An Overview of Biology[*]

The Phenotype

The **phenotype** includes all of its measurable internal and external structures and processes. The phenotype makes up the features of an organism that allow it to survive and interact with its environment. Behaviors can be viewed as the results of internal processes that affect the external environment, as such, they are also part of the phenotype. Thus, athletic performance, being that it is behavior, is also an attribute of the phenotype.

We often distinguish it from another group of structures whose job is to store some of the information needed to construct and maintain the phenotype. The instruction-bearing portion of the organism is termed its **genotype**; these instructions are typically stored in molecules of deoxyribonucleic acid (DNA) but the DNA is not the genotype per se -- it is simply the medium on which genotypic information is stored. More on all of this later in the course -- for the moment simply try to understand what the phenotype and genotype are.

Form and Function

A central theme of biology is the intimate association of the phenotype's **structure or form** and its **function or activity** (usually we just say **"form and function"**).

- **Form** is the shape and physical properties of some structure, whether it be a molecule, collection of large molecules, cell, limb or even a behavior. Put another way, when biologists talk about form, they talk about some facet of the organisms phenotype -- its physical appearance or internal structures.
- **Function** refers to the *use of forms* -- what does a particular bone do (usually many things!), how does a particular behavior serve the individual that displays the behavior, *etc*. The two are intimately connected to each other. As with mechanical devices, for a particular function, certain shapes are better than others, others are more or less equivalent or offer other possibilities.

Two of the "big questions" commonly pursued by modern biologists spring from the study of form and function:

- How form relates to function. This is the substance of physiology, anatomy and biochemistry. It is the main content of our course. Whenever we look at a structure, we will think about how its shape and properties determine its functions.

- How genes and environment interact to determine the phenotype throughout an organism's life; this is the stuff of genetics and developmental biology. It will be a major theme for us later in this course.
- How the environment and populations of organisms interact over time: the subjects of ecology and evolutionary biology. We will have little to say about these in exercise physiology except in regards to our discussions of whether or not "racial types" are valid biological concepts.

Variation

Phenotypes vary. No biological individuals are ever absolutely identical; no structures have identical form nor identical function. Compare this with chemistry. If I consider molecules of diatomic oxygen (O_2) where both atoms are isotope 16, then every one of these oxygen molecules is for all intents and purposes identical. Sure, there may be slight differences in energy states, but anyone one of these molecules can be put into essentially identical states with others. There is no variation. The same is largely true of any chemical species (again ignoring the chance of different isotopes being used in different molecules).

Discussion Questions
Why are organisms not identical? What are the causes of biological variation?
What is complexity and what does it have to do with variation?
What are traits and what do they have to do with the concepts of phenotype, form and function?
Do individuals have variation with respect to form or function of one trait?

Much of the study of biology is concerned with exploring the causes and quantifying the degree and effects of variation. When we see variation we see evidence on the phenotypic level for possible genetic differences. We see differences which may well affect the ability of an organism to reproduce and may have important implications for evolution. The fact that variation is central to biology requires a statistical approach be used when dealing with organisms. It means very little to discuss what one individual or one structure does. Instead, we will tend to look at the characteristics of groups (called **populations**) of individuals.

The Description, Display, and Measurement of Variation

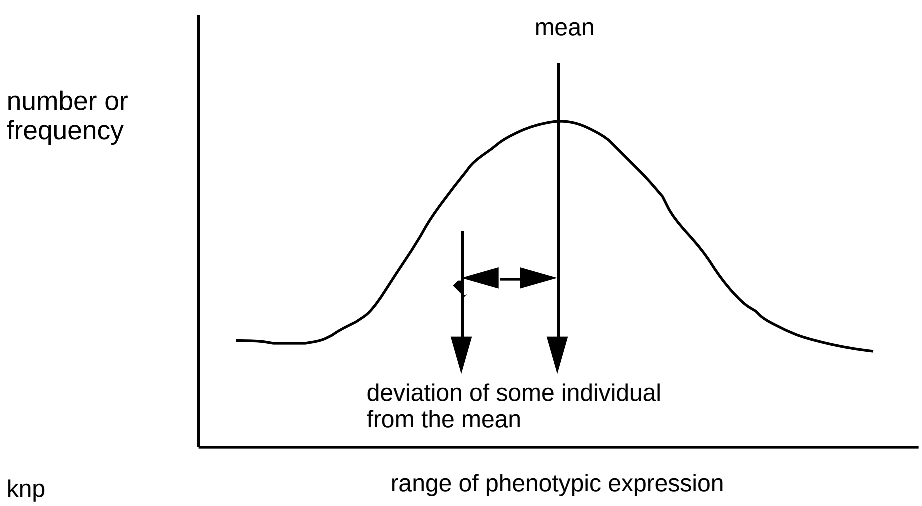
In lab you will learn the ways we attempt to describe difference. In some cases, the particular phenotypic trait we study varies more or less continuously between individuals. There are no sharp demarcations between one value of this trait and another. Mass is a good example. Potentially organisms can put on or lose mass in almost infinitesimally small amounts (single atoms). From the scale of everyday existence, masses may appear to change or to vary **continuously**. If this concept is difficult, then lets look at its opposite. Other phenotypic traits have only a few, well defined and offer very different states. Such characteristics are said to be **discontinuous or discrete**. The sex of an individual is an example. In some species, color pattern or even behaviors may be essentially discrete.

To some degree is the differentiation between continuous and discrete variation artificial? Explain.

When we want to study variation, we often are interested in finding ways to display it graphically. One common technique is to use a **histogram**. These graphs always have the number or frequency of something plotted on the Y-axis and some measure of the trait on the x-axis. On the next page is an example of a population where the trait has a special type of variation called a normal distribution. During class we will construct a histogram and see how they are read.

What is a frequency? How would you calculate a frequency?

Normally Distributed Variation



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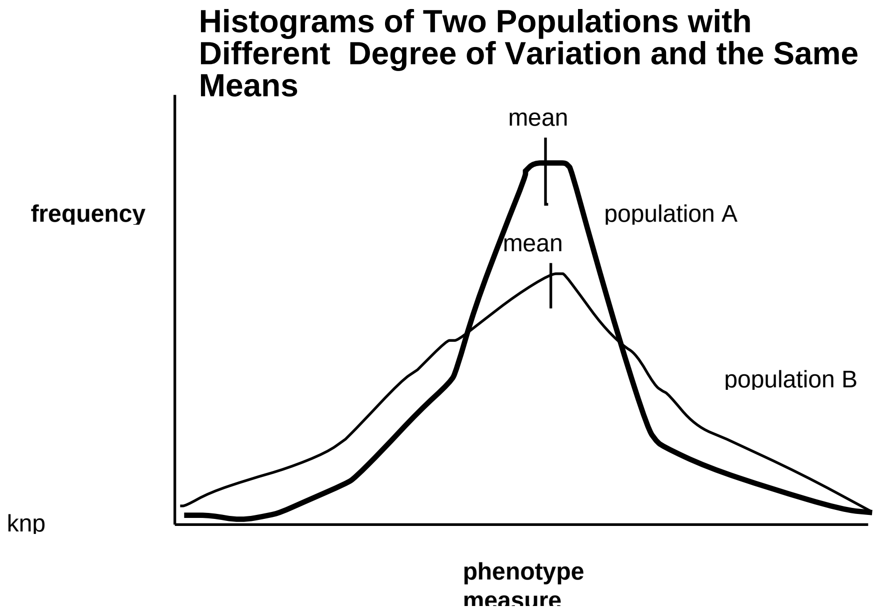
We will see other types of distributions in class and lab throughout the semester.

Any population can also be abstracted to a description consisting of its average or mean **and** some type of measure of variability. Here is an example of histograms of two populations with the same averages (means) but with some differences in their variability:



Describe the differences in the variation between the two populations. How are they similar? Be sure you know how to construct and read a histogram, the difference between continuous and discrete variables, and the ways a population is commonly characterized with descriptive statistics.

We will learn a bit more about measurements of variation in later in the course (especially the standard deviation).

Hierarchy, Complexity and Biological Organization

The range of structure studied by scientists runs from subatomic particles, *e.g.*, quarks, to the universe as a whole (the cosmos). Biologists study a limited portion of this spectrum: their interest begins with macromolecules and ends with ecosystems. The full range of the biologically meaningful portion of the spectrum, called the levels of biological organization, consists of **hierarchically arranged structures** (*i.e.*, each level is composed of the structures in the preceding level) as follows from lowest or least encompassing to highest or most encompassing. The usual organizational levels are: **macromolecules, cells, tissues, organs, organ systems, organisms,**

populations, communities and **ecosystems**. In this course we will only be concerned with the hierarchy between macromolecule and organism (or occasionally, population).

The Fundamental Questions and Approaches Used in Biology: Generally, all biological investigation can be seen as asking one of two types of questions:

- How did the structure or function arise during the developmental history of the individual (i.e., during its **ontogeny**). What sort of chemical and physical mechanisms are responsible for the phenotype. These types of questions are said to deal with **Proximate Causation**.
- How did the structure or function arise during the history of the species to which it belongs (i.e., during **phylogeny**)? What were environmental forces and chance events that determined the phylogeny. Such types of questions are said to deal with **Ultimate Causation**.

Major Unifying theories and principles in biology

Despite the high level of fragmentation in biological subject matter (see the hierarchy on the bottom of the last page -- it is one source of the fragmentation), there exist several major inductive generalizations which unify the field of biology as a whole.

1. The Cell Theory: The **cell theory** was promulgated independently in 1839 by the zoologist, Schwann and the botanist, Schleiden, and it provides a common basis for all living things studied by biologists. The theory states that **all living beings are composed of cells**, and thus establishes the cell as the smallest unit of independently existing life. In 1858 Virchow went even further by adding to the cell theory his **theory of biogenesis** (or theory of cell lineage) which states that **all cells come from pre-existing cells**. These two statements (all life is composed of cells and all cells come from pre-existing cells) constitute **the cell theory** as it is known today. The force of this theory is to provide a unitary basis for life and continuity over time among all living organisms.

2. The Central Dogma of Molecular Biology: all organisms are unified by using DNA (or sometimes RNA) as the hereditary molecule. Moreover, information flow is **from** the DNA **to** the cell, not the other way around. We will see examples of the central dogma when we discuss the connection between genes and proteins.

3. Organisms are opened systems and are constrained by the laws of chemistry and physics, particularly relevant and ubiquitous are the laws of

thermodynamics: This traces back to materialism as compared to vitalism and implies we can, in principle, understand living systems in the same terms as machines. We will cover thermodynamics shortly but suffice it say that among other things it places essential constrains how matter and behavior can behave and therefore on the ways that organisms function. In any case, organisms are just as bound by these laws as are simple chemicals in a reaction flask. The idea of an open system simply indicates that organisms are constantly incorporating and releasing matter and energy. This idea will tie directly into our very materialistic treatment of the body as a type of sophisticated machine.

4. Regulation: Biological processes, unlike non-biological processes, tend to be regulated. For instance, reactions that should be feasible may be prevented from occurring or they will only occur at a slow rate. Likewise, reactions that might normally proceed very slowly can be speeded up when appropriate. More on this later.

5. Evolution: Whereas the four items above provides a common structural basis for all living beings, **the theory of evolution by natural selection** explains the diversity of life. If all life is composed of cells and all cells come from pre-existing cells, why is it that living beings are so different and can be classified as belonging to different species? **Darwin** and **Wallace** explained this as **"descent with modification"** *i.e.*, as life perpetuated itself over time, differences appeared and these differences gradually transposed living beings into different species. Thus, from a common cellular origin there arose differences and these differences accumulated over time to produce the diversity of species we observe today. In his monumental book, *On the Origin of Species by Means of Natural Selection*, Darwin present a wealth of evidence supporting evolution and proposed a specific theory to explain the process behind this pattern of change. Although his theory of how evolution operates was not immediately accepted, he did convince the scientists of his day that evolution had occurred, and so his name is forever linked to the concept of evolution.

Curiously, although no one seriously doubts the validity of inductive generalizations 1 through 4, the inductive generalization of evolution is under constant attack by nonscientists and even a few scientists. The reason is partially that the first four generalizations have minor historical implications in regard to human nature as compared to the theory of evolution. The difference in popular acceptance of evolution compared to the other generalizations given above points to the importance of human history in understanding the development of biology as a science.