

# Measuring a Fitness Component in Students: Fluctuating Asymmetry

Buzz Hoagland, Biology Department, Westfield State College, Westfield, MA 01086

Steve Brewer, Biology Department, UMASS, Amherst, MA 01003

Tom Hogendyke, Biology Department, UMASS, Amherst, MA 01003

## Introduction

Many students in introductory biology courses substitute the concept of physical fitness for the important biological concept of evolutionary fitness. This is likely a result of the many evolutionary misconceptions that students bring into our biology classes. Another contributing factor to this misunderstanding is the lack of meaningful experience with measuring fitness in the laboratory. The exercise described herein gives students an opportunity to measure a fitness component and analyze real data using simple tools and a spreadsheet program. The learning objectives for this exercise are:

### Knowledge

1. What is evolution?
2. What is natural selection?
3. What is fitness?

### Skills

1. Precisely measure various human body parts.
2. Analyze measurement data through use of a spreadsheet.
3. Pose an evolutionary problem that can be addressed with these measurement data.
4. Propose a solution to this problem from the analysis of the measurement data.
5. Prepare a report/presentation to convince one's peers of the adequacy of the problem solution.

### Dispositions

1. Come to see science as a social activity organized around solving problems.
2. Come to see that evolution can be studied in a classroom environment.

## Background

Evolution is simply defined as a change in the genetic structure of a population across generations. A major driving force of evolution is natural selection, which is merely the differential survival and reproduction of certain genetic variants as compared to others. A commonly used measure of differential survival and reproduction is fitness. In evolution, fitness is measured by a genotype's rate of increase relative to other genotypes. In other words, individuals possessing genotypes that allow them to more efficiently obtain resources, secure mates, and avoid predation will tend to survive longer and produce more offspring than those individuals who do not possess those genotypes; those individuals have greater fitness. A simple example is coat color in Snowshoe Hares (*Lepus americanus*). In the summer these animals are brown and in the winter they turn white. Snowshoe hares are related to other hares such as Black-tailed Jackrabbits (*L. californicus*) and Antelope Jackrabbits (*L. alleni*), who live in the drier regions of the southwestern US and Mexico, and do not turn white in

winter and lived in a warm climate. As this species extended its range into colder climates where snow was present for a few months of the year, those individuals who shed their brown coats and grew white pelage in the winter would likely have greater protection from predators and survive longer. In other words, those individuals in the population of northern hares who turned white in winter would experience greater fitness than those individuals who retained their brown coats.

An additional trait that appears to influence fitness in animals is the level of morphological asymmetry. In most cases of performance and locomotion, symmetry is the ideal phenotype. Symmetry keeps a body in stable equilibrium, whereas asymmetry makes a body unstable and will make performance less efficient. "After all, if birds had asymmetric wings they would fall out of the sky; and if dogs had asymmetric legs, they would be forever chasing their tails" (Møller and Swaddle, 1997; pg. 156). Symmetry also appears to influence reproductive output, growth rates, and metabolism. Mating success in the lek breeding black grouse (*Lyrurus tetrix*) is negatively correlated with levels of skeletal asymmetry (Rintamäki et al., 1997). Eurasian shrews (*Sorex araneus*) with higher levels of skeletal asymmetry have smaller litter sizes (Zakharov et al., 1991). Gest et al. (1986) reported a negative correlation between femur asymmetry and growth rates in rats (*Rattus rattus*). Pankakoski (1985) reported a similar results between skeletal asymmetry and growth indices among populations of Muskrats (*Ondatra zibethicus*). A study of adult human males demonstrated a positive association between skeletal asymmetry and resting mass specific metabolic rate (Manning et al., 1997).

Biologists recognize three types of asymmetry: fluctuating asymmetry, directional asymmetry, and antisymmetry. Fluctuating asymmetry results from the inability of individuals to undergo identical development on both sides of a bilaterally symmetrical trait. The resulting asymmetry is a product of random, local disturbances in development that are caused by environmental influences and/or mutations. Because these disturbances are random, the average expression of the trait is symmetry, although a small proportion of individuals may exhibit noticeable asymmetries. Expression of individual asymmetry in a population that exhibits fluctuating asymmetry for a trait then is an estimate of how well that individual can buffer its development against genetic and environmental stresses during development. Additionally, the level of asymmetry in a population reflects the developmental stability of the entire population. Therefore, the differences between left and right sides of a bilateral trait provides an excellent index of developmental stability at both the individual (fitness) and population levels.

Directional asymmetry and antisymmetry result from natural selection and thus are considered adaptive. Directional asymmetry occurs when one side of a trait develops more than the other side. Two examples of directional asymmetry include the bill of the wry-billed plover (*Anarhynchus frontalis*) and ear placement in many species of owls. The bill of the wry-billed plover is approximately 3 cm in length and is always bent to the right at the tip by up to 12° (Neville, 1976). They use the bill to flip over stones as they search for food in shallow waters. The external ears of many owls are asymmetric in their positioning which facilitates more effective sound localization (Norberg, 1978). Ear placement is invariant within a species but may vary among species.

In contrast to the invariant distribution of directionally asymmetric traits, antisymmetry occurs when one side of the character is larger than the other, but there is no handed-bias as to which side will be larger (Timofeeff-Ressovsky, 1934 cited in Møller and Swaddle, 1997). Examples of this type of asymmetry are relatively rare. The most frequently cited example of antisymmetry is the larger signaling claw of male fiddler crabs of the genus *Uca*. There appears to be an even distribution of large right-clawed and large left-clawed individuals within each species. This bimodal distribution

apparently results from the fact that the smaller of the two claws is the one which was damaged, subsequently is shed and regrown. The likelihood of becoming damaged appears to be random (Neville, 1976).

Indices of fluctuating asymmetry have traditionally been used to measure developmental instability (e.g., Palmer and Strobeck, 1986), and will be used in this exercise as an estimate of fitness. Palmer and Strobeck (1986) reviewed the pros and cons of various fluctuating asymmetry indices and concluded that indices based upon the variance of asymmetry in a population (i.e.,  $\text{Var}(R-L)$ ) outperformed those based upon absolute values of unsigned asymmetry ( $|R-L|$ ). A more thorough discussion of the various indices and the statistical properties of fluctuating asymmetry can be found in Møller and Swaddle (1997).

### Procedure

In this exercise we will measure the lengths of your fingers, hands, ears, body, and feet. We will also measure the width of your hands at the knuckles and the position of your ears. Before you record these data in the data sheet below, develop an hypothesis about the level of asymmetry you expect to observe in some or all of these measurements. Also, include a rationale for your hypothesis that is supported by a logical argument and factual information.

**Asymmetry Hypothesis:** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Rationale:** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Before you continue, discuss your hypothesis and rationale with your instructor. Download the extended data set from <http://biology.wsc.ma.edu/biology/experiments/symmetry/body/body.html>, add your class measurements to these data, and begin your analysis. After completing your analysis answer the following questions:

**Does your analysis support your hypothesis? If not, develop a new hypothesis with a new rationale.**

**New Hypothesis:** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**New Rationale:** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

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**Human Body Symmetry Data Sheet**  
**Biology Department**  
**Westfield State College**

Agreement

I, \_\_\_\_\_, acknowledge that the information recorded on this data sheet will be used for educational purposes only. The data sheet will be viewed only by the investigator and/or her/his associates. No copies, facsimiles, or electronic versions of this data sheet shall be produced. These data, at the discretion of the investigator, may be made available in any format as long as these data can't be traced to me. I also understand that my name will remain confidential, and that a number will be assigned to these data if they are made public. My name will not be associated with these data in any format other than this data sheet.

Date: \_\_\_\_\_

Participant Name: \_\_\_\_\_

Participant Number (leave blank): \_\_\_\_\_

Sex (1 - male, 2 - female): \_\_\_\_\_

Age (in years): \_\_\_\_\_

Handedness (1 - right, 2 - left): \_\_\_\_\_

Height (in cm): \_\_\_\_\_

**Measurements (please record all measurements in cm):**

- Foot Length: Place a ruler on the floor and against the wall in a position that is perpendicular to the wall. Remove your socks and shoes and place one foot on top of the ruler with your heel against the wall. Record the longest distance of your foot, but do not include nails.
- Hand Length: Measure the length of your hand along a line perpendicular to the crease across the medial side of your wrist to the tip of your third digit. Do not include the nail.
- Hand Width: Measure the width of your hand using a caliper placed along a line extending across the knuckles of digits 2-5 with your hand placed palm-side down on a flat surface and your fingers together.
- Finger Length: 1 - thumb, 2 - pointer, 3 - middle, 4 - ring, 5 - pinky. Measure the length of each finger from the crease at the base on the palm-side to the tip. Do not include the nail in your measurement.
- Ear Length: Measure the maximum length of each ear using a caliper.
- Ear Position: Stretch a string from the midpoint between the eyes to the bump in the middle of the "V-shaped" notch at the base of the skull. Measure the distance from the string to the top of each ear.

Right Foot Length: \_\_\_\_\_ Left Foot Length: \_\_\_\_\_ Right Hand Length: \_\_\_\_\_  
Right Hand Width: \_\_\_\_\_ Right Hand Finger 1: \_\_\_\_\_ Right Hand Finger 2: \_\_\_\_\_  
Right Hand Finger 3: \_\_\_\_\_ Right Hand Finger 4: \_\_\_\_\_ Right Hand Finger 5: \_\_\_\_\_  
Left Hand Length: \_\_\_\_\_ Left Hand Width: \_\_\_\_\_ Left Hand Finger 1: \_\_\_\_\_  
Left Hand Finger 2: \_\_\_\_\_ Left Hand Finger 3: \_\_\_\_\_ Left Hand Finger 4: \_\_\_\_\_  
Left Hand Finger 5: \_\_\_\_\_ Right Ear Length: \_\_\_\_\_ Left Ear Length: \_\_\_\_\_  
Right Ear Position: \_\_\_\_\_ Left Ear Position: \_\_\_\_\_