

# Phenotypic and Genetic Variation, Lab 01

The response of a population to natural selection depends on two important factors: the strength of selection ( $S$ ) and the heritability ( $h^2$ ) of the character under selection. This relationship was concisely described by R.A. Fisher,

$$R = h^2 S.$$

In three labs this semester (labs 1, 4, and 8) you will explore this extraordinarily simple relationship by conducting a selection experiment, and by measuring these three variables. After the third lab, you will prepare a report that summarizes your experiment and results. In this report you will discuss whether your experience shows that this relationship is well supported or not.

## System

*Brassica rapa*, or field mustard, is a weed that grows in many temperate parts of the world, including the US. It is a close relative to many vegetables and spices that you know in the genus *Brassica*, including broccoli, cauliflower, cabbage, and mustard. That distinctive flavor that all these vegetables and spices have in common is due to a family of molecules called glucosinolates. *Brassic*as produce glucosinolates that effectively deter many potential herbivores. It is widely believed that they evolved this purpose by natural selection. *Brassic*as have several herbivore deterrents, and in addition to an arsenal of chemicals, they produce trichomes (spiny hairs), that have been shown in the lab to deter leaf-eating caterpillars<sup>1</sup>. You will conduct a selection experiment this term on trichome density by introducing a new "herbivore" whose success at consuming the plant depends on trichome density. That herbivore, of course, is you, and the effect that you choose your "herbivore" to have will influence the *fitness* (survival and reproductive success) of the plants in your experimental population.

## Variation

The ability of a population to respond to natural selection depends, as you know, on four critical elements:

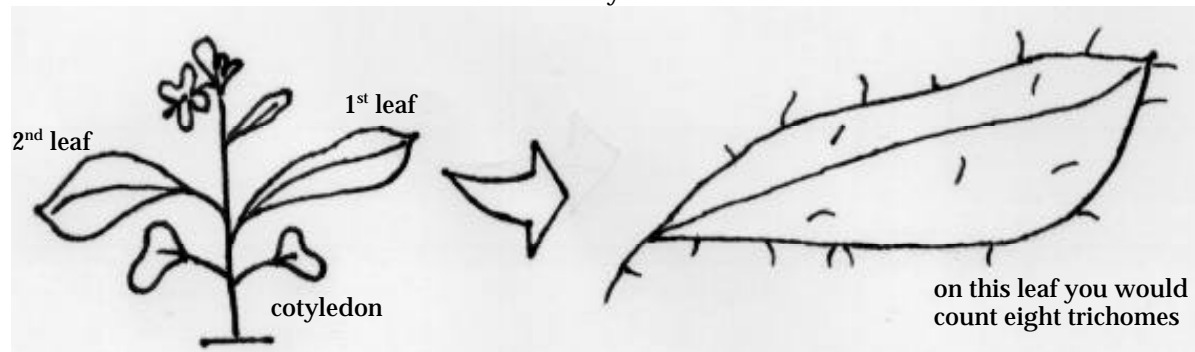
1. Variation in phenotype (trichome density)
2. Heritability of phenotype (trichome density)
3. Struggle for existence (not all offspring survive)
4. Differential survival or reproduction based on phenotype (trichome density)

Question for thought: What happens if a population has all elements but #1? #2? #3? #4?

The first part of this study will be an assessment of the first element, variation in trichome density, in a population of rapid cycling *Brassica rapa*. To make this assessment you must measure the trichome density of each plant and use descriptive statistics to describe the variation in trichome density.

## Variation measurement

The class will work with a population of *Brassica napus* that were planted on August 18<sup>th</sup>. Each of you will get a sample of plants from that population. For each plant in that sample, you will count the number of trichomes on the right edge of the first true leaf, excluding the petiole. Trichome density changes as the plants age; new leaves typically produce fewer trichomes than older leaves. However, once a leaf is formed, the number of trichomes does not change. By adopting this measurement convention, we will be able to pool class data to get an overall assessment of variation in trichome density.



<sup>1</sup> Ågren, J. and D. W. Schemske. 1993. The cost of defense against herbivores: an experimental study of trichome production in *Brassica rapa*. *American Naturalist* 141:338-350.

**Data**

Use the following data table to record your measurements.

Plant ID	trichomes	Plant ID	trichomes

**Statistical analysis<sup>2</sup>**

You will calculate the variance in trichome density. Variance is a measure of scatter: the more that individual data deviate from the mean, the greater the variance. It is important that you understand *in your gut* what variance is, since it is an essential element of evolution by natural selection.

*Population mean and sample mean*

The arithmetic mean of a sample of measurements from a population is the same as the mean of measurements from the whole population. It is calculated as the sum of all the measurements divided by the number of measurements. You should already know this and deeply understand it.

$$\bar{Y} = \frac{Y}{n}$$

Calculate your sample mean here.

*Individual deviation*

It is the deviation of a particular measure from the average measure for a given variable. In graphical terms, it is the vertical distance of a point from the mean.

$$y = Y - \bar{Y}$$

*Population standard deviation*

Just as the mean is an average of all measured values, the standard deviation is an average of all sample deviations. The average is calculated in a slightly different way. As with the mean, the measures are added together and divided by the number of measures. However, since some deviations may be negative, the measures are first squared before they are added together. The final ratio is then square rooted, to scale the average back appropriately.

$$= \sqrt{\frac{y^2}{n}}$$

<sup>2</sup> The notation used in this handout is the same as is used in: Sokal, R. R. and F. J. Rohlf. *Biometry*. 2<sup>nd</sup> ed. W. H. Freeman and Company. New York.



*Example*

Consider a Siamese cat who is particularly dark in color. She is dark because she has genes that make her darker than average, but she is very dark because she grew her fur in a very cold climate. Cold temperature makes Siamese fur dark. Thus her kittens will get her genes for darkness, but they may not be as dark as she is because they may grow their fur where it is warmer. Incidentally, the kittens also inherit color genes from their father, who may or may not be dark-furred.

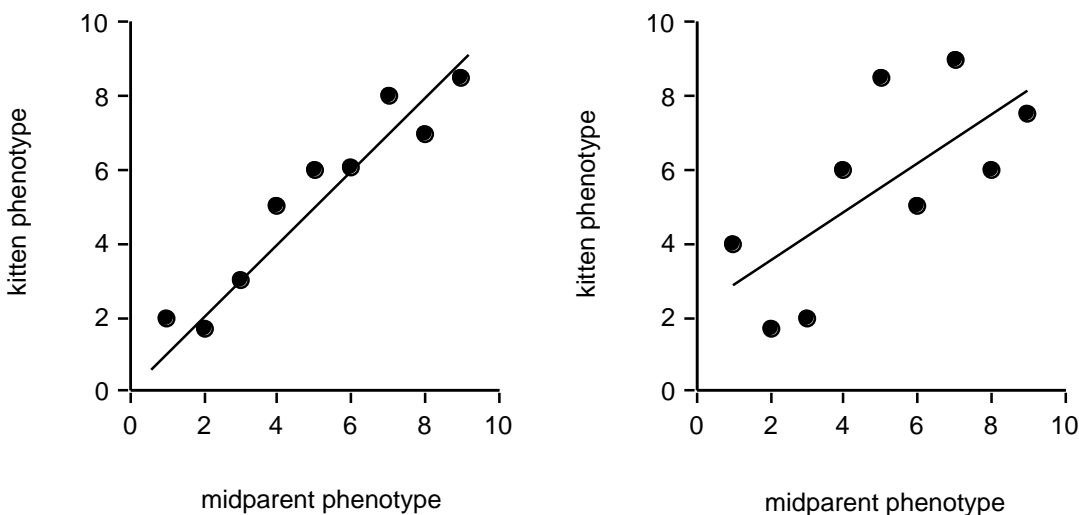
**Heritability**

The heritability,  $h^2$ , of a character is the proportion of phenotypic variance due to variance in genes. Its value ranges between 0 and 1<sup>4</sup>.

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

It should be clear then, that estimating phenotypic variance is not be enough; you also have to estimate genetic variance. How do you do that? Well, the fur color of our Siamese kitten is due to the genes of its father, the genes of its mother, and the environment. If we know the phenotype of the kitten's parents, we can determine the relationship between its phenotype and theirs. If the kitten's phenotype is exactly the average between the phenotype of each parent, then environment had no detectable effect on the kitten's fur color. If the kitten's phenotype is not the average of the two parents (we call this average the "midparent value"), then the environment also influenced it.

In fact, this can be shown graphically. Above are data<sup>5</sup> from two populations of kittens that were produced by an assortment of parents. In the first population (left), all of the variation in kitten phenotypes is due to variation among their parents. In other words, the environment played no measurable role in modifying the phenotype of the kittens. The slope of the relationship is 1. In the second population (right), the environment modified the kitten phenotypes, and the slope of the relationship is 0.67.

*Questions for thought:*

How does the slope of these two graphs relate to the heritability of the character?

How can two populations of the same species exhibit a different relationship between midparents and offspring?

**Heritability measurement**

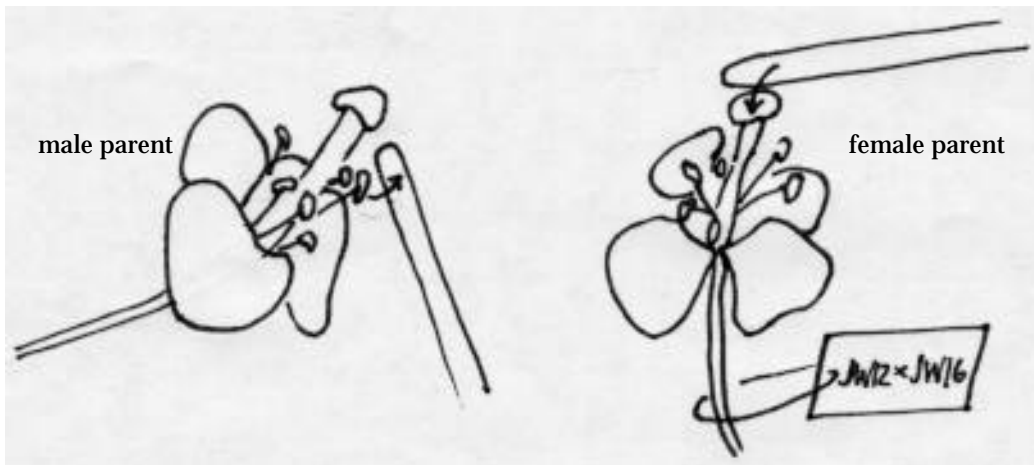
To measure heritability, you will need to create graphs like the ones above. You have phenotype measurements for one generation, but not two. You will need to create the second generation by breeding your plants.

<sup>4</sup> Note that the symbol for heritability is squared. This is to help remind us that it is a relationship of variances, which are also symbolized by squared variables ( $s^2$  and  $\sigma^2$ ). Note also that heritability, as defined here, is "broad-sense heritability."

<sup>5</sup> These data are not real, and are intended only to illustrate a point.

Breeding plants is called cross-pollination, and may take you a few days. Be prepared to come in on your own time to do about 100 pollinations.

To create offspring from a pair of parents, choose two plants and decide, for a single mating, who will be the father and who will be the mother. Take pollen from the prospective father by rubbing a ripe anther with a toothpick. Pollen should stick to the toothpick. Now unload the pollen from that toothpick onto the ripe stigma of the prospective mother (see the figure below). Throw the toothpick away. Now take a tag and label the mother with the ID of the two parents in the cross. Put that label on the flower petiole, not on the plant stem.



In three weeks, we will return to these plants. They will have matured the seed that you fertilized. At that point, you will design an experiment with appropriate controls to examine the effect of a new herbivore on the variation in trichome density in your population.