Human Physiology **Lecture Notes Chapter 1**

Human physiology is the study of **how** the body works.

The information we have about how the body works has been derived from the application of the scientific method (FOX pg 4-6). The scientific method involves:

1. observing natural phenomenon
2. guessing what could be causing a specific effect (formulating a hypothesis)
3. designing an experiment that tests the hypothesis
4. performing the experiment
5. collecting and analyzing the data
6. drawing conclusions regarding the results

Even well designed experiments can never prove a hypothesis is correct, they either support the guess or they demonstrate the guess was wrong. Unfortunately poorly designed studies may not actually answer the question or address the hypothesis they were intended to answer/address, and may actually provide little information. All experiments have limitations. The most important phase in an experiment is design; the goal is to reduce bias as much as possible by careful design.

For example

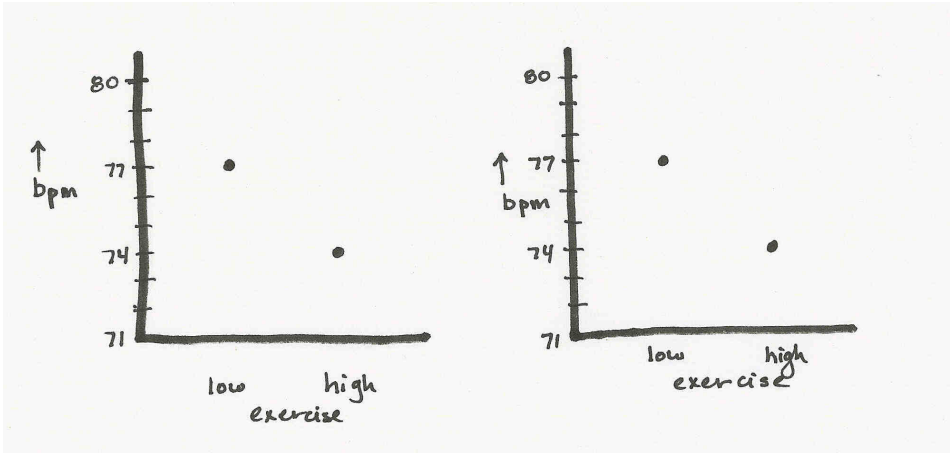
It has been demonstrated that well trained athletes have lower heart rates (HR) than sedentary individuals. It makes sense that there could be a critical point of "fitness" where people above that point would be have lower heart rates than people below that point.

Hypothesis: People that do aerobic exercise (HR above 140 bpm) for 30 minutes five times a week would have a slower resting HR than people that do aerobic exercise for 20 minutes three times a week.

Experimental Design 1 (Observational Study) **:** Find a group of people that fit the high exercise profile and the low exercise profile and compare their resting HR.

Experimental Design 2 (Clinical Trial)**:** Find a group of similar people and divide them into two groups. One group will do high exercise routine for four weeks and the other will do the low exercise routine for four weeks. Compare resting HR at the end of four weeks.

Hypothetical Results: No significant difference between the two groups.



Low exercise = 77 bpm

High exercise = 74 bpm

Possible Conclusions/Bias Problems:

- Group too small to detect significant differences in HR
- Groups had unequal distribution of confounding factors (smoking, diet, stress) that also effect heart rate and obscured the results. This is typically more of a problem with observational studies.
- HR lowering effects take six weeks to become apparent.
- Person taking heart rates wasn't blinded to the treatments and may have counted HR in such a way as to support their own hypothesis (no difference between the groups)
- Different person took the rates for each group and simple counted differently.
- etc.

The value of the scientific method is not demonstrated in any one experiment, but by the accumulation of the results of many experiments performed by different research groups. Scientist tend to be somewhat conservative, and often times results that support a controversial hypothesis (endosymbiotic theory) simply won't be published, until enough research by various groups point to the same conclusions. This is called publication bias. In general, studies that reflect negative or no results are also not published.

Other areas of bias: Funding source supports a certain conclusion
Personal interests (financial or other) of the researcher
Context effects not considered (need placebo control)

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anatomy = structure and physiology = function

In order to talk about biological function (physiology) we must know the names of the structures involved.

We will also find throughout the course that knowledge of a system's, organ's, tissue's, or cell's structure provides us with insight into the function of the system, organ, tissue, or cell. Hence anatomy and physiology are intimately related.

For example, in order to talk about how the kidney's regulate blood pressure we need to know the following structures: arterioles, renal medulla, renal cortex, macula densa, nephron, basic cellular structure, etc.

as well as have a basic understanding of: communication via the endocrine and nervous systems
basic function of the kidneys
blood pressure (definition)

For ease of study, the human organism can be organized as follows:

cells: basic units of structure and function in the body

tissues: groups of cells that have similar functions
there are four major types of tissues: muscular, nervous, epithelial, connective (FOX pg 10-19)

organs: groups of the four primary types of tissues into anatomical and functional units

systems: groups of organs that perform a common function: (Table 1.4)

nervous
endocrine
musculoskeletal
circulatory
respiratory
urinary
digestive
immune
reproductive
integumentary (skin, hair nails)

We will find that this artificial organization is an important tool for learning about the body, but most physiological processes are complex and require the coordination of multiple systems. In addition, some organs are equally important in a variety of systems (bones are important in the musculoskeletal system as well as the circulatory and immune systems) and some processes (such as metabolism) can not be defined by a group of related anatomical structures.

For example, **how does food become translated into movement**?

We understand movement requires energy and humans get energy from food. The details on how the energy in food is transformed into the energy for movement is physiology.

What systems are involved in this process? (Maybe better to ask what isn't involved.)

digestive system
musculoskeletal system

- reproductive system

nervous system
endocrine system
circulatory system
respiratory system

- urinary system
- immune system

What is this process like?

Digestive system:
Food into mouth - activates cephalic phase of digestion (**nervous system** tells gut food is coming). Food into stomach - more **nervous system** involvement (gastrocolic reflex) and **endocrine system** involvement information regarding content of the food is conveyed to the liver and pancreas. Chyme into small intestine. Food further digested - **enzymes** from epithelial layer of gut and pancreas; process aided by bile from liver/gall bladder. Major absorption of nutrients - nutrients passed through epithelial cells into **circulatory system**. All blood from gut goes to **liver**. (Why? structure defines function) Carbohydrates, proteins, fats - **metabolism**. The **endocrine** hormones, insulin and glucagon, rise in response to increased blood levels of nutrients. Nutrients are picked up by cells - including muscle cells.

Muscle contraction:
Requires signal from **nervous system** and **energy** in the form of **ATP**. So need to transform fuel sources (protein, carbohydrate, or lipids) into ATP. That takes **oxygen** (so the respiratory and circulatory systems are needed to deliver oxygen to the cell). Nerve firing also requires energy in the form of ATP.

Involvement of **urinary system** is indirect. It regulates blood pressure and eliminates the waste

generated from the functioning of the other systems. The **immune system** functions to protect the body in general from infectious agents that may disrupt these processes.

As we can see, describing the complete process in detail could easily take the whole semester, and that is what we are here to do.

To simplify the study of physiology we will begin with general processes that are common to a wide variety of specific physiological processes. We will review the basic features of the cell and then expand on them when we cover each system in detail. The course is also organized so that organ systems that perform universal functions are considered first. For example, two systems are responsible for communication: the nervous and endocrine systems. We will cover these first since, as already noted in previous examples, they are responsible for communication between systems and between organs within a system.

In order for the body to function many parameters must be maintained at a steady state. Maintenance of a steady state internal environment is called **homeostasis** (FOX pg 6-9). In general, in order to maintain life an organism must have mechanisms for nutrient acquisition and transformation, waste removal, energy production, and specialized functions such as defense against pathogens. These needs are mimicked at the cellular level with an additional need for communication between cells, organs and systems. Complex mechanisms are at play maintaining homeostasis in the body, but it can be noted that the body closely regulates a variety of **parameters**. What are these essential parameters and why are they controlled?

1. Heat (measured as temperature)
2. pH
3. oxygen
4. ion concentration
5. water / blood pressure
6. glucose

The body closely regulates water, pH, heat, oxygen, glucose, a variety of ions, and blood pressure. The maintenance of these variables at optimal levels is critical for the functioning of the body and typically there are multiple systems of checks and balances in place to ensure these parameters stay at set levels.

For example: pH regulation

What is pH? $pH = -\log [H^+]$

as $[H^+]$ goes up, the value for pH goes down.

acids donate a proton (H^+), which tends to increase the $[H^+]$ leading to lower pH.
bases accept H^+, which lowers the $[H^+]$ in solution, leading to higher pH.

Average value in blood: 7.4 Normal range: 7.35 - 7.45 (Table 1.2 for normal ranges)

Why do we control pH? Proteins active at certain pH (FOX pg89)
Chemical reactions happen only at certain pH

How do we control pH?

1) Let say we start at a plasma pH of 7.4.
2) Then something happens - we eat, we work - and the pH drops.

All important functions in the body have a back up plan for regulation.

Buffer aside (FOX page 28-29)
a buffer acts to prevent changes in $[H^+]$ and thus stabilize the pH of a solution. Bicarbonate is the major buffer in the blood plasma:

$$\underset{\text{(bicarbonate)}}{HCO_3^-} + \underset{\text{(proton)}}{H^+} \rightleftharpoons \underset{\text{(carbonic acid)}}{H_2CO_3}$$

3) Sensor: - detector, sensor, chemoreceptor is activated
- cell reacts to stimulus (signal transduction - more later):
internal communication (enzyme cascade - second messenger system)
cellular response - protein made or vesicles released

(For pH aortic and carotid bodies have chemoreceptors that detect Δ $[H^+]$. FOX pg 500-503
Note: Triangle symbol means change.)

4) Communication (nerve impulse, hormone) to control center (integration unit)

5) Control center checks value of pH with set point
Average value in blood: 7.4 Normal range: 7.35 - 7.45

6) If outside of set point range, sends signal to the appropriate effector.

7) Effector: - secondary effector, muscle or gland is activated
- cell reacts to stimulus (signal transduction):
internal communication (enzyme cascade - second messenger system)
cellular response - protein made or vesicles released

(For pH activity of the bone (carbonate released if needed), pulmonary system (chapter 13, pg 377-378) and renal system (chapter 17 pg 548-549) are affected.)

Overview Homeostasis - negative feedback control