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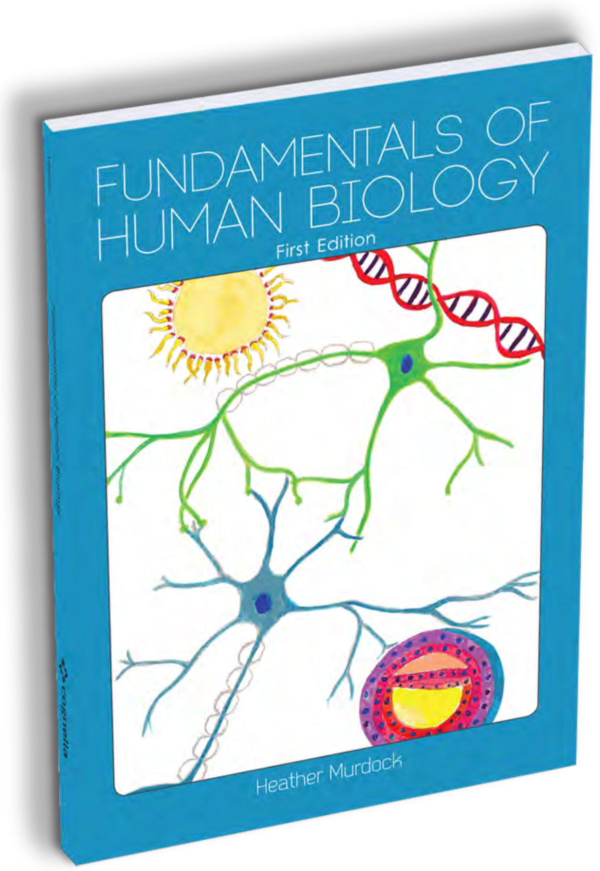

Fundamentals of Human Biology

by Heather Murdock

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FUNDAMENTALS OF HUMAN BIOLOGY

Form, Function, Fitness, and Fun Facts

Heather Murdock

Biol 100

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This is dedicated to my daughters, Ella and Gillie. I love their curiosity, fascination, and sense of humor when it comes to the human body!

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PREFACE

The following reader is based on my lecture notes for the past three semesters. I have taken the information from a variety of sources listed in the bibliography, including textbooks, magazine and newspaper articles, health journals, and Internet sources. This is not a complete picture of the human body and how it works. It is more a summary of the basic forms and functions of different systems in our incredible bodies, along with some topics that I think students might find interesting and relevant. I have created this because I am hesitant to make you buy the $150 textbooks usually associated with this course, because this is not for your major and we're all dealing with budget issues these days. I realize many of you are taking this course to fulfill your science requirement at SFSU and may never have to study biology again, but I hope I can relay the basics so that you will walk away from this class with a solid understanding of how human cells, tissues, organs, organ systems, and whole organisms operate, as well as knowledge that will allow you to make good choices about what you do with your own bodies.

Because this is really just skimming the surface of every topic, I encourage you to read other books to supplement your knowledge, especially for the subjects that you find interesting or that you don't fully understand just from my simplified notes. You can also seek other sources to see pictures and diagrams, because visuals are also helpful when learning a new subject. You can pretty much Google anything these days, and I have provided a list of good Websites on the syllabus. There is way more in this reader than we will have time to cover in lecture, but by having my notes you will be more prepared for each class and won't have to frantically take notes and decipher my cryptic handwriting on the board. You should, however, read each topic before coming to class so that you will have a better understanding of what we're talking about in lecture. I will mostly test you on what we discuss in class; the additional information in this reader is just to give you more of a background in biology.

This reader is a work in progress, and I will be adding to it for future semesters. Feel free to make suggestions of how to improve it. The study of biology is constantly evolving; if you hear of research that contradicts any of these notes or helps supplement them, please let me know. I learn new information every time I teach a class and find that my students have a lot to teach me, so let's learn together and hopefully have some fun in the process.

Heather

CHAPTER 1

Introduction to Biology and the Diversity of Life

Biology: the study of living organisms and their characteristics.

What does is mean when we say "living organisms"? Seems pretty basic, but you need to know the definition of life in order to classify whether something is living or not. For example, viruses, although they can spread and cause great harm, are not actually classified as "living organisms."

HERE ARE SOME OF THE MAIN TRAITS OF LIFE

1. Living things are made up of **cells**; organisms can be uni- (one-celled) or multicellular (many-celled).
2. Living things **respond to stimuli** in their environment, through chemical receptors or some sort of nervous system—from the very basic to our incredibly complex nervous system.
3. Living things increase in size and/or number or cells (they **grow and develop**).
4. Living things **reproduce** new organisms of their own species and pass on hereditary material (in the form of DNA). Reproduction can be asexual (cloning themselves) or sexual (reproducing with a partner, which increases genetic variability).

5. Living things utilize an **energy** source (from food) to fuel functions. Energy utilization is also known as **metabolism** where chemical reactions in the body break down nutrients and build compounds needed for life.
6. Living things maintain an internal environment that is favorable to cell function. The physical and chemical environment inside the body must be kept within certain limits that can support life. For example, we need to keep the pH of our blood around 7.4; if blood is too acidic or too basic, our cells can't function—death can result from these conditions. "Staying the same" is also called "**homeostasis**."
7. Living things may **adapt to environmental changes** resulting in an increased ability to reproduce. Darwin's Natural Selection theory states that the organisms that are best adapted to their environment will pass on the most genes. Species will change over time in the process we call Evolution. Organisms have been evolving on Earth for the past 3.8 billion years. Before we can understand ourselves, we need to take a look at what has gone on before humans even inhabited the planet:

Life on Earth

Earth formed 4.6 billion years ago (bya)

Life began roughly 3.8 bya (primitive anaerobic bacteria cells evolved possibly from protobionts (organic molecules in a membrane-like structure). Primordial atmospheric gases formed these organic molecules. We are still unclear about the process.
Photosynthesis by early bacteria 3 bya produced O_2—important for other species to evolve
Eukaryotes cells (more complex than prokaryotic cells) evolved 2 bya
Complex **multicellular life** evolved 1 bya (colonies of cells like early protista)
Simple **Animals** came 600 million years ago (echinoderms, early chordates, arthropods, mollusks, all still in the sea; there were no terrestrial organisms yet)
Complex animals are in the fossil record around 550 mya and
led the way for **Fish** (500 mya)
Land plants evolved from algae around 475 mya
Fungi came along around the same time (475 mya)
Insects and seeds (gymnosperm plants) came along 400 mya
Dinosaurs and other reptiles evolved 300 mya, after the amphibians (360 mya)
Mammals evolved 200 mya (small insectivorous egg-laying mammals came first and the placental and marsupial mammals evolved 70 million years later)
Birds evolved from dinosaurs 150 mya
Flowers (angiosperms) came 130 mya
Non-avian dinosaurs became extinct 65 mya; mammals radiated everywhere and evolved even more; the first primates showed up in the fossil records around this time

25 mya ancestors of apes and humans diverged from ancestors of old-world monkeys
Distant bipedal ancestors of man occurred 5 mya
2.5 mya the genus homo is found in the fossil evidence
200,000 ya humans started looking like they look today
25,000 ya extinction of Neanderthals
Population isolation, natural selection, and sexual selection caused different genetic traits in various populations, forming what we now call racial differences (skin color, hair color, hair texture, eye shape, and body stature)
(Dates prior to 1 billion years ago are speculative.)

DIVERSITY OF LIFE

There are so many different kinds of species on our planet, so it's good to talk a little about the groups of organisms out there. We've only classified about two million to date, but it's been extrapolated that there have been anywhere from 5–100 million living and fossil species on Earth!

Scientists now group organisms into **three Domains**. Before 1990 they were usually grouped into **five Kingdoms**; since I'm old school, I still like the kingdom method, but I'll give you both here:
The three domains: Archaea, Bacteria, and Eukarya.
The five kingdoms: Bacteria, Protista, Plantae, Fungi, and Animalia.
Here are some of the defining characteristics of the domains and kingdoms.

1. **Archaea**—unicellular prokaryotic organisms. (Prokaryotes don't have membrane-bound organelles, they just have free DNA, cytoplasm, and microtubules making flagella or cilia on the outside for movement.) Archaea usually live in extreme conditions without oxygen in places like swamps, volcano vents, landfills, salt water, and acidic water. They are VERY similar to the next domain in form but have very different gene sequences, but are basically bacteria like the second domain, which is
2. **Bacteria**—also unicellular and prokaryotic and are found EVERYWHERE! They are the types found in food, our bodies, soil, on plants, etc., etc. They are mostly **decomposers** and get food from outside sources—breaking down plant and animal matter and absorbing the nutrients into their cells—but some are **producers** and are able to make their own food through photosynthesis (using sunlight) or chemosynthesis (using chemicals). (This is also referred to as "autotrophic" = "self-feed") Cyanobacteria (blue-green algae) are incredibly important since they started producing their own food 3 bya and in the process made oxygen, which led the way for

most other species to evolve. Bacteria are the first kingdom in the old classification system.

3. **Eukarya**—the third and last domain is extremely diverse, and holds the four other kingdoms, protista, plants, animals and fungi, all of which have eukaryotic cells. Eukaryotic cells differ from prokaryotic cells in their complexity and the fact that they have discrete membrane-bound organelles performing different functions within the cells. We will cover the parts of the cell in chapter 3, but some organelles that you have probably heard of before are the mitochondria (to make energy), endoplasmic reticulum (to help make protein), Golgi bodies (shipping and processing), and the nuclei (location of DNA synthesis and transcription). Some Eukarya are autotrophic and can make their own food, such as the plants and various protista species. Many eukarya are called "heterotrophic"(other-feed) since they cannot make their own food and must get it from another source, either as a decomposer or a ***consumer***.

The four eukaryotic kingdoms:

- **Protista****: so many different kinds of protista exist; some are producers, consumers, or decomposers; some are multi-, some unicellular; some don't have cell walls, and some do (cellulose or chitin). Some can move via flagella, cilia, or pseudopodia. They are sometimes classified according to whether they are animal-like (move and ingest other organisms), plant-like (can photosynthesize), or fungus-like (produce spores). Examples include paramecia, algae, slime molds, and parasites like plasmodium (causes malaria). An example of a protist that is very important for all life on Earth are the diatoms that live in the sea—they make roughly one-third of the oxygen we all breathe!
- **Plants**: all are producers, which means they make their own food through photosynthesis (even carnivorous plants can photosynthesize as well). They make oxygen during photosynthesis and use carbon dioxide, are multicellular, and have cell walls made of cellulose. They are providing most of the food and oxygen for everyone else on the planet, directly or indirectly.
- **Fungi**: most are multicellular, although one of our favorite fungi is unicellular (yeast: important for breads, beer, wine, etc.). Fungi have cell walls of chitin and they are usually decomposers, and some are parasites. They cannot move on their own. They are very important because they help recycle nutrients back into the soil. Animals are more closely related to fungi than to plants.
- **Animals**: all are multicellular organisms, have no cell wall, and are consumers because they can't make their own food and must get it from an outside source. (Herbivores eat only from the plant, fungi, and/or protist groups; carnivores eat only animals; and omnivores will eat certain organisms from all four eukaryotic categories.) Animals require oxygen for cellular processes and produce carbon dioxide in

the process. They can move by using cilia, flagella, or muscle systems. There are two major groups of animals: invertebrates (animals without backbones make up 98% of the animal kingdom), such as annelids (worms, leeches, etc.), arthropods (insects, spiders, crustaceans, etc.), echinoderms (starfish, sea urchins, etc.), and mollusks (snails, clams, octopi, etc.); and the vertebrates (animals with a backbone are the remaining 2%), such as fish, amphibians, reptiles, birds, and mammals.

** There are really more than five kingdoms since the bacteria are divided into two kingdoms and the protista have been broken into several kingdoms, but for our purposes we will just refer to five kingdoms to simplify things.

The Hierarchical System of Classification—the study of biology is also about ordering the natural world from macro to micro or vice versa in order to understand connections between organisms. **Taxonomy** assigns organisms a name versus **phylogeny**, which goes beyond naming to understand the relationships between organisms.

Some basic definitions of some of these groups that we talk about regularly:

Species: a group of organisms that can interbreed and produce fertile offspring.

Genus: a group of species related by common descent and the species within a genus share certain derived features.

This system of classification is hierarchical in that the taxonomic categories form groups within groups, assigned by phylogenetic relationships. Higher categories contain greater numbers of species and have broader definitions:

Taxon (**taxa**): refers to a taxonomic group at any level. The major taxonomic categories used in biology are

- Kingdom;
- Phylum or Division (for plants);
- Class;
- Order;
- Family;
- Genus;
- Species.

When I was in school I was taught a phrase to remember the order:

Kings **P**lay **C**hess **O**n **F**ine **G**lass **S**tools

Now that Domains have been added, I have heard students say,

"Dumb kids play catch on freeway go splat"!

You can make up your own way of remembering the hierarchical order to classify organisms.

Binomial name: name for a species that consists of a genus name and a species epithet;

- Genus and species name are always italicized or underlined, and always Latinized (ex: Homo sapiens = "wise man")

Every species of organism has one and only one scientific name, governed by the **International Codes of Nomenclature**; common names are useful but sometimes confusing, since different languages have different common names, etc.

Humans are Eukarya, Animalia, Chordata (subphyla vertebrata), Mammalia, Primates, Hominidae, *Homo sapiens.*

Looking at some of the features that put us in these taxa:

Eukarya because we have complex membrane-bound cells; **Animals** since we are all multicellular, consumers (heterotrophic by ingestions), we have no cell walls, are motile (can move), and our embryos pass through a blastula stage. **Chordata** means we share features with all the chordates, like notochord, dorsal hollow nerve tube, post-anal tail (in utero), and pharynx with gill slits (in utero), and also have vertebra and teeth. We are **mammals** with hair, mammary glands, and three middle ear bones (and a placenta since we're placental mammals); we are **primates** with forward-facing eyes, color vision, opposable thumbs, and many facial expressions (as opposed to some animals who only have one). **Hominids** have even more complex social organization and brain development, longer parental care, larger body and brain size, sexual dimorphism, and 32 teeth. And finally, as ***Homo sapiens*** (humans), we have great manual dexterity with extremely developed nervous and muscular systems, erect posture, highly complex brain with sophisticated language skills, self-awareness, ability to plan for the future, etc. (Just to clarify the connection between humans, apes, and monkeys, we are not descended directly from apes or monkeys; rather, we have common ancestors.). The human–ape line diverged from the old-world monkey line 25 million years ago, and then the humans and apes diverged again 5–8 million years ago. Human, chimpanzee, and bonobo DNA are all around 98% the same due to this relationship.)

Okay, now that we have a basic understanding of the species on Earth and where we fit in, let's talk about how we are related in terms of energy and nutrients.

Energy Flow—everything is related, and energy and nutrients are recycled in the process:

The ultimate source of energy … the SUN provides the energy for PLANTS to make SUGARS (glucose) via

Photosynthesis: $CO_2 + H_2O \rightarrow$ Sun's energy $\rightarrow$ Glucose ($C_6H_{12}O_6$) + O_2

Meanwhile, all of the other organisms use the sugars made by plants and break down these sugars to make energy in a process called

Cellular respiration: Glucose ($C_6H_{12}O_6$) + O_2 → CO_2 + H_2O + ATP

The energy used to run our cellular processes. Energy is stored in our cells and tissues in the form of adenosine triphosphate (ATP); when it is broken down, it gives off heat. CO_2 is toxic* and we can't handle TOO much water in our system either, so we need to get rid of the byproducts of cellular respiration. They both diffuse out of our cells into our circulatory system and we release CO_2 when we breathe out, and release H_2O in our urine, with our breath, and through our skin. (Water makes up at least 60% of our tissues, however, so we do need to keep a lot of water in our systems for many of our chemical reactions and to move substances around in our body, etc.)

*CO_2 is toxic because it combines with H_2O to form carbonic acid (H_2CO_3), which can then break apart to form hydrogen ions (H^+) and carbonate (HCO_3). The buildup of acids in our cells can dissolve cell membranes and the cellular contents spill into the body. We have a complex system to make sure that we don't build up too much acid in our cells. (The fact that you can't hold your breath for more than a few minutes is your body's way of making sure you get rid of your CO_2!)

Our bodies don't make or destroy chemicals, but rather reorganize to build different compounds or expel them. Notice that in these simplified equations, **cellular respiration** is the opposite of **photosynthesis**—the plants need CO_2 to make their sugar; oxygen is a byproduct that we need to make our energy, and our byproduct is CO_2, used by plants. (They are also using CO_2 in our atmosphere created as a byproduct of the combustion of fossil fuels or the burning of vegetable matter, among other chemical processes. Carbon dioxide is also emitted from volcanoes, hot springs, and geysers, and also comes from breaking down carbonate rocks.) Plants go through cellular respiration as well as photosynthesis (they are both happening simultaneously during the day). So they are making oxygen as well as carbon dioxide at the same time.

Animals can't make their own sugar, so they are relying on plants for the glucose source for cellular respiration. Herbivores and omnivores are eating the plants to get the energy from the starch that the plants are making via photosynthesis; other animals (carnivores and omnivores) are eating other animals who have already consumed plants and are now storing the sugar as glycogen. Meanwhile, the decomposers like fungi and bacteria are decomposing all of the dead plant, animal etc. matter and using the sugar for cellular respiration to make energy, and in the process they are recycling the nutrients like nitrogen and carbon to the soil to be used again by plants. Everything is interconnected. We'll look at how affecting one part of the chain of life affects others when we get to the last portion of the semester and talk about ecosystems and conservation. But for now you should know the basic equations of photosynthesis and cellular respiration.

In order to classify life on Earth and understand how different processes work, scientists have universal guidelines that they follow when researching a topic. It has taken thousands of years of curious people to have the knowledge we now have about our planet and its inhabitants, and scientists keep discovering new things every day. I'm sure you've all gone over this in high school, and you will be learning about it more in the Biology 101 lab if you are taking that as well, but I just want to make sure you know the basics of the fundamental steps used when performing scientific research.

The Steps of the Scientific Method:

1. **Observation**. Pay attention to what's going on around you. It can be on a macro or microscopic level. Ask questions about your observations.
2. **Hypothesis**. Form a tentative explanation to your question(s) called a hypothesis (an educated guess), based on your observations. You can make predictions based on this hypothesis to be tested. (If your hypothesis cannot be tested, it is not valid for a scientific investigation since you cannot prove or disprove your hypothesis.)
3. **Experiment**. Design an experiment to test your hypothesis; make sure to have enough replication and a control (something that differs from your experimental treatment by one variable).
4. **Analyze results**. See if there is statistically significant data to either accept or reject your hypothesis.
5. **Conclusion**. Provide a detailed explanation of what your data means in terms of your hypothesis. If your hypothesis is proven to be incorrect, you can start all over again with a new hypothesis. Every experiment is helpful!
6. **Results**. Share with the rest of your class, the scientific community, or the public at large so that others can build on the new knowledge and review your work. (Otherwise science wouldn't move forward as fast as it does, since many scientists would be researching the same topics over and over, and without peer review, the experiment might not be considered credible.)