Heritability of Traits in Humans

Background about heritability.
Darwin identified three necessary and sufficient conditions for evolution by natural selection: (1) individuals within populations vary in traits; (2) trait differences are associated with differences in survivorship and/or reproduction (fitness); and (3) the variation in the traits is **heritable**, i.e., offspring resemble their parents in these traits. We now know that heritable traits among individuals are due to individual genes passed from parents to offspring via molecules of DNA. However, it is important to remember that the features of organisms result from developmental processes that are influenced by environmental conditions as well as genes (**phenotypic plasticity**).

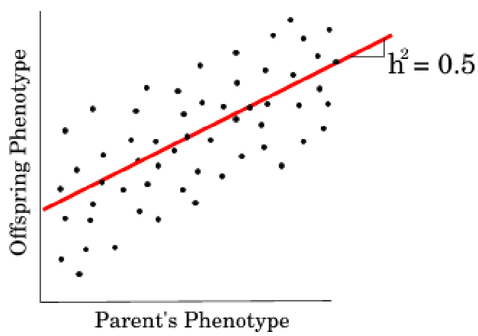
The fact that phenotypic variation can have both genetic and environmental sources generates two complications for biologists in understanding evolutionary change. First, not all phenotypic change over generations is evolutionary. For example, human height has increased dramatically in developed countries over the last 100 years, *not* because taller individuals have higher survivorship and reproductive opportunities, but because childhood nutrition has improved in these countries. Should levels of nutrition decline, the average height of populations would decrease. Second, consistent differences between individuals in survivorship and reproduction may not lead to phenotypic change over generations.

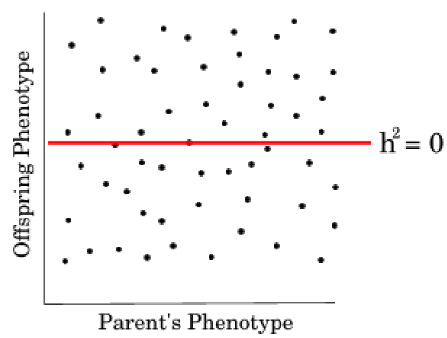
For example, let's say that one sunny April morning you dig up your front lawn and replace it with watermelon plants (of course, if you live in Minnesota there is no reason to be planting anything in April), but you add fertilizer to only half of the area. At the end of the summer, the fertilized plants are much larger and bear bigger watermelons. Your envious and apparently unkind neighbor likes your idea and in the dark of night he steals two of the biggest watermelons, thinking that the seeds from these melons will yield gigantic plants that resemble the parents. The next summer, his (unfertilized) watermelons are much smaller than the melons from which these seeds came. Outraged, he knocks on your door and demands an explanation (so much for neighborly relations). You explain that the phenotypic differences in your melon patch last year were primarily due to the environmental effects associated with fertilizer. In other words, there was no genetic basis for the difference in size and juiciness; these differences were not heritable.

Because of these complications, biologists need to be able to quantify the contribution of genes and environment to variation among individuals, in order to assess the potential for traits to respond to selection. Phenotypic variation in traits is due to both genetic and environmental differences. The proportion of phenotypic variation (Vp) that is due to <u>genetic</u> differences among individuals (Vg) is called **heritability**. The proportion of variation that is not due to genetics is due to environmental differences and is referred to as Ve. Heritability is the proportion of the total, so it is a statistic that can range continuously from 0 (in which case genetic differences do <u>not</u> contribute to phenotypic variation) to 1 (in which case genetic differences account for <u>all</u> of the phenotypic variation among individuals). It is important to note that heritability is a property of a given population in a given environment. It is not a static value that a trait maintains across all environments.

Measuring heritability – Evolutionary biologists, breeders, and statisticians have developed techniques to quantify the sources of phenotypic variation among individuals. This field is known as **quantitative genetics**, since most of the traits of interest vary continuously and are thus measured on a **quantitative** scale. Examples of continuous traits are height, weight, longevity, and the activity of the alcohol dehydrogenase (ADH) enzyme. Note that some traits measured on a discrete scale (e.g. number of teeth, number of syllables in a bird call) may also have a quantitative genetic basis (i.e. many genes).

There are several ways to measure heritability. Two common ones are *parent-offspring regression* and *response to selection*. In a parent-offspring regression, the distribution of offspring phenotypes is plotted against the distribution of phenotypes from their parents and the slope of the line is measured. Thus, if large parents tend to produce large offspring, the slope of the line will be significantly greater than zero and will indicate a high heritability. We could then estimate the fraction of the phenotypic variance that is attributed to genetics by measuring the slope of the line. A slope of 1 indicates that all of the phenotypic variance can be attributed to genetic variance.

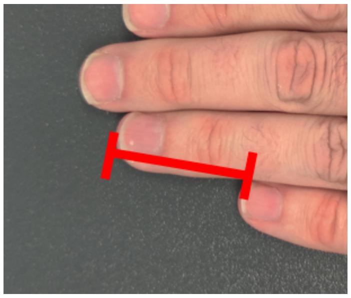




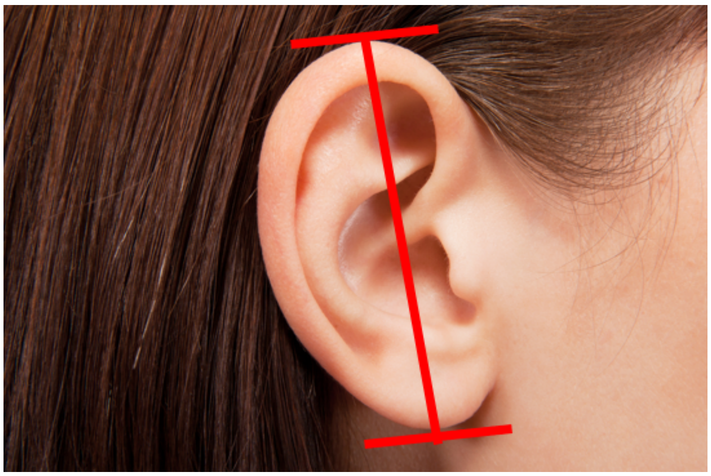
In this lab, you will **compare trait values between parents and offspring** to **estimate heritability** in humans. For this exercise, you may submit trait measurements for both yourself and your parents. **Data collection for this exercise is 100% voluntary and will be randomized/anonymized!**

We will be recording five traits:

1) Height (in feet-inches, to nearest inch)
2) Hair Length (in inches, to nearest inch) - measured as the length of the longest hair on your head
3) Length from tip of Pinky to tip of Ring Finger (in inches, to the nearest 1/8th inch)



4) Length of your ear (top to bottom, in inches, to the nearest 1/8th inch)



5) Number of days you drink caffeine in an average week (days)

Data can be entered here.

Questions:

1) Which of these traits do you think will be most heritable between parents and offspring? Why?

2) Which of these traits will be the least heritable? Why?

3) Could any other factor aside from heritability explain a correlation between parental traits and offspring traits?