beak depth of each individual
- Regressing parental vs. offspring phenotypes gave him a heritability estimate of 0.90
- This estimate remained the same even under different environmental conditions
  - 1976 was a wet year; 1978 followed a drought)

Case study: *Geospiza fortis*



Since beak size has a high heritability, you'd predict that it will respond strongly to selection. And that, in fact, is exactly what happened during and after the 1977 drought.



EXAMPLE:
Heritabilities of some traits of chickens

- Egg hatchability: 0.10
- Total egg production: 0.25
- Age at sexual maturity: 0.35
- Egg weight: 0.40
- Body weight: 0.40
- Shank length: 0.45
  - Source: DPIF, Queensland, Australia

EXAMPLE:
Heritabilities of some human traits

- Number of fingerprint ridges: 0.95
- Height: 0.94
- Foot length: 0.81
- Waist circumference: 0.66
- Extraversion: 0.50
- IQ: 0.53
- Weight: 0.42

Within a single domestic dog breed, heritability of behavioral traits is low (between 0.09 and 0.24 for seven traits, in a 2002 study of German Shepherds). But when comparing *across* breeds, many behaviors are strongly inherited and have been selected for many years (herding behavior in sheepdogs, “soft mouth” in retrievers, etc.)

Major Disclaimers:

- Many traits are tightly genetically controlled but have low narrow-sense heritability, because of Mendelian dominance effects.
- Many traits are tightly genetically controlled but have no heritability at all, because they have no variance at all.
  - Example: We know that many genes control embryonic development of the nose, but the number of noses per human is always 1—no variance in the trait means no way of defining heritability!

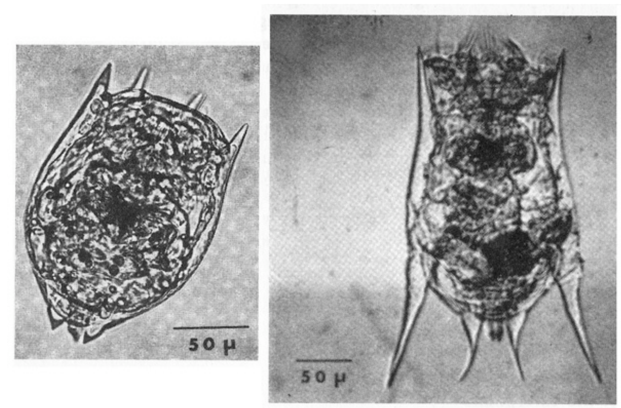
Major Disclaimers:

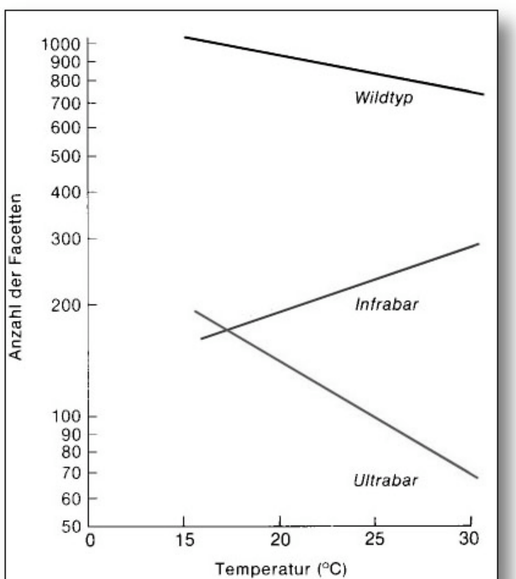
- Heritability can only be estimated if you know that V_E (variance due to environmental factors) is zero.
- As the example of German shepherds shows, V_G may be large *between* populations but very small *within* one population—you have to know the frame of reference!
- There's another wrinkle: V_{GxE}, variation caused by gene-environment interactions. . . which sets up a relationship between phenotype and environment known as a *reaction norm*.

Reaction Norms

- The genotype often doesn't specify exactly what the phenotype will be.
  - Genes often determines a range of phenotypes that an organism will have under different environments.
- The fact that phenotypes vary with environment is known as *phenotypic plasticity*. (Variation due to gene-environment interaction is written V_{GxE}.)
- The specific relationship between phenotype and environment, given a certain genotype, is called a *reaction norm*.

The rotifer *Brachionus calycoflorus* develops spines when predators are present in its environment (right), but not in their absence (left). This is *phenotypic plasticity*.



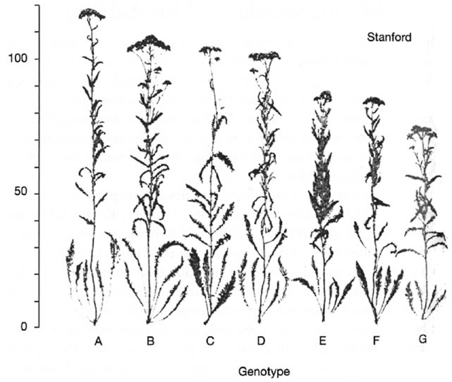


Two different fruit fly mutant alleles, called *infrabar* and *ultrabar*, both produce a phenotype with unusually small eyes (the y-axis shows "number of facets" in the eye)—but they differ in their reaction norms.

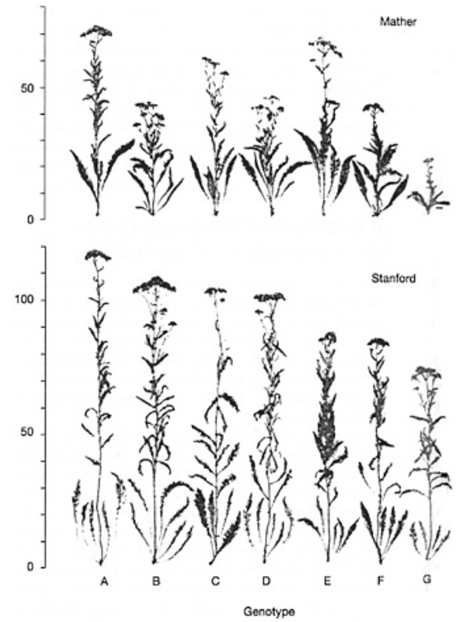
Clausen et al. (1948) grew cuttings from seven wild yarrow plants (*Achillea*) in the same garden at Mather, California. Here's what they got. . .

They all grew in the same environment, so differences in height must be genetic.

When they grew cuttings from the *same* seven wild plants in a different garden at Stanford, California, they got this:



Again, they all grew in the same environment, so the differences in height must be genetic. . .



Here's the two compared directly. Remember that the Mather and Stanford plants are genetically *identical*—both grew from cuttings from the seven original wild plants. What's different about them is their norms of reaction.

Reaction Norms—Case Study

- Caspi et al. (2002) studied several hundred human males. . .
  - There's a brain enzyme called monoamine oxidase A, or MAOA, that breaks down neurotransmitters
  - Differences in the promoter sequences of MAOA mean that some men have low MAOA activity, and some have high activity—and this is genetically controlled.
- Caspi et al. also recorded whether the men had been abused in childhood. . .
- . . . and they scored them for antisocial behavior (which you can measure using psychological tests).

Caspi et al. (2002) found that men with low vs. high MAOA activity have different reaction norms. . .