INSTRUCTIONS

Welcome to your Continental Academy course. As you read through the textbook you will see that it is made up of the individual lessons listed in the Course Outline. Each lesson is divided into various sub-topics. As you read through the material you will see certain important sentences and phrases that are highlighted in yellow (printing black & white appears as grey highlight.) **Bold, blue** print is used to emphasize topics such as names or historical events (it appears **Bold** when printed in black and white.) Important Information in tables and charts is highlighted for emphasis. At the end of each lesson are practice questions with answers. You will progress through this course one lesson at a time, at your own pace.

First, study the lesson thoroughly. (You can print the entire textbook or one lesson at a time to assist you in the study process.) Then, complete the lesson reviews printed at the end of the lesson and carefully check your answers. When you are ready, complete the 10-question lesson assignment at the [www.ContinentalAcademy.net](http://www.ContinentalAcademy.net) website. (Remember, when you begin a lesson assignment, you may skip a question, but you must complete the 10 question lesson assignment in its entirety.) You will find notes online entitled “Things to Remember”, in the Textbook/Supplement portal which can be printed for your convenience.

All **lesson** assignments are open-book. Continue working on the lessons at your own pace until you have finished all lesson assignments for this course.

When you have completed and passed all lesson assignments for this course, complete the End of Course Examination on-line. Once you pass this exam, the average of your grades for all your lesson assignments for this course will determine your final course grade.

**If you need help understanding any part of the lesson, practice questions, or this procedure:**

- Click on the “Send a Message to the Guidance Department” link at the top of the right side of the home page
- Type your question in the field provided
- Then, click on the “Send” button
- You will receive a response within ONE BUSINESS DAY
FORWARD

Keep these thoughts in mind …

“Evolutionary biology is now uttering and seeking those forces that link us with all those that have being.” — Adrian Forsyth

“Anthropology is the most humanistic of the sciences and the most scientific of the humanities.” — Alfred L. Kroeber

“The cloning of humans is on most of the lists of things to worry about from Science, along with behaviour control, genetic engineering, transplanted heads, computer poetry and the unrestrained growth of plastic flowers.” — Lewis Thomas

“The uniformity of earth's life, more astonishing than its diversity, is accountable by the high probability that we derived, originally, from some single cell, fertilized in a bolt of lightning as the earth cooled.” — Lewis Thomas
About the Author…

Dr. David H. Menke was born and raised in the St. Louis area. After high school, he enrolled at the University of California at Los Angeles, and over the next eleven years, earned his two bachelor’s degrees, his four master’s degrees, a teaching credential, and a Ph.D. in Science Education.

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Dr Menke serves as the First Vice-President and COO of the International Planetarium Directors Congress, and as Chief Astronomer for the Sossusvlei Mountain Lodge in Namibia, Africa. As a world traveler, Dr. Menke has served as leader of many expeditions, including observations of eclipses and comets – on land and at sea. Dr Menke speaks, reads, and / or writes 16 languages.

Dr Menke is married and has six children ranging in age from 7 to 28. He also has 4 grandchildren. Dr Menke’s wife is an elementary school teacher and mental health counselor.

Biology
by David H. Menke, Ph.D.

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INTRODUCTION TO BIOLOGY
By Dr. Dave Menke

There are many branches of science, and biology is one of them. It consists mostly of the study of plants and animals.

As a scientist and writer, I have found the study of biology most rewarding, and it is hoped that you do, too. Many of our daily questions about the plants and animals that inhabit Earth can be reasoned well with a study of biology.

This textbook is outlined to cover the most fundamental aspects of life forms. First, there is a Lesson on genetics, including DNA. Then there is a discussion of the BioSphere I and II. Beyond that, we explore the different types of plants that grow there and we continue with the many and varied animal life forms. We examine ourselves as humans and as biological creatures. We delve into the distant past to find a common origin of all life, including the immediate past ancestors of humans. In the end, we talk about the most recent advances in research.

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LESSON 1

THE SCOPE OF THE BIOLOGICAL SCIENCES

In this Lesson, you will get a feeling for the uniqueness of life. You will also understand our place, as humans, in the scheme of life.

The Lesson includes:

The Science of Biology

Energy and Life

THE SCIENCE OF BIOLOGY

Biology is the science of life. In fact, the word “biology” comes from the Greek words *bios* and *logos*. **Bios** means “life” and **logos** means “study of.” Thus, when one pursues a course of study in biology, then one really studies life itself.

Biology is close to the hearts (and liver, lungs, etc.) of all of us humans, as we are biological Lessons. Simply put, life’s only requirement to be considered life is the ability to replicate – to perpetuate itself; to have descendants in some form or other. Yes, life forms need to have some type of circulatory system and respiration system, but it’s not as simple as just that. In fact, in the early 1950’s, biochemists were able to fabricate life forms in the lab. These forms, called “coacervates,” were not
much more than leaky bags of enzymes, but they could replicate themselves. Technically, they were “life.”

The word “biology” was first used about 1800 in Germany, and later it was made popular by Jean-Baptiste de Lamarck – a French scientist - as a way to combine all the sciences studying plant and animal life forms. The study of plants is called “botany,” whereas the study of animals is called “zoology.”

The idea that gave a unified field of biology its greatest impetus came from a British scientist Thomas Huxley (1825 – 1895). Not to be confused with his more modern grandson, the surrealistic writer Aldous Huxley (1894 – 1963), Thomas Huxley specialized in the biology of animals, and thus, he was more of a zoologist than a botanist. He felt it was nonsense, poppycock, and baloney to bifurcate biology into separate fields that studied plants and animals. Rather, he felt that they should be examined together.

Huxley was a strong supporter of Charles Darwin. His perspective to studying biology is rather important, even today. This is because, for some very small life forms, it is virtually impossible to determine whether they are plants or animals.

Two branches of biology, biophysics and biochemistry, have made some really great advances in modern biology, particularly in the area of molecular biology.

Recent research discoveries in heredity provided great insights into modern science. Another recent breakthrough included the study of cellular metabolism, that is, the relationship between cells and energy.

Molecular biology also includes the study of cellular biology. This is because those biologists that study the molecular level inside the cell must interact.

There is a plethora of other branches of biology, including organismal biology, developmental biology, physiology, neurophysiology, and ethology.

Evolutionary biology, made popular with Charles Darwin, made a come back as a focus of interest in the 1970’s. The genetics of a population – gene pool changes - and ecology have been intertwined more than ever before. Exosociology is a branch of astronomy that concerns itself with the societies in other worlds out in space. Meanwhile sociobiology studies the contributions that genes make for interpersonal relationships.

And now we begin our study of life. A biologist studies life. However, an astronomer studies outer space. There is a cute definition of an astronomer which goes something like this: “An astronomer is a person who spends all his time looking for life on other worlds, while ignoring it here at home.” And, well, that may be true.

When we talk about the study of “life,” we are not meaning the study of the “night life” or “cultural life” of certain cities. Yes, we have all heard things like, “Austin has a wonderful night life,” or
“Boston is the center of cultural life.” These terms refer to the “way of life” in regions, not the biological definition of life itself.

**Life is very persistent** - and very resistant to hostile environments. For example, a variety of bacterial microbes can flourish even in the extreme harsh environment of Antarctica. Thus, we would expect that there may be some life forms existing in other harsh environments - such as on the planets Mars and Jupiter. But more on that later.

As biological entities, we are all “practicing biologists,” or biotechnicians, even if we are not aware of it. As humans, we eat, digest, and excrete; we respire by taking in oxygen-rich air, and we expel oxygen-poor air; we replicate by mating with the opposite gender of our species. In fact, we are nothing more than biological factories. That in itself should be amazing enough to want to study all that there is about biology.

**The study of biology can be summed up in one word: “cell.”** All life forms are made of one or more cells. And this will be the underlying motif of the entire textbook.

The science of biology, as in all sciences, is filled with words and phrases that only a medical doctor would understand. Or maybe only a PhD biologist would understand. Just about every object, life form, chemical, and process is identified with a name. And most of these names are not only hard to pronounce, they are hard to remember. Fortunately, most of the biological terms do come from Latin or Greek in some way, and we can then understand them more easily if we get some basic biological etymology under our belts. Right. We’re going to learn the origin of biology words as we learn biology. Got that? Good. Now, let’s move on. For a comprehensive explanation of the most common biology words, refer to the Glossary in the Appendix.

We humans can procreate with other humans. But why can’t we mate with other life forms? While it is possible for a Caucasian (white) male to mate with an Ethiopian (black) female and produce healthy offspring, it is not possible for a human of any race to mate with a chimpanzee, even though 98% of the DNA is identical. Since humans cannot mate with chimpanzees – the closest relative of humans – then it is understandable that humans cannot mate with other life forms that are more distant in the gene pool (DNA configuration).

Interestingly, horses can mate with zebras, since, well, zebras are in the horse family. Foxes and wolves can mate with dogs, because they are in the dog family. Humans can mate with other humans in the homo sapien sapien family, but humans cannot mate with other apes, even though humans are part of the ape family. Many years ago there was a story – a hoax as it turned out – that a dog and a cat had mated and produced a litter of “dats” or “cogs.” The story was all the rage at the time, but later turned out to be false.

In our study of biology, we will be exploring each and every one of these items, and more. And, beyond that, we will also examine life that most likely exists on other planets around distant stars.
Without energy there would be no life at all. In fact, the most basic form of life, the cell, thrives and flourishes on energy. Thus, we need to make sure that each life form has the energy it needs to exist. Frankly, life can be summed up in one word – “cell.” And the cell will be examined in detail later in this textbook. But for now, let’s simplify the energy equation.

A plant is able to gain most of its energy directly from the Sun. Wouldn’t that be great if we humans could merely sit out in the Sun and soak up energy? Well, we can’t. Humans do like to sit out in the Sun and soak up “rays” that may provide them with a “healthy-looking” tan, but no energy is transferred to those persons.

However, regarding plants, they are able to “make” their own energy source (food) by using the Sun’s rays and the abundant elements on Earth. They do this by absorbing energy from the Sun, and by “breathing” in gases, and “drinking” water in the following chemical formula:

$$6 \text{CO}_2 + 6 \text{H}_2\text{O} + \text{E}_\text{O} = \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2$$

where \text{E}_\text{O} means the energy from the Sun. Notice that the plants are able to combine water and carbon dioxide and make a complex sugar, called glucose \((\text{C}_6\text{H}_{12}\text{O}_6)\), which is the main food supply of the plants. Thus, plants are “solar powered,” but, then again, all things on Earth are solar powered.

**EXAMPLE**

Are we, as humans, solar-powered? The answer is “yes.” How so? Well, we humans eat plants, and we eat animals (most of us). When we eat fruits and vegetables, we are ingesting the energy from the Sun that the plants had taken in. When we eat animals, we are taking in the solar energy that those animals had received from when they had eaten the plants, or perhaps, other animals. So, if we ride a bicycle, it is, in reality, solar powered. We pump the pedals on the bicycle, and it moves forward. We get the energy to pump the bicycle from the food that we eat. And the energy in the food we eat comes directly, or indirectly, from the Sun.
LESSON 1 STUDY QUESTIONS. FILL IN THE BLANK WITH THE CORRECT WORD. CHECK YOUR ANSWERS.

1. Simply put, life’s only requirement to be considered life is the ability to ______.
2. The study of plants is called ________.
3. Thomas Huxley specialized in the biology of ________.
4. ________ biology, made popular with Charles Darwin
5. An ________ studies outer space.
6. All life forms are made of one or more ________.
7. Without ________ there would be no life at all.
8. A plant is able to gain most of its energy directly from the ________.
9. Plants are able to combine water and carbon dioxide and make a complex sugar, called ________.
10. ___ means the energy from the Sun.

ANSWERS TO LESSON 1 STUDY QUESTIONS

1. replicate  6. cells
2. botany  7. energy
3. animals  8. Sun
4. Evolutionary  9. glucose
5. astronomer.  10. E₀
LESSON 2

GENETICS AND EVOLUTION

In this Lesson, you will understand biochemistry and how atoms and molecules combine to form millions of life species.

The Lesson includes:

Cell Creation and Reproduction

Genetics and the Fruit Fly. (Lab 1: Dr. Lewis Held, Jr.’s research)

Genes and DNA

Evolution of Earth Life

Evolution of Humans (Lab 2: From primates to humans)

CELL CREATION AND REPRODUCTION

Introduction to the Cell

The cell is the “man,” the “big cheese,” the “head honcho,” the “real it.” Cells are the basic unit of life. They are able to consume food, excrete leftover stuff, and even reproduce themselves. There is no life without cells. To sum up “life” in one word, it’s “cell.” Didn’t you read that somewhere? Well, here it is again.

Some really tiny forms of life, like bacteria and protozoa, are “unicellular,” which means they exist as a single cell. It has nothing to do with cell phones or unicycles. Each cell has about a billion molecules, all involved in some very important activity.

Most other life forms, like plants and animals, have many cells which work together, similar to workers in a factory. Instead of “uni” cellular, these are “multi” cellular.

As a wise person once said, “The cell has a marvelous design and is very efficient.” Why? That is because cells are able to perform thousands of different biochemical reactions – per minute - and reproduce brand new cells that continue life!

The smallest cells are only about $\frac{1}{10}$ of a micron in size. It would take 10 thousand of them to be the size of 1.0 centimeter (about $\frac{2}{5}$th inch). The largest cells may be found in the neck of a giraffe – about 3 meters (almost 10 feet) long!

How many angels can fit on the head of a pin? Well, if an angel were the size of a cell, 10,000 could.
Long, short, skinny, fat, round, square, cells come in all sizes and shapes. For example, the bacterium escherichia coli (e. coli) is shaped like a rod or stick. The **paramecium** almost looks like the ruby red slipper in the *Wizard of Oz*. Many plant cells resemble boxes. Skin cells in humans are mostly flat. Some nerve cells can look like miniscule octopi. And, of course, some cells don’t really have any shape, and are irregular, or they take the shape that their environment dictates, such as an amoeba.

The shape of a cell is not randomly picked out of a hat. Each shape is chosen to fit what the cell needs to do. Each cell has a “job” and it takes its form from its function.

**Cells are quite self-sufficient**, in some odd way similar to the city-states of ancient Greece. However, just like Las Vegas – the city that never sleeps – cells are always “on” and filled with a flurry of activities.

**The cell, however, never forgets its function**, as it transports essential molecules from hither to yon, and it’s all in a day’s work. As independent as a cell is, it is also a “team player.” It combines in certain functions and activities with other cells, and thus, needs to be able to communicate with the cells on its “team.”

Innumerable cells form teams, or groups, called **tissues**. By the sound of what they are, they must form something that is thin. After all, facial tissue is light and thin. For example, skin is made of **epithelial** tissue, which makes sense, since *epi* is Greek for “on,” and “thelial” comes from the Greek word *thele* which means “nipple.” As all mammals have nipples, and nipples are part of the skin, it does fit, even though it may sound odd to us now. Another better-known word, “epidermis,” comes from *epi* and *derma*, or “on” and “skin.” While typically we may call our skin the epidermis, that is essentially the “on” skin, or the skin “on top” – the outer layer, as it were. A medical doctor who treats the skin is a “dermatologist;” s/he is not an “epidermatologist.” The outer layers of skin are dead anyway, so there is no real reason to treat dead tissue, as it is already, well, dead.

The **amoeba** is single-cell creature. Imagine 25 trillion of them, all working together, in an organized way. Well, that is what a human is. More or less. No, we don’t have 25 trillion amoebae inside us. But we do have 25 trillion cells.

Innumerable cells form teams, or groups, called **tissues**. By the sound of what they are, they must form something that is thin. After all, facial tissue is light and thin. For example, skin is made of **epithelial** tissue, which makes sense, since *epi* is Greek for “on,” and “thelial” comes from the Greek word *thele* which means “nipple.” As all mammals have nipples, and nipples are part of the skin, it does fit, even though it may sound odd to us now. Another better-known word, “epidermis,” comes from *epi* and *derma*, or “on” and “skin.” While typically we may call our skin the epidermis, that is essentially the “on” skin, or the skin “on top” – the outer layer, as it were. A medical doctor who treats the skin is a “dermatologist;” s/he is not an “epidermatologist.” The outer layers of skin are dead anyway, so there is no real reason to treat dead tissue, as it is already, well, dead.
Bones and tendons are made up of connective tissue. These terms have become more “mainstream” in the past few years due to the television programs dealing with crime scene investigations, such as C.S.I. and N.C.I.S.

Organs are made of different tissue types, with each organ having its own function. Most of us know that organs include the heart, liver, lungs, kidneys, and so forth. An organ may be classified as part of the nervous system, or the circulatory system, and whatever. Add all these together, and we have a fully-functional body.

Structure of the Cell
Within the cell are molecules, and they are made from two or more atoms. More complex molecules can be created by combining simpler molecules. And the beat goes on.

The four most important molecules that support the make-up of the cell include carbohydrates, lipids, nucleic acids, and proteins. They all are actively involved in cellular activities. The membrane wall is made of a combination of fats, proteins, and simple carbohydrates.

Within cells, there are units which are, in some ways, similar to internal organs in animals. They are called organelles and they have their own membranes, made from proteins. In order to plan and execute the biochemical reactions within cells, certain proteins called enzymes work to accelerate such events. Anything which speeds up reactions is called a catalyst. Do not confuse a catalyst with a person who owns cattle.

Specialized nucleic acids carry vital ancestral information, and work to create whatever proteins that the cell itself may require. Examples of these include the well-known DNA molecule, or deoxyribonucleic acid. A companion nucleic acid called RNA (ribonucleic acid) combines with DNA in many of these efforts. Now you know something about the famous term “DNA,” and you can go out and impress your family and friends!

Types of Cells
Cells are classified as being one type or the other. Alphabetically, the first type are the “eucaryotes,” and the second type is called “procaryotes.” However, the procaryotes are the simplest cells, and we will discuss them first.

The term “procaryote” comes from Greek words pro and karyon. Since you just learned the latter term, the first term, pro, has a variety of meanings, but in this case, is means “before,” or “in front of.” In fact, it is the root of the prefix “pre.” Thus, a procaryote is in front of the center, or in front of the nucleus. It is also spelled “prokaryote,” and either spelling is correct.

Procaryotes exist only in bacteria. Thus, the DNA, instead of being inside a nucleus, just wanders about with everything else.
Cell Dynamics

A complex cell wall protects the cell itself, and acts as a “gatekeeper,” allowing only certain things into and out of the cell. The inside part of this wall is often referred to as the “plasma membrane.” All the stuff inside “floats” in a fluid called the “cytoplasm” which is about 65% water.

Try not to confuse this “plasma” stuff with the high-energy charged particles that are a fourth state of matter. Also, don’t confuse it with the plasma aspect of human blood, although there is a connection. And it certainly has nothing to do with high-definition plasma televisions. The word “plasma” comes from the Greek word \textit{plassein}, meaning “to make” or “to shape.”

And, “cytoplasm” has nothing to do with “cyberspace,” since prefix is “cyto-“ not “cyber.” The prefix “cyto-“ comes from the Greek word \textit{kýto} which means “hollow” or “empty.” Thus, “cytoplasm” means “the shaping of something hollow,” such as a single cell. In most cells, the cytoplasm is everything inside the cell except the nucleus (or brain) of the cell. However, procaryotic cells are so simple, that the cell is, essentially, the nucleus and vice-versa.

Even so, the DNA, typically located in the nucleus, has all the genetic information that the cell needs.

Meanwhile, another organelle inside a tiny “factory” that creates needed proteins is called a ribosome. 

DID YOU KNOW?

We sure have a lot of new words to learn. But let’s break this one down, too. The word “ribosome” comes from two words, \textit{ribose} and \textit{some}. The suffix word, “some,” in its Greek form is \textit{soma}, meaning “body.” This word, “some” is pronounced like “home,” the place we live. This is not to be confused with “some” which is pronounced like “sum,” which is a bunch of numbers added up.

The other word, “ribose” is not Greek, but comes to us from the way the German scientists pronounced the word “arabinose,” which is a simple carbohydrate, or sugar, albeit a 5-carbon sugar, but a sugar nevertheless.

In general, the chemical names for sugars include sucrose, glucose, fructose, etc. And here we have “arabin – ose.” So, just about anything with an ending of “-ose” is a sugar. Well, not the words “close,” or “hose,” but you get the idea. Thus, one can say either arabinose or ribose, as now they mean the same thing.

So, now that we know that arabinose is a sugar, what is “arabin?” There is a substance known as “gum arabic.” And gum arabic is the gooey sap from an acacia tree. Another way to say “gum arabic” is “gum acacia.” And what is gum arabic used for? Making candy, medicine, and glue.

It is interesting to note that gum arabic must be related to the Arabic language, or to the Arabs, or to Arabia. Well, it is. The Arab peoples are those individuals who live in the land of the acacia trees. The Arabic language is the language spoken by the people who live in the land of the acacia trees. And so on. Now, back to biology.
Did you ever wonder how one cell is able to transmit information to another cell? Probably not. But you will now. It may be on a test someday! As bacteria are procaryotes, let’s see if we kind find out how to do that.

What complex molecule contains the information – the genetic information – needed? Yes, you’re right. The DNA molecule. Well, each bacterium (plural, bacteria) has an “arm,” like the Space Shuttle; or a tether, like an umbilical; or a broadcast “antenna” like a radio station. This little thing is called a pilus (plural pili). If it is able to “hook up” with another cell’s pilus, then, BOOM! communication is established, and data flows. Cool, huh?

Since a bacterium is a single cell, how does it get from “point A” to “point B?” In other words, does it have wings, feet, fins, wheels, or what? Can you remember the types of ocean-going boats that the Vikings (and others back then) used? They were long, low level boats, with maybe 20 men, or more, on each side of the boat. Each man held an oar, and when told to “stroke,” they all stroked in unison. The oars propelled the vessel forward.

Well, every bacterium has a number of “oarsmen,” each one called a flagellum (plural, flagella). Of course, flagella are not unique to bacteria, but it is a good case in point. (This word is from the Latin word flagrum, or a “whip.” The flagella “whip” the cell forward).

DID YOU KNOW?
Once again, the meaning of the word “flagellum” makes sense, as the word “flagellate” means to “flog, beat, whip hard.” In earlier years, people who broke the laws of the land, or the laws of God, were punished with a public flogging. In other words, they were tied to a pole and whipped. The flogging device was a whip. The word “flog” is a derivative of the past participle of the word flagrum.

Most procaryotic cells are infinitesimally small. The smallest is about one ten-thousandth of a millimeter (0.0001 mm). Even the “large” procaryotes are only three-thousandths of a millimeter (0.003 mm). Do you remember than a dime (that’s 10 cents) is as thick as one millimeter? Just imagine that it would take 10,000 procaryotic cells to be as thick as a dime!

Procaryotes can be shaped like sticks or rods; or like balls; or even corkscrew-like. Procaryotes exist in a damp part of the world, such as in puddles, mud, blood.

The perimeter of the procaryotic cell has two sides: an inside and an outside. The outer part is called the “cell wall,” and is somewhat like a sieve (or a strainer, a colander, etc.). Virtually anything can pass through. However, on the inside is a special filter – sort of like the white coffee filters used in automatic coffee makers – that “filters out” or blocks stuff that is not desirable. That gatekeeper, as mentioned, is the plasma membrane. The plasma membrane acts to keep the cell unique, preventing if from dissolving into the fluid environment around it.

Generally, small molecules have no problem passing through the plasma membrane. Examples include carbon dioxide, oxygen, and water. However, more complex molecules get “scrutinized” as they try to gain entrance into the cell. Only if these larger molecules have the right “password” or credentials shall the plasma membrane open its mighty gates. After all, some molecules, such as amino acids, are very desirable to have inside. Other molecules may cause damage and are screened out.
How does the cell do all of this? We don’t really know, but most scientists think it is done by magic. Just kidding. The “acceptable” molecules are able to enter if, and only if, they are able to “connect” or hook up with special proteins that are at the edge of the boundary. Like pieces in a puzzle, if they fit, then they get in. If they aren’t the right shape or configuration, they are “shown the door.” In essence, these guardian proteins act like large “bouncers” at a chic lounge.

Animals and plants are made of the eucaryotes. The word “eucaryote” comes from the Greek words eu and karyon. The Greek word eu means “good,” or “true.” Meanwhile, karyon means “nut” or “kernel,” as in a kernel of corn. In the sense of biology, karyon also means “center,” or “nucleus,” as in the central “brain” of the cell. This word is also spelled “eukaryote,” so either spelling is correct. The molecule DNA resides within the nucleus of the eucaryote.

The Command Center
Animal cells have different kinds of organelles inside them, with the “captain of the ship,” the nucleus, giving the “orders.” One of the organelles is the mitochondrium (plural, mitochondria) which is like a “power plant” for the cell. It makes the energy that the cell needs. Just as in the procaryotes, there are ribosomes which manufacture proteins. Another organelle, with a strange name, acts like UPS or FedEx, or another company, but packing and shipping proteins. The strange name is the Golgi apparatus, which was named for an Italian biologist named Camillo Golgi (1844 – 1926).

The lysosome organelle breaks down and digests the nutrients in the cell. The word comes from the two Greek words lysis and soma, which mean “loosening” and “body.” In some way, the lysosomes “loosen,” or dissolve, or digest the foods in the cell, using powerful destructive enzymes.

Eucaryotes are about ten times bigger than procaryotes. Animal cells don’t really have an outer cell wall, but, instead, a plasma membrane. However, it acts pretty much the same as in procaryotes.

While procaryotic cells have a random system of internal floatation, eucaryotic cells are a miracle of complexity and organization. It’s almost like an efficient corporate center.

The largest “organelle” in an animal cell is its brain, the nucleus. And that goes pretty much for humans, too. At least in mass. The nucleus is packed with DNA, with its double-helix molecule all twisted and compacted. Like Secret Service Agents protecting the U.S. President, a two-layer membrane envelopes the nucleus, so as to prevent damage to the DNA from cytoplasmic reactions. Information passes back and forth between the nucleus and those events in the “outside” world of the cytoplasm. Very much like “runners” in a wartime battle, these “messengers” are often electromagnetic, with a frequency of about ten hertz (10 Hz, or ten times per second).
The Famous Endoplasmic Reticulum

Connected to, and virtually part of, the nucleus’s membrane is an amorphic (no particular shape) and diaphanous (light, feather-like) organelle called the endoplasmic reticulum. Wow! That almost sounds like it’s an extra terrestrial alien from some distant galaxy! But what could it possibly mean, and why was it named that? Well, here’s the deal. The word “endoplasmic” comes from two Greek words, *endo-*-, meaning “within” or “inside,” and *plasma*, which we had learned previously means “to make” or “to shape.” Meanwhile, the word “reticulum” comes from the Latin word *reticulum*, meaning “net.” In other words, the “net” catches stuff, or blocks stuff, or holds things in. In sum, “endoplasmic reticulum” is not only fun to say, but it means “holding the created stuff together” meaning the nucleus and all its contents, including DNA.

Clinging to the endoplasmic reticulum are numerous ribosomes, much like a newly-married couple may drive away in a car with various cords and ribbons dragging behind it. Together, these form very dense units which create proteins – to be exported like Midwestern wheat to a foreign nation. And what, pray tell, is exported? Things like the “Knights Templar” of the body - the white blood cells that combat evil and cold-hearted bacteria and viruses. White cells are the vanguard of the immune system, and they shoot their lethal darts – antibodies – at any invading enemy.

There are two forms of endoplasmic reticulum. One is called “rough” because it is carrying a retinue of ribosomes, as described above. The other is called “smooth,” as it has no ribosomes. Most of the smooth ER’s are found in the cells of the liver. There, the smooth ER’s use their enzymes to make carbohydrates and fats. The smooth ER’s also cleanse and filter the blood to remove toxic substances, such as drugs, alcohol, and various other poisons. These bad things are then transported to the bladder, among other places, where they are jettisoned from the body.

Old Bones

Imagine what life would be like if we didn’t have a firm support system, such as our skeleton? We’d most likely end up on the floor, as a pile of goo, similar to the melting witch in the *Wizard of Oz*. Some animals have endoskeletons, such as mammals (they’re inside us). Some creatures have exoskeletons, such as many insects (they’re on the outside). Cells have cytoskeletons, as you might expect.

The miniscule procaryotes really have no need of a support system. However, the eucaryotes do, especially the larger ones. So, what is the cytoskeleton like, actually?

Imagine a system of numerous ropes, booms, pulleys, cords, hangers, connectors, all crossing hither and yon. That’s pretty much it. The various “ropes, booms, pulleys, cords, hangers, connectors” at the cellular level are made of proteins.

Each individual part of the cytoskeleton helps keep the cell together, ties down organelles, and ends up shaping the cell itself. Parts of the cytoskeleton are either made, or dismantled as necessary. It’s all like watching a construction company build some magnificent edifice, one brick at a time.
Plant Cells vs. Animal Cells

Animals and plants are, well, very different. And yet, they are very much the same. Animals are mobile, while plants, for the most part, pick a spot to live, and stay there, in the same location, until the ends of their lives.

While plant cells have virtually the same stuff that animal cells do, they have a few more things. For example, they have chloroplasts and vacuoles, not to mention a specific and relatively solid cell wall. But what is the function of a chloroplast, and why don’t animal cells have them?

The word “chloroplast” comes from two Greek words, kloros and plassein. We have already learned that plassein, which is also the root for plasma, means “formed” or “molded into a shape.” However, kloros is one of the many colors we see. In this case, kloros is Greek for a pale green, or yellowish green color. Thus, a chloroplast is something that, when molded or created, is a light green color. Green leaves have chlorophyll, which is Greek for “green leaf.”

The function of chloroplasts is critical. They change solar radiation into food energy – glucose as a matter of fact. The process, or reaction, is called photosynthesis and its chemical formula is:

\[ 6 \text{ CO}_2 + 6 \text{ H}_2\text{O} + E_0 = \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2 \]

where the food, glucose, is \( \text{C}_6\text{H}_{12}\text{O}_6 \) and \( E_0 \) is the Sun’s energy. In this reaction, the plant cell takes in carbon dioxide and water (6 molecules each) and uses the Sun’s energy to make the large food molecule, glucose. Notice that this process releases free oxygen into the air – a gas that animals can use! Plants make their own food!

Chloroplasts have a similar function as the mitochondria, and they contain a round chromosome (from kromos, “color”) as well as ribosomes, which make the necessary proteins for the chloroplasts. Thus, animals don’t have chloroplasts, since animals eat their food, they don’t make their food.

Meanwhile, the main vacuole of a plant cell “hogs” a lot of the space inside the cell. But here again is another vacuous word. What does it mean, and what does it do?

DID YOU KNOW?

Both words, “vacuole” and “vacuous” come from the same Latin root, vacuus, meaning “empty.” Just like the word “vacuum.” The word “vacuous” is an adjective also meaning “empty,” or “without meaning or value.” Thus, sometimes when we read all these new biology words, at first they seem vacuous, or they seem to have no meaning, since we don’t usually talk that way in our daily lives. But eventually, we will come to understand what they mean. We hope.

So, what does a vacuole do? It is an organelle that’s pretty much empty. It has fluid in it, but does little besides act as a large closet or storage bin inside the cell. It keeps a stockpile of nutrients, proteins, salts, and sugars. The vacuole also keeps “jars” of color, or pigments, that cause the plants (flowers, trees, etc.) to produce their colors. In one part of the main vacuole is a “vial” of bad-smelling and bad-tasting stuff, often made of waste, that is used as a defense against bugs that may want to eat it. Pretty cool, don’t you think? It has its own shield!
Plants work on hydraulics. What? Yes, hydraulics. That means a plant uses fluid pressure (usually water) to keep it inflated, or pumped up. Plants that don’t have enough water “deflate” or wilt, and fall down. When plants take in water, usually at the roots, the water is absorbed by the cells, and most of it ends up in the vacuoles. The vacuoles swell up, expanding the cell.

Since one cell is right up against another, they all push on each other, causing the plant to have stem strength. In animal cells, doing that would cause the cells to burst. But plant cells have much stronger cell walls, so they don’t explode.

For us humans to stay alive, we must do a variety of things. We have to eat food and drink water. We must sleep and we must have shelter from possible natural dangers. In order to have all that, we have to work to earn money so that we can pay for food, clothing, and shelter. And before we can get a job, we must have some sort of preparation, such as education, training, and / or experience. And on it goes. Well, cells must be able to “work” in order to stay alive as well.

Life in Motion
Procaryotes, animal eucaryotes, and some plant eucaryotes cells must be mobile. All cells must be able to replicate themselves – by division. Cells multiply by dividing.

It is imperative that cells keep the proper ratio of chemicals inside their membranes. They need to be able to “eat” food and turn it into useable energy. They also must be able to replace “broken” parts, adapt to their surroundings, and dispose of waste.

To get around, some cells, such as the eukaryotes, use a flagellum or two. It waves back and forth, in some instances, like a tail. For example, animal spermatazoa have what look like tails that propel them forward in search of the ova, and they resemble swimming tadpoles.

Other ways that eucaryotes get from one point to another is to use a short, protein-rich fiber called a cilium (plural, cilia). Each cilium is made by another organelle, the centriole. You can pretty much guess that word. Instead of a “vacuole,” this is an organelle in the center of the cell, and it uses the suffix “-ole.”

DID YOU KNOW?
It may sound “silly,” but a “cilium” is really an “eyelid.” The word cilium comes from the Latin word, cillum, which literally means eyelid. How on Earth did they come up with that name? Many years ago in a far off land there lived scientists that studied plants. Leaves more exactly. Some leaves have tiny hair-like fibers on them, and a few of those have fibers that, upon close inspection, resemble eyelids. No fooling. Thus, it was the observation of the leaf-hairs that the name originated, and when more advanced scientists examined cells with powerful microscopes, they saw similar types of “hairs,” and borrowed the name used for the leaf fibers. All’s fair in love and science.

Ambulatory cells use cilia as the oars we had mentioned before, in order to move around. There are some cells, however, that don’t move much at all, and yet they still have cilia. Why? Let’s see. In the windpipe and brachial tubes that lead from our mouths to our lungs, the walls are lined with cells containing huge numbers of cilia each. Instead of moving themselves forward, they “intercept”
incoming dust, debris, pollen, poisons, and germs, and toss them into a river of slimy goo, known as mucous. In that way, humans can then expectorate and get rid of them (spit them out), or they can swallow them. In any event, they are prevented from entering the lungs. Does it sound disgusting? Too bad. Without it, you wouldn’t live long enough to learn to read these words. So be grateful.

Do you realize that some simple cells, such as the amoeba, actually walk. More precisely, they crawl like babies? The amoebae create “temporary” feet, and crawl along “on all fours.” These fake feet are called pseudopodia, which means, “fake feet.” It all sounds so bizarre. And this entire universe of tiny creatures is thriving beyond the vision of our normal eyesight.

**Food and Drink**

We all need food to supply us with the energy to sustain life. There are many ways of obtaining food. And we’re not talking about merely going to the local grocery store to pick out what we need. A subset of the human population is engaged in growing food, raising animals for food, or catching food (such as fish). And the methods we use to create such nourishment are as varied as the grains of sand on a large beach.

Cells are no different. Well, they are very different, but they still have a variety of ways to obtain their food. Some creatures merely glide through pond scum and ingest the nutrients dissolved in the water.

The highly flexible and limber amoeba surrounds and “swallows” whatever food it can. In fact, it reminds me of the 1950’s sci-fi horror movie called The Blob, in which a humongous blob creature does exactly that – with humans. Ugh.

Even so, cells need to make available the energy that is stored in the nutrients in order to do work. What they do is to create what is known as the ATP molecule. The word “ATP,” comes from some distant extra terrestrial language. NOT. There is no such word as “ATP.” Those are just the initials for a molecule with an impossible name to pronounce, “adenosine triphosphate.” Drop that term at a family gathering, and you will impress everyone. The chemical formula for ATP is $\text{C}_{10}\text{H}_{13}\text{N}_5\text{O}_4(\text{PO}_4)_3$. In this case, there are three (tri-) phosphates (each phosphate is $\text{PO}_4$) attached to adenosine. More could be explained, but it gets very detailed in chemical analysis, and this is a course in biology. Suffice it to say that ATP is the actual energy “pill” to get the cell moving.

Each second, hundreds to thousands of ATP molecules are built within the walls of a cell. This reaction needs oxygen to happen in eucaryotes, and thus, it is an aerobic reaction, also known as respiration.

Of course, a few procaryotic cells have respiration, but most don’t. This is because procaryotes live in reducing environments with little or no oxygen. The first life forms on Earth existed in oxygen-free locations, or in anaerobic conditions. Once free oxygen began to accumulate in the atmosphere, most life forms died off, due to their oxidation. In essence, they “burned up.” However, a few still survived.

Anaerobic respiration can occur using something other than oxygen – sulfur for example. Yeast, which exists as single eucaryotic cells, constructs ATP anaerobically in a reaction called “fermentation.”
Do you like cheeseburgers? Grilled salmon? Cheese omelets? What do all these have in common? A large amount of protein. Meats, nuts, cheeses, fish, and many other foods are loaded with proteins. And that is good, since each cell has a hunger for proteins that cannot be satisfied.

An average cell may have 25,000 or more active proteins at any moment. Some are used to build molecules or dismantle old ones, or they are part of the infrastructure of the cell. Animal cells use proteins as hormones and as units in the army of the immune system. And in many cases, proteins take molecules from one part of the body to another, like DHL, or FedEx, or UPS. One really critical protein for us is hemoglobin. Why? It carries the life-giving oxygen in the red blood cells. (I wonder where that name came from?).

**DID YOU KNOW?**

**Hemoglobin is a protein**, for sure, but it is a shortened version of what the word used to be, “hematoglobulin,” which came from two words, “hemato” and “globulin.” In turn, “hemato” came from the original Greek word, *haima*, which means “blood.” The other word, “globulin,” comes from the Latin word *globule*, or “globe.” As we know, globes are round, or spherical, in shape. Thus, hemoglobin really means blood balls, or more precisely, drops of blood.

**Divide and Multiply**

During the average life cycle of a cell, it divides many times. This is done to pass on the genetic information. Cell numbers grow by dividing, and the resultant new cells then get nourished, and grow larger, until they, too, divide. This is their form of reproduction. In some cases, cells get damaged, and even die off. Dividing sometimes helps “save” the healthy part of the cell.

**Cells divide in one of three ways: fission, mitosis, and meiosis.** Fission is the choice of procaryotes, and it results in two identical cells. It is interesting to note that in nuclear physics, the process of fission happens when a large atom splits into two smaller atoms, creating new elements from an old one.

Mitosis is a procedure that’s a bit more complicated than that of fission. While it, too, creates two genetically identical cells, the larger and more complex organisms employ the process of mitosis to fix damaged cells, to grow, and / or to replace worn out cells. Of course, single cells divide and go their separate ways, while in mitosis, the cells divide, and remain part of the organism.

**DID YOU KNOW?**

Between 20 and 30 million mitosis divisions happen, each and every second – just to replace dead and dying cells – in a typical human body.

The third of three types of cell division is the special one needed for reproduction. This is called **meiosis**. Your osis? No, meiosis.

In mitosis, one cell divides asexually into two identical cells. In meiosis, when a cell divides, it ends up with only half of the genetic material. It doesn’t grow by itself into a full cell. In fact, it must unite with another “half cell” in order to be a complete and whole cell. However, it cannot unite with an identical cell. Instead, it must unite only with another “half cell” that has the genetic information that it doesn’t.
These half cells are called **gametes**. When two opposite gametes combine, it forms a whole cell, known as a **zygote**. What kind of goat is that? A zygote.

**DID YOU KNOW?**
The word “gamete” comes from the Greek word **gamein**, meaning “marriage.” In fact, a husband is a **gametes**, and a wife is a **gameta**. When you put them together, as in marriage, babies may follow. In fact, a person who marries, and remains true and faithful to that one spouse, is monogamous. A person who has more than one spouse at a time is bigamous, or polygamous. In the late 1800’s some members of the Mormon Church practiced polygamy. Meanwhile, the word “zygote” comes from another Greek word, **zygota**, meaning “yoked together,” as two horses pulling a carriage, or two oxen pulling a plow. A zygote is a whole cell, with the two gametes yoked together.

**The Adam Cell**
How life came to exist on Earth remains a mystery, but the key to understanding it is locked in the cell – and its evolution from some primeval beginning cell. More than 50 years ago, in 1953, two scientists named Harold Urey and Stanley Miller, ran an experiment to determine if they could manufacture life in some artificial way by replicating the Earth’s primordial environment. They mixed the gases of hydrogen, methane, ammonia, and water vapor, and placed them in a sealed container with liquid water at the bottom. Then, they sent electrical shocks through the gases, similar to lightning that existed at that time. A week or so later, the liquid became dark, and amino acids were produced. Amino acids are the building blocks of life. Further work by Urey, Miller, and others produced DNA, and eventually, coacervates – forerunners of simple life. Coacervates were not much more than “leaky bags of enzymes,” but they respired and reproduced themselves.

Thus, as scientists had shown over 50 years ago, it was possible for simple life to have formed in the Earth’s oceans and in the Earth’s air. The first life forms, it turns out, were anaerobic – they lived without oxygen. This is similar to the life form called botulism – a toxic substance that thrives in a reducing atmosphere (without oxygen). Perhaps the first cell (shall we call it the Adam cell?) began in a similar fashion, and “the rest is history” or in this case, “biology.” One thing is for sure, cellular life existed on Earth more than 3 ½ billion years ago.

Cells were first observed in the late 1600’s by the British Physicist Robert Hooke – better known for his discovery of Hooke’s Law of Springs. Anyway, he used a simple homemade microscope to look close up at really small things. One day, he looked at a thin piece of cork. Examining the pulp of the dead wood, he saw a criss-cross pattern that looked like boxes. What came to mind next was the type of life that went on in a monastery. For it is there that monks would have their little cubby holes, or bedrooms, to live in, and these were called cells. Thus, he coined this phrase, “cell.” Other European scientists furthered the work with more powerful microscopes, but it was not until the mid-1800’s that the true importance of cellular research dawned upon the educated world.

A branch of cellular research, genetics, began in earnest in the early 1900’s, and the brilliant research of James Watson and Francis Crick in the early 1950’s lead to the discovery of DNA.
Cellular Demise

In the past 50 years, an area of fervent research has dealt with the topic of the death of cells. More precisely, the planned and executed program of cellular self-destruction, a sort of mass-suicide for millions of cells, per second, has mesmerized the unlearned. Cell death also has a name, of course, and it is apoptosis. This pre-programmed death program may be a way to fight disease, for when internal mutations occur in a cell, and they do, at some point the cell either has to die, or it has to divide and form more “bad” cells. In a way, the cell shuts itself off, or dies, in order that other cells, and the whole organism, can live. If cells don’t do this, the rate of mutations will increase exponentially, leading to tumors, some of which may be cancerous.

Cells, Disease, and Aging

Biological molecules of many types are found in cells. When we breathe in oxygen our bodies use this oxygen in chemical reactions. The results include “free radicals” as by-products.

Free radicals are complex molecules that have atoms in them with one “empty space” for an electron. A free electron makes the free radicals very reactive, always searching for another molecule to share, or steal, its electron. Free radicals then roam throughout the body and cause damage to cells by stealing stable electrons from within other cells, which then causes more free radicals, more instability, and more cell destruction.

This cell damage can really hurt our body’s ability to fight disease. In fact, studies have shown that this damage is connected to every part of the body’s aging. In essence, the cells and their molecules are being “oxidized,” or burned up. Thus, it is necessary to find something that will “put out the fire,” or, in other words, something that is the opposite of oxidizing. Biochemists call them “antioxidants.”

Antioxidants protect against this oxidation reaction in cells by rendering free radicals harmless – making sure that cellular molecules are not attacked for their electrons. Our bodies naturally produce some antioxidants, but most must be eaten. Fruits and vegetables have the largest number of natural antioxidants – particularly broccoli, blueberries, and pomegranates.

However, most people don’t eat enough fruits and vegetables, so taking food supplements may be a good idea.

Free radicals, as a result of their collective cellular damage, contribute to aging, and thus, ultimately to death. Theoretically, if we can find a way to limit, or remove, free radicals, humans could live forever. Unless they died in an accident, a war, or in some other tragedy.
Summary
In conclusion, if there were only one section that you would read and study about biology, this one on
cells is the one. By gaining a good understanding of the cell, comprehending the rest of this textbook
should be, not only easy, but most pleasant.

Key Concepts and Terms
• Adam Cell
• amoeba
• antioxidant
• ATP
• bacteria
• catalyst
• cell
• chloroplast
• cilium
• cytoskeleton
• DNA
• endoplasmic reticulum
• enzyme
• epidermis
• epithelial
• eucaryote
• fission
• flagellum
• free radical
• gamete
• hemoglobin
• hydraulics
• meiosis
• membrane
• mitochondrion
• mitosis
• nucleus
• organelle
• photosynthesis
• plasma
• procaryote
• protozoa
• ribosome
• tissue
• vacuoles
• zygote
Questions
1. What is an Adam Cell?
2. How do antioxidants work?
3. Explain the difference between bacteria and viruses.
4. What is the endoplasmic reticulum?
5. What does an enzyme do?
6. Discuss the difference between eucaryote and procaryote.
7. Compare and contrast fission, meiosis, and mitosis.
8. What is a mitochondrion?
9. What is a protozoa?
10. What is a zygote?

GENETICS AND THE FRUIT FLY
(During this lesson, do Lab 1: Dr. Lewis Held, Jr.’s research)

Genetics is the study of genes, and geneticists are scientists who examine and study genes. But what, exactly, are genes? And what, you might ask, do scientists study about them?

As you may have expected, we are going to delve into the etymology of the word “gene.” Say what? We’re going to break down the word and find out where it came from. Oh, now I get it. Why didn’t you say so?

The word “gene” comes from the Greek word genea, which means “breed” or “kind,” in the sense of “what is the breed of that animal?” or “why doesn’t that animal stay with his own kind?” There are a whole host of words that have genea as the root. For example, “generation,” which means a group within a family who are all about the same age. And the word, “genealogy,” which means “the study of generations,” or in simpler words, “family history.”

Some people may be led to believe at this point that the word “genius,” or the word “genie” may also have derived from genea. Not so. Both words came from the Greek word gignere, to “beget” (or to give away or to transfer). Genies and geniuses impart to others some of their power and wisdom.

So, geneticists like studying how genes behave, and what their “jobs” are within the cell itself. Simply put, genes are organic data, carrying information and instructions on how to use the information. Genes are found in all cells.

Heredity & DNA
Let’s pretend for a moment that you, the reader, had two parents. One was a male (your dad), the other, a female (your
mom). Now you’re here, and you have a blend of genetic stuff from each parent. You are half your mother, and half your father. But the mixture is a blend, so you don’t look like your dad on your left side and your mom on your right side.

Each of your parents has a blend of genetic data from his/her parents, and so forth, for generations. And when you came along, you inherited all of your dad’s and all of your mom’s. Of course, there are always dominant traits that may be quite prominent. For example, you may look just like your mother. However, you won’t act just like your mother. But you get the picture.

Essentially you inherit genetic characteristics from your ancestors. The study of this passing along of genetic information within family lines is called “heredity.” This word has the same root as “heir,” from the Latin heres, which is a person who inherits, or gets something, from another after s/he dies. You are the heir to the genes of your parents, and other ancestors.

What geneticists want to figure out is how the genetic inheritance is imprinted on the cell, and how this specific information can get passed along over and over again.

EXAMPLE

Thomas Jefferson was the 3rd U.S. President. Recent research has shown that some present-day humans who are descendants of a one Sally Hemings are also descendants of Thomas Jefferson. (Sally Hemings was the half-sister of Jefferson’s wife. Apparently after the death of his wife, Jefferson offered to contribute some genetic material in a cooperative effort with Hemings). So, genetics can be most interesting.

The information about genes is imprinted in the chromosomes that make up DNA. Wait – here is a new word: chromosome. Well, “chromo-“ comes from kromo, which means “color,” and we already know what “somes” are.

The DNA molecule is made of many, many sections. Each section forms a gene. And then genes supervise the creation of proteins.

Ever since the time we Cro-Magnons walked the Earth, we have wondered about how certain characteristics are passed on from father to son and from mother to daughter. The Greeks (the ones who seem to have given us most of these funny sounding science words) began to ponder this very thing around 350 B.C.

Serious research in genetics didn’t take root until the late 1800’s. An Austrian monk named Gregor Mendel wondered about certain changes that
he noted while he was tending the monastery’s vegetable garden. His “guinea pig” was a row of peas. Do not confuse Gregor Mendel with Josef Mengele, although both spoke German, and both were involved in genetic “research,” if you can call Mengele’s work that. (Mengele was an evil and cold-hearted doctor who worked for the Nazi war machine and experimented on people - while they were still alive.)

While genetics has made vast strides in the past 100 years, only in the past 15 to 20 years has this science begun to impact the daily routine of just about everything. A new branch of genetics, known as “genetic engineering,” has grave consequences for the future. We are able to make new and varied types of foods, and improve what we have. We can create new life forms, such as innumerable variations of flowers. We are able to identify and isolate the causes of diseases – which gives us hope for curing many of them. We even are using this science in criminology, where a DNA “marker” has virtually replaced the fingerprint as evidence. Yes, indeed, it sure seems like a brave, new world.

One of the greatest projects of all time happened during the last decade of the 20th Century: the Human Genome Project. This enormous undertaking happened with a cooperative effort consisting of a group of researchers, nations, and pharmaceutical companies. By working together, these individuals helped to “map out” the chromosomes in human genes. This will allow untold numbers of laboratory experiments geared at not merely understanding the working of genes and chromosomes, but also at understanding what may cause defects leading to mutations, illnesses, and disorders. The drug manufacturers can then formulate new types of medications that may help cure the incurable diseases, and / or prevent a number of fetal maladies.

However, there are those who fear genetic engineering, and rightly so. Some “new” organisms could injure or kill humans and other life forms (such as new bacteria). Evil dictators may wish to use these techniques to engineer a “race” of loyal subjects, or cause the death and destruction of enemies.

While genetic engineering may, indeed, completely remove some diseases, some mental illnesses, and so forth, it may also be a passport to rid the Earth of “less desirable” humans – those who are deformed or deranged or “stupid.” It could be used in some ways like Hitler’s “Aryan Race” theory, and applied to discriminate against others. But risks are always what we humans take.

EXAMPLE

As one case in point, we realize that for centuries, and millennia, only the strongest and fittest survived. Perhaps that is why the Neandertals are no longer here on Earth. No matter. The weak, the helpless, the sick, the “stupid,” and so forth, did not last long. Subsequently, most of them did not mate or reproduce. Their defective genes dropped out of the “gene pool.” The end result was a stronger, healthier, smarter gene pool. Over a long time, the average intelligence and health of humans increased. But then something remarkable happened. The best and brightest of humans were able to develop new ways of helping others so that they would survive, and, thus, their defective genes would remain in the gene pool. While we have more geniuses than ever, the average intelligence has leveled off, since the smartest people have figured out how to keep the worst people alive. It does seem a bit ironic.
In order to reproduce, or to replicate life, DNA is surely involved. There are two main ways to reproduce: sexually and asexually. In sexual reproduction, a male and a female are needed to contribute their genes.

Some creatures replicate themselves, by themselves. They do not interact with another biological unit. This type of reproduction is known as asexual reproduction. What life forms can have “children” without another partner? Amoebae and bacteria can. In these cases, all “children” are identical twins, and they are identical to their parent. In fact, the “parent” divides into two, so there is no parent any longer. It would be almost as if your dad (or your mom) split into two young identical twins, each exactly like your dad (or your mom), only younger. And your dad (or your mom) would no longer exist. Wouldn’t that be weird?

Key Concepts and Terms
- gene pool
- genealogy
- genetics
- genome project
- heredity

Questions
1. Where does the word “gene” come from?
2. What does “heredity” mean?
3. What is the purpose of the Genome Project?
4. What does “gene pool” mean?

GENES AND DNA

Genes That are “Look-Alikes”
In chemistry, one finds out that each element may have several versions, or isotopes (“iso-“ means “equal.”) A similar thing occurs among genes. The Austrian scientist Mendel (remember him?) observed that genes are found in different versions. Instead of calling these different versions “isotopes,” they were called “alleles.” Hmmmm…. This word must come from somewhere. And it does. The Greek words allelon and morphe combined to form “allelomorph.” And their meanings are, respectively, “of each other” and “in the form of.” So, an “allelomorph” is in the form of another one, i.e., a twin. Over time, the word was shortened to “allele.”

Dominant Genes
Mendel came to believe that when a life form has two alleles dealing with the same characteristic, and they are different alleles, then one is stronger than the other and “wins out.” We call that the “dominant gene.” The other allele would be known as the “recessive gene.” The characteristics of the dominant gene will be apparent while the other won’t even be noticed – except in a future generation.

Always interested in short hand icons and fancy jargon, scientists thought it would be a good idea to represent dominant genes with a capital letter, “R.” For recessive genes, the lower case letter, “r.”
Genes and Diseases
Malfunctions of many individual genes (or alleles) are inherited and result in a permanent long-term illness if both parents contribute the same bad gene. Cystic fibrosis – causing a salt imbalance - is an example. Sometimes, just one dominant gene will trigger (causes) a serious malady, such as Huntington’s disease (named after the researcher who discovered it). A person with Huntington’s is given a very harsh penalty – some muscle movements are involuntary, the person becomes deranged over time, and ultimately, death will claim him at a far earlier age than normal. Another condition, hemophilia, comes from a defective gene on the X chromosome. Those with hemophilia have blood which is not able to clot (get hard) to heal cuts and bruises. Girls born with one defective gene on their X chromosome have a “back up,” as their other X chromosome is usually healthy, and able to direct the production of the clotting proteins. However, boys do not have a second X chromosome, so it is generally only men who suffer from hemophilia.

Sadly, genetic diseases are not like bacterial or viral diseases, which can be treated with medications, fluids, and rest. One cannot simply take a pill to change the body-wide creation of genes. Therefore, a person with a genetic illness is essentially doomed to suffer from it throughout his life – if he has a life at all.

Observe or Research?
How many ways can one classify a life form’s alleles? Well, one way is simply to observe, or look at, the organism. In many cases, mere observations can conclusively determine which allele is dominant. However, there must be a more quantitative way to do this, and there is. Thus, scientists developed the concept of phenotypes vs. genotypes.

The casual reader can guess immediately that the word “genotype” has something to do with genes, or genetics. Research here is cellular biology. One can’t merely look at cells, but one must delve deeply at the molecular level to figure this out. So, the word “phenotype” must have something to do with the “mere” observation technique.

The word “phenotype” comes from the Greek words phenein and typo, which mean “to show forth” and “type.” Thus, a phenotype shows itself (available to naked eye observation), where as a genotype can be determined only by more in-depth research of the genes themselves.

Mutations
For reasons yet unknown, errors happen once in a while during the division process. A structural genetic change as a result of these errors is called a “mutation.” Essentially, these changes seem to be done at random. However, their changes remain in place after they happen, and this altered replication goes on in this altered state. The consequences could lead to faulty protein creation. It is possible that a mutation may happen in any cell, the most critical areas of change would be in the gametes, as descendants would exhibit the changes.

In spite of the proper combination of alleles to bring forth new generations of life forms, once in a while something odd happens. The offspring turn out to be quite a bit different than any expected combination. Is it a mutation? Not really. It’s called a “crossing over.” As meiosis begins, once in a while a pair of chromosomes may get “tangled up” and sections will break off. Shortly thereafter, the
chromosomes re-combine, but not exactly the way they were at first. In some cases, this is part of the evolutionary process that may in reality help the creature adapt and survive longer and better.

Generally, mutations cause irreparable damage to cells. The protein’s main duties may be changed. In one case, the change of one amino acid due to a mutation leads to sickle-cell.

Of course, in a few occasions, a mutation could end up doing little or nothing. But on a rare chance, the cell could possibly be augmented in its function. Thus, mutations lead to genetic diversity and only those that can adapt will survive.

Major mutations include adding or removing one or more bases from a DNA molecule. That wouldn’t be good, as things would change a great deal.

Sometimes genes can make a “leap” and go from one chromosome to another. Most of these mutations can strengthen future generations.

**Human Sex Chromosomes**

**Human females carry two X chromosomes; human males carry an X and a Y chromosome.** These sex chromosomes are labeled “X” and “Y” because their shapes resemble the letters “X” and “Y”, not because they are “unknowns” or because they have strange names that begin with an “X” or a “Y.”

The Y chromosome is a bit smaller, and has fewer genes. Because of this disparity, untold results may happen. First of all, let’s assume that there is a gene, a recessive gene that carries a disease or defect, on the X chromosome of the woman. When it combines with the Y chromosome, the dominant gene may not be there, since the Y chromosome has fewer genes. Thus, even though it may be recessive, it prevails, and the child may end up with the genetic problem. What kind of problem? There are many to choose from – color blindness, hemophilia, muscular dystrophy, sickle cell, etc.

**The Role of DNA**

DNA molecules are programmed with the necessary data and processing that cells have in order to work and to succeed. As we know, DNA has a copy of the hereditary information and is able to copy it and pass it along to another generation.

**DNA molecules** are made out of nucleotides, which are deoxyribose sugar molecules. The sugar connects with two other chemicals - a phosphate molecule and a nitrogen base. There are four “bases” interwoven into the DNA molecules, and they all have letters: A, C, G, and T. The “A” stands for adenine; the “C” is cytosine; the “G” is guanine; and the “T” is thymine. The way that these four are organized within the DNA molecules will dictate a protein’s order of amino acids. They are called “bases”
in the sense that all of life is based upon them, or that they are the base upon which all life stands. It is not related to acids and bases, per se, nor baseball.

To review, let’s explain what these A, C, G, and T bases are. First of all, adenine is a chemical with the formula C$_5$H$_5$N$_5$, and was originally found in the glands of mammals. The word is derived from the Greek word for “glands.” Cytosine has the chemical formula C$_4$H$_5$N$_3$O, and has the same origin as the word “cytoplasm.” Guanine’s formula is C$_5$H$_5$N$_5$O, and its name originated from the native language of the Incas, Quechuan. In that language, the word *huanu* meant the dung of bats and certain birds. Yes, dung, poop, feces, whatever you want to call it. When the Spaniards came to the area, they called this stuff “guano,” with the “g” sounding like an “h.” This is because guanine was first discovered in this animal doo-doo. Finally, thymine has the formula C$_5$H$_6$N$_5$O$_2$. It was discovered the first time around in the thymus gland.

The exact copying of the DNA molecule guarantees that generation’s information that is imprinted in the DNA can always be utilized in all future generations in order to create the method of operation of the cell in question.

In a type of “hand off,” just like in a relay race, the genetic information is first given to another molecule called RNA, which stands for ribonucleic acid. In many ways, RNA resembles DNA, however, there are several important distinctions:

1. RNA has ribose instead of deoxy-ribose
2. RNA has one different base than DNA: it has uracil (U) rather than thymine (T).
3. RNA is an individual spiral rather than the double helix of DNA.

Aspects of RNA act as “messengers” and “transfer agents.

As mentioned, mutations can be caused by many external factors.

For Example:

**Radiation**
By strong light rays or radioactive decay – can damage a whole chromosome. In doing so, the damage negatively impacts genetic function. In chromosomal translocation, a piece of one chromosome may split from its original location, and then it re-combines with another chromosome. Some parts get lost. Occasionally, large subsections will do this. The process is called translocation (across – location).

**Self-Repairing Cells**
Fortunately, and almost by “magic,” cells have the ability to fix themselves, and, thus, can negate any harmful changes caused by these mutations. This is done in such as way as to prevent the “bad” mutations from being passed on to another generation.

A group of unique enzymes search for and find bad DNA sequences and cut out those problems. Following the replication of DNA, these enzymes look for errors and correct them.
Self-Control
The mechanisms that assist in the information copying process from one gene to another must be controlled, or the results will be disastrous. Virtually all cells within a biological life form have the same set of chromosomes. Every cell has some genes which carry on duties with other genes that lay dormant. Hemoglobin is made by red blood cells while the enzyme trypsin is made by cells in the pancreas. Red blood cells could make trypsin, but that’s not the function of a red blood cell. Pancreas cells could make hemoglobin, but they don’t, as they are needed. So, a certain biochemical regulation is carried on.

Recombinant DNA
Biochemists have created some interesting procedures that can actually separate parts of DNA, shuffle them, and put them back together. The results can then be studied to see the effects. Genetic “tools” can be used to create new entities that are helpful to society.

DNA of all forms of life on Earth are identical. They have the same design, structure, and bases. Knowing this, biochemical engineers have invented the technology of recombinant DNA. Within the lab, genes from one life form are injected into a second life form, which can alter that second life form in some interesting way. Usually new, or different, proteins are produced as a result of such tactics. An example is in the laboratory manufacture of insulin for diabetics.

Key Concepts and Terms
- allele
- base
- dominant
- messenger
- mutation
- phenotype
- recessive
- recombinant
- translocation
- x and y chromosomes

Questions
1. Explain what an allele is
2. What does a base have to do with DNA?
3. Compare and contrast dominant and recessive
4. What is a mutation?
5. Phenotype refers to what?

EVOLUTION OF EARTH LIFE

Evolution is a process of change, such as a person may evolve from a child to an adult. A city may evolve from a small town to a large metropolis. An amateur artist may evolve into a Michelangelo; and so forth. Biological evolution includes the genetic changes over multiple generations. Notice in the previous sentence, two of the words were derived from genea: genetic and generations. There is no
way to study evolution without invoking the research of genes, i.e., genetics. Fortunately, you have just completed studying that in the past few lessons.

The word “evolve” comes from the Latin *evolvere*, which means “to roll away,” or “to unroll.” In a way, our genes unravel and then re-combine to form new shapes and patterns. Don’t confuse this with the Swedish word *e-volvo*, which is a car that you can purchase online.

Evolution is the branch of biological science that aims to comprehend how today’s life forms came to exist based upon multiple generations of ancestors.

One cannot examine Earth’s history, from its beginnings billions of years ago, without factoring in evolution. In its most basic form, evolution would argue that all life forms: plant, animal, or bacteria, have some common “gene” that is the basis of life.

Since the time of “Adam,” everyone, his grandmother, and third cousin, has attempted to explain where life came from and how it all fits together. The only trouble is that these thinkers vary widely in their interpretations.

There was a time that most people believed, or were expected to believe, that a supreme being, or a god, created the Earth and all that was on it. Come to think of it, many people believe that, today, too.

It is not the purpose of this textbook to confirm or dispute the existence of one or more gods, or any religion. Rather, it is primarily to explain biological phenomena using the tools of scientific research, and to let the evidence lead us to where it may.

The study of modern evolutionary theories began at the time when researchers began to “dig up” evidence of early life forms, e.g., fossils. More research was done in anthropology and archeology, finding evidence of early humans and even earlier life forms of other species.

Whether you feel comfortable in pursuing science as a way to answer such valuable questions, or if you feel better believing in a divine cause for all things, it is still your responsibility to learn what others have discovered and what they believe in order to live in the world of the 21st Century.

A British scientist named Charles Darwin wrote a book in 1859 called *On the Origin of Species by Means of Natural Selection*. The ideas in the book described the theory of *natural selection*. Life forms, it was argued, had to fight and struggle to continue to live, and that only the “survival of the fittest” could be reasoned. Those stronger life forms will then pass their strengths on to their children and grandchildren. In the end, the weaker life forms end up becoming extinct, as the resources for life become dominated by the stronger life forms. The strength mentioned here lies in the adaptation of the life form, not necessarily its muscular build.

In spite of Darwin’s *On the Origin of Species* being on the best-seller list for an extended period of time, his critics virtually barbecued him. Some accused him of what Galileo was
accused of: treason against God. It didn’t help that Darwin’s theory could not explain everything - for example, what really causes life forms to evolve?

Some of the opposition and resistance to Darwin’s ideas began to diminish, however, as scientists did their own examinations of the theories.

It was the more modern researchers in the 20th century that were able to uncover the aspects that had previously been absent from Darwin’s work. Genetic structure was revealed with further biochemical studies, as were the methods of passing on of genetic information.

New discoveries in paleontology gave indication as to when species that no longer exist lived, and gave some clues as to why they vanished.

Most contemporary biologists hold fast to the concept that evolution is the main foundation of the science.

The concept of “natural selection” deals with genetic information that is given through inheritance from parent to child. For us, we inherit from our ancestors our blood type, how tall we are, and the color of our eyes, to name a few things. Among other living creatures, there are patterns, markings, shapes, and other features in such a large number of combinations that it is as complex as a computer.

The genes themselves control each and every aspect of such characteristics. And it is within the genes that we find the DNA molecules that direct the manufacture of proteins among other numerous duties.

Evolution is a process that takes a long time over many successive generations. Evolution does NOT occur during any one person’s lifetime, but, rather, may be seen in a person’s child, or grandchild, or other later progeny. Therefore, we take a close look at the results of the children of mixed populations (such as the descendants of two parents of different ethnic backgrounds).

When a male and female of different races mate, their genes are combined in some random pattern, not like either of the original race members. The combination makes a new individual who has a new and different pattern of genes. Of course, one will never find two persons in any population who are genetically identical (except identical twins, who share the same DNA). This genetic variation is critical to evolution, which, in turn, is vital to the survival of the population of individuals mentioned. The larger the pool of people, and the more varied the genes in that pool, the greater is the probability that evolution will accelerate in such a way as to produce offspring able to adapt to the changing environment.

The random shuffling and recombination of the genes during sexual reproduction will guarantee future good health. This process creates “recombinant DNA”.

Let’s imagine a man who is of one particular race, and he decides for his own reasons to visit groups of other races. Let’s also imagine that this man elects to mate with women in each of the other races. When this happens, then “new” or “exotic” genes are added to the population gene pool that had not been their before. Termed “gene flow,” this can happen either on purpose, or by accident, within the realm of nature.
EXAMPLE
Using we humans for an example, let’s follow this above-referenced man. Let’s also say that he is a 
Caucasian – one of the five races recognized by anthropologists today. So, one day, this man chooses 
to move to Kenya and live among its citizens for a period of time. While there, he mates with a local 
native woman, and she bears a child. This child will have genes from both Caucasians and the race called Ethiopians. If the child remains in Kenya and marries a local native woman, then the Caucasian genes will become part of that gene pool. Now let us say that this Caucasian man travels to China, and lives there for a while. During his time in China, he mates with a local Chinese woman, and she bears a child. Assuming that this new child remains in China and later procreates, then we will realize that the Caucasian genes have been introduced into this Asian gene pool. And on it would go, with Pacific Islanders, Native American Indians, and so forth. This example is given for academic illustration only, and does not constitute supporting such an experiment where a man would recklessly impregnate women all over the world and in essence, abandon the family only to move on.

Gene flow happens naturally when creatures move from one place to another (migrate). This happens with humans as well as animals. For example, a fox may drift too far from his birth place, and end up mating with canines in another part of the globe, thus introducing new genes into an existing pool.

EXAMPLE
There are some animals that can be found only in certain places. For example, some animals on Sri Lanka are not found anywhere else. This is also true about some animals in Australia and on Tasmania. The ocean has provided a natural barrier to prevent gene flow. That can be remedied by physically transporting animals from one place to another, and releasing them into the wild. However, transplanting gene pools is not limited to animals alone. There are many species of plant which have been introduced in parts of the world where it never had ancestors.

EXAMPLE
An example of gene flow is buffel (not buffalo) grass, imported from Kenya by Texas cattle ranchers. It is not native to the Western Hemisphere, but the ranchers thought it would be a good idea to get some tough grass that would survive the heat, lack of water, and being stepped on. In this way, cattle would have a source of food all the time. Little did they realize that buffel grass has now migrated west into New Mexico and Arizona, and it has begun to disrupt the existing ecology of the desert. Gene flow is not always a good thing!

When a gene changes, or is altered, it is known as “mutation.” Sometimes a mutation can be a natural occurrence, but other times outside influences cause the mutation. Something which causes a mutation is known as a “mutation-causer,” or “mutagen” for short. These include radiation (both light rays - such as the Sun’s tanning rays known as ultraviolet – and from radioactive decay), chemicals, and other stuff.
Since mutations cause genes to change, or be different, then the whole gene pool is affected as a result of a mutation. Of course, the majority of mutations are benign and have no impact on the life form. But every once in a while, such as change is lethal to the organism that has inherited it. On the other hand, occasionally a mutation will give the new life form an “edge” over its parents, and it may become healthier and stronger than either of its parents.

Like a factory worker reviewing parts, the process of natural selection picks out the beneficial changes in the gene pool, causing the population to change, or evolve. If a gene is bad for the organism, it is often identified and removed.

The selection of a sexual partner to mate with is a function of how attractive the mating partner is. It seems quite obvious that a creature would prefer to mate with an attractive partner. Some males pass along as much of their own genetic material as they can.

Males who actually do this are genetically healthy and fit, and in some way it is due to the males’ ability to attract females. The more females that they mate with, the more of their genetic material will be passed along in the gene pool. Thus, overall in the animal kingdom, it is common for males to compete with each other to “win” the female for mating.

Now, imagine two different events happening. First, let’s say that there is a population of cats living – scattered randomly - across a lovely and hilly grassland. Altogether, the population has one gene pool. Along comes an earthquake and a flood, effectively dividing the grassland into two parts. Since cats cannot fly, and don't like to swim, the one population has now become two.

At first, the gene pools are pretty much the same. But after a while, the mutations in one pool will be different that the mutations in another pool, and after many generations, the two groups of cats will diverge genetically and become separate species of cats. This process is called speciation. It is the reverse of merging, or combining, two pools.

How could two pools become merged? Let’s say that there are similar animals on both sides of the Bering Strait (between Alaska’s Aleutian Islands and Russia), but they cannot intermingle due to the barrier of water. Then one day an earthquake pushes up the land under the water, and voila! We have a land bridge that ambulatory animals can pass back and forth. Now, if there were two different breeds of canines, one on each side, they could form one group, and one gene pool. Well, not right away, of course, but over several generations.

Some people have said that now there are virtually no barriers between human beings world-wide, that in many generations from now there will be just one, huge, gene pool, and everyone will “look alike” in the sense that there will no longer be 5 races of humans, but only one.
Thus, we learn that by mixing and matching genes, or by changing them, we can create a whole host of different types of creatures.

**Key Concepts and Terms**
- evolution
- gene flow
- mutagen
- natural selection

**Questions**
1. What does the word “evolution” mean?
2. What do we mean by gene flow? Give an example.
3. What does a mutagen do?
4. The concept of natural selection came from what scientist?

**EVOLUTION OF HUMANS**

*From Life Forms to Animals to Primates to Humans*  
*(During this Lesson, do Lab 2 in the Appendix)*

It is interesting to ponder who could be considered the first human on Earth. Historically, many believe the first man was named *Adam*, and surely some male ancestor of humans must have existed. Therefore, for the sake of academic argument, we will just agree that there was a first male human, and we will call him “Adam.” However, who was he, and when did he live? We’ll come back to that later.

**Meanwhile, in the chain of Human Evolution we begin by realizing that life exists.** And life forms are either plant or animal (or the undefined bacterial types, but I digress). Therefore, some original life form came into existence, and over time, it divided into two life forms, the animal type and the plant type. It is unlikely that we were descended from a primeval plant, therefore, we must have been the result of thousands or millions of generations of animal life forms.

Therefore, we humans are part of the *Animal* Kingdom. The animal kingdom contains over a million existing species, in more than 30 subdivisions. The most overwhelming life forms are the subdivision called “Arthropoda,” which includes insects, crustaceans (like crabs, lobsters), and arachnids (spiders). The arthropoda outnumber, and outweigh, all other animal life forms put together.

We humans have internal skeletons, thus making us part of a subdivision known as “Vertebrates.” Even so, vertebrates make up less than 1% of the animal kingdom! The remainder of life forms includes worms, mollusks, starfish, sponges, and other marine animals.
Among the *vertebrates*, there are **five major subdivisions:** amphibians, birds, fish, mammals, and reptiles. Amphibians include frogs and toads. Birds range from the tiny humming bird to the majestic eagle. Fish are both those in the oceans, like tuna, and those in lakes and rivers, like trout and bass. Mammals are what we are most used to: cows, pigs, rabbits, and primates. Reptiles include all the lizards, alligators, crocodiles, and it even includes the extinct dinosaurs. Reptiles are “cold blooded,” in that they cannot regulate their own body temperature.

It may be obvious that we humans are not cows or pigs or rabbits. Rather, we are part of the primate group. Among the 235 versions of primates (yes, that many!), primates are divided into two main groups: the prosimians and the anthropoids.

About one-third of primates are the prosimians, which means “pre-apes.” An example of a prosimian is the **lemur**. Prosimians are primarily nocturnal animals (day sleepers).

It is interesting to note that lemurs are found only on two islands in the world, of which one is Madagascar.

The anthropoids (“human-like”), comprising two-thirds of all primates, include apes and monkeys. We must fit into one of these, since we are not night animals. Anthropoids are night sleepers, and so are we. (Don’t confuse anthropoids with arthropods). *You will learn more about the primates (and do a lab about them) in Lesson 7.*

Some individuals believe that monkeys and apes are the same. But this is not the case. Monkeys have tails and apes don’t. As we don’t have tails, it means that we humans must be part of the Ape Family.

Monkeys are listed as either “new world” or “old world,” meaning, western hemisphere or eastern hemisphere. The new world monkeys are in Central and South America, and are relatively small. Most of the better-known monkeys are from Africa and other similar places, and they include the Rhesus Monkey and the Baboon.

Since we don’t have tails, it is obvious we are not monkeys. But as mentioned before, we are part of the Apes.

Apes include the Chimpanzee, the Gorilla, the Orangutan, and – you guessed it – the Human. Yes, many of us may be upset and refuse to believe that we are part of the ape family. But the evidence clearly shows that it is where we belong. For example, 98% of the DNA in humans and in chimpanzees is identical. In fact, the closest relative of ours among animals is the chimpanzee. Therefore, somewhere in the distant past, both humans and chimpanzees must have had a common ancestor.

In the spring of 2003, anthropologists unearthed evidence of what might be a new type of Ape. The research, discovered in the Democratic Republic of Congo, gave rise to what may be either an extra large chimpanzee, or a type of gorilla that acts more like a
chimp. This new creature, tentatively given the name *Gorilla gorilla uellensis* for the location near the Uele River, makes ground-based lodgings, just like gorillas. However, the food that they eat is more like the food consumed by chimpanzees. More research is required on that one.

Well, now that we know that we are apes, we also know that we are NOT chimpanzees or gorillas or orangutans. We are humans. And thus, we need to trace our human roots, perhaps back to the ancestor common to all apes, or at least to us and the chimp.

The official scientific name of the ape family is the “Homindae,” or hominids. Among the apes, only one type is bi-pedal, i.e., walks upright on two legs (or two feet). The only bi-pedal ape is the human, and this subcategory has a name, too. This is the “Homininae,” or more commonly, the “Hominines.” This now brings us back to our search for “Adam.” In Judeo-Christian cultures and religions, a man by the name of “Adam” was believed to be the first man on Earth. In fact, the word “adam” in Aramaic means “first man.” So, it’s aptly applied.

**DID YOU KNOW?**

Aramaic is a Semitic language closely related to Hebrew, used in many dialectical forms in Mesopotamia and Syria before 1000 BC. In time, the Aramaic language became the lingua franca of the Middle East (an Assyro-Babylonian Language). Aramaic survived the fall of both Ninevah (612 BC) and Babylon (539 BC) and remained the official language of the Persian Empire (539-337 BC). Before the Christian era, Aramaic had become the language of the Jews in Palestine. Jesus preached in Aramaic, and parts of the Old Testament and much of the Jewish literature were written in that language. The influence of Aramaic began to decline in favor of Arabic at the time of the Arab conquests in the 7th century AD. **You will learn more about the apes (and do a lab about them) in Lesson 7**

Meanwhile, in 2004, scientists in Spain came across what may be a common ancestor to all living members of the ape family. A creature, tentatively called *Pierolapithecus catalaunicus*, is almost 13 million years old. It was dug up near Barcelona. Its body is stocky, like a gorilla, but its fingers resemble more those of chimpanzees than those of a gorilla. The general posture seems to be upright, making them more like the bi-pedal human.

Meanwhile, in 2004, an international team of scientists confirmed what is believed to be a member of the “human family” that may be a million years older than *Millennium Man* (read further to understand this).

Tentatively called *Ardipithecus ramidus kadabba* (ARK for short), this ancient progenitor was bi-pedal (walked on two feet). His name comes from the Kadabba region of Ethiopia. His original discovery in 1997 lead scientists to believe it to be 5.2 million years old. That has been pushed back to more than 6 million years.

For the record, an archeological group from France dug up the fossilized remains of a humanoid (human-like) animal initially
estimated to be 6.5 million years old, not far from where ARK was found. This would make the French
discovery older than ARK; however, at this point, the evidence is not solid enough to put in on the
humanoid evolutionary tree. Again, more research is required. For the sake of this writing, we will call
this “mystery” creature the “French ARK.”

ARK’s teeth, mouth bones, and the bones in the arm, collar, foot, and hand clearly identify it as
humanoid. The evidence for being bi-pedal comes from the structure of the toe bones of the feet.

The discovered humanoid fossils of ARK are from very early in human evolution, shortly after the
separation of chimpanzees and humans. For example, the angled joint at the back of ARK’s toe bone
shows that it used its design to push off, or move forward, in a way that chimps don’t. In fact, none of
the apes, save humans, have this feature. And ARK has it.

While it is true that apes, and particularly chimps, can walk on two feet, their walk is very unbalanced
and awkward, and it is not a natural way of movement for them. Instead, they use their back legs and
forearms to walk on. In essence, they walk on their front knuckles. Once in a while they do lean
against objects and are upright, but, again, it is a brief position.

Interestingly, archeologists and anthropologists began their trek by using satellite imagery that
showed the most promising locations for finding such remains.

In summary, this research has shown that, in only a two year period of study, the oldest ancestor of
humans has gone from Ardipithecus ramidus, 4.4 million years ago, to Millennium man about 5.8
million years ago, to ARK, about 6.0 million years ago, to the French ARK of about 6.5 million years
ago. And that doesn’t even include the 13-million-year-old *Pierolapithecus catalaunicus* found in
Spain, that may have been the common ancestor to both humans and chimps. You will learn more
about these hominids (and do a lab about them) in Lesson 7.

As one might expect, there are always divisions of groups, and the Homo Sapiens are no different.
There are two subcategories of Homo Sapiens: Homo Sapiens Neanderthalensis and Homo Sapiens
Sapiens.

At one point, about 300,000 years ago, there was a species of humanoids known as Homo Sapiens.
However, about 150,000 or so years later, genetic evolution began to divide this one group into two
different groups: the Neanderthals and the Cro-Magnons. It is also interesting to note that the Homo
Sapiens Sapiens literally means “twice wise” or “wiser than wise.” In other words, the Homo Sapiens
Sapiens were wiser than the Neanderthals, and that is perhaps how they survived, while the
Neanderthals became extinct. It is not known why they were not named Homo Sapiens Cro-Magnonus
or some similar term. You will learn more about the Neanderthals (and do a lab about them) in Lesson
7 and about Cro-Magnon in Lesson 7.
Key Concepts and Terms

- anthropoids
- arthropods
- hominid
- invertebrates
- primate
- vertebrates

Questions

1. What is the difference between an arthropod and an anthropoid?
2. Compare and contrast vertebrates with invertebrates.
3. What is a primate?
4. What is a hominid?

LESSON 2 STUDY QUESTIONS. FILL IN THE BLANK WITH THE CORRECT WORD. CHECK YOUR ANSWERS.

1. Bacteria and protozoa are “unicellular.”
2. The amoeba is single-cell creature.
3. A bacterium is a single cell.
4. Animal cells don’t really have an outer cell wall, but, instead, a plasma membrane.
5. Innumerable cells form teams, or groups, called tissues.
6. Bones and tendons are made up of connective tissue.
7. The membrane wall is made of a combination of fats, proteins, and simple carbohydrates.
8. DNA, typically located in the nucleus, has all the genetic information that the cell needs.
9. The information about genes is imprinted in the chromosomes that make up DNA.
10. One of the greatest projects of all time happened during the last decade of the 20th Century: the Human Genome Project.

ANSWERS TO LESSON 2 STUDY QUESTIONS.

1. unicellular  6. connective
2. amoeba  7. carbohydrates
3. plasma  8. genetic
4. membrane  9. chromosomes
5. tissues  10. Human Genome Project
LESSON 3

BIOSPHERE

In this Lesson, you will understand how life forms interact and survive in many environments.

The Lesson includes:

Ecosystems (Lab 3: Terrarium)

Space ship Earth (Lab 4: The fragile Earth)

BioSphere 2 in Tucson, Arizona (Field trip to Tucson)

Limitations of Life Forms

ECOSYSTEMS
(During this lesson, do Lab 3: Terrarium)

An ecosystem is a “closed system” in which all the life forms within that environment interact in a synergistic way. The word “synergy” comes from the Greek word *sunergos*, meaning “working together.” Thus, the plants and animals “work together” within that environment to not only survive, but to thrive.

The name of the science that studies ecosystems is “ecology,” which comes from two Greek words, *oikos*, meaning “house,” and *logos*, meaning “study.” Thus, ecology is the study of a house. More applicable, it is the “study of a home,” or a “study of a home environment.”

Plants and animals react to their physical and biological environments. The physical environment includes light and heat (mostly from solar radiation), moisture, the atmosphere (wind, oxygen, carbon dioxide), nutrients in soil, water, and other items. The biological environment includes organisms of the same kind as well as other plants and animals.

Ecology depends on a whole host of related sciences to find out the relevant information. Thus, there is some overlap between ecology and these other sciences.

Ecology was suggested as an independent science by the German biologist Ernst Heinrich Haeckel in 1866. Ecology was advanced by the likes of Charles Darwin, who had advocated the ability of life forms to adapt and change as a function of their surroundings.

A helpful way to study the realm of earthen and liquid environments is to see them as ecosystems. The word, “ecosystem” was used by a British Botanist, Arthur Tansley, in 1935.
An ecosystem can be divided into subdivisions. For example, some aspects produce (the vegetation). Some aspects use (plant eaters and meat eaters), and others help break things down (bacteria and similar life forms). There are also the inanimate substances that contribute, such as the nutrient rich soil and minerals.

**External aspects that are thrust into, or absorbed by, the ecosystem, include the air, water, and the sun’s energy.** In return, the ecosystem exports stuff, which also include air, water, and heat. All of this process is driven by the sun. The air that is given off is NOT identical to the air coming in, as the ratio of air’s gases (nitrogen, oxygen, carbon dioxide, etc.) change.

**Ecosystems are marvelous examples of the recycling of nature.** Solar energy is absorbed by plants which use this energy, along with nutrients from the soil and rain water, to create their own food supply. This process is known as photosynthesis. In turn, animals eat the plants (herbivores) and gain some of this natural nutrition. Then other animals may come by and eat the herbivores, and, thus, get their nourishment. (Animals who eat other animals, i.e., meat eaters, are called carnivores. Humans are typically omnivores – we will eat both plants and animals).

Of course, not all the material from plants and animals gets eaten. For example, leaves, branches, fallen trees, fecal matter, leftover animal body parts, and so forth, merely rot, or decompose, and become part of the nutritious organic compound of Earth’s soil. The decomposition is, in reality, caused by the tiniest of life forms, such as bacteria and microbes, that “eat” the leftover stuff, and their waste material is the rich soil. About 40% of Earth’s soil is organic – recycled dead stuff. The remaining 60% is made of rocks and minerals from Earth’s geologic origins.

It is not a good thing for humans to eat dirt, as it has so much “dead stuff” and bacteria in it. However, in the long run, it may not hurt the consumer, and may actually help him develop a stronger immune system. There once was a man, born in Denver, Colorado, who used to eat dirt when he was a child. His family later moved to Salt Lake City, Utah. The boy found the flavor of Utah dirt unpleasant, so he stopped eating dirt. His culinary taste in soil didn’t seem to negatively impact his life, as he grew up healthy, and went on to marry and have children, eventually settling in Carson City, Nevada.

**It is most interesting to realize that nature wastes nothing, but just recycles all it has,** over and over - even with this somewhat unusual dirt-eater. However, it is recommended that one have a diet rich in fruits and vegetables, with a moderate supply of meats and other proteins, as well as grains.

**Ecosystems are very sensitive and survive on a balanced regimen.** The proper level of recycling keeps things going. Even so, some ecosystems lose more needed moisture and/or nutrients than they can deal with, requiring that they “import” from outside the ecosystem what they need. In other words, while ideally ecosystems are “closed” and self-supporting entities, **real ecosystems have “holes” or leaks in their systems which cause a negative drain of resources. Importing water and nutrients from the outside becomes mandatory to the survival of the ecosystem.** Where would outside nutrients come from? Well, when it rains or is windy, nearby rocks or hillsides are eroded, and some of that material finds its way into the nearby ecosystem. Rain often brings dissolved chemicals from other areas, too. Of course, the same kinds of erosion can remove nutrients
from the ecosystem, and that must be replaced. This is one of the reasons why we must fertilize certain lands in order to grow crops.

**Now, if the outflow of nutrients is greater than the inflow, then the ecosystem will eventually fail.** But the same is true if more material pours into the ecosystem than goes out. The result of this could lead to pollution. For example, *industrial waste and raw sewage* from metropolitan regions, all flow into creeks, canals, rivers, streams, and lakes. This results in the death and destruction of many plant life forms, and any animals that rely on those now dead plants. Another example is acid rain, which upsets the acid-base equilibrium in the soil, and depletes the natural limestone there. As some life forms die, others that are more tolerant begin to dominate, and thus, a whole ecosystem changes.

All populations survive or die based upon the ratio of their birth rate to their death rate, or BR/DR. When the ratio of BR/DR > 1, then there is growth. When the ratio BR/DR < 1, then there is decline. And, of course, when BR = DR, then it is called “zero population growth.” There are many agencies around the globe that are trying to promote zero population growth so that the carrying capacity of our planet will not be exceeded.

Sometimes explosive growth occurs when a plant or animal species arrives in an area with abundant resources and no other life forms to compete with. The problem is that the growth reaches a limit, the resources are used up, and the population declines, or even dies out. This could happen to Earth as humans continue to multiply, but the planet’s resources are not infinite. Eventually, with our current rate of population growth, the time will come when the total mass of humanity will exceed the mass of the entire Earth, and, of course, that is not possible.

Naturally, other life form ecosystems may begin in an explosive manner, but for some reason(s) they naturally level off. This natural level of population comes when they reach zero growth. The tendency is to provide fewer births, but better care for those new life forms. The term “birth” here includes the germination of new plant life, too.

The “survival of the fittest” is invoked when several life forms compete for available resources; the successful ones continue. The rest move on or die off. Small herbivores, such as rodents, may forage the forest floor and eat the smaller and weaker plants, thus thinning an area that was meant to be thinned anyway. Thus, the rodent becomes a predator of plants. Of course, a carnivore may come along and eat the rodent, the carnivore becomes the predator of the rodent. If all the rodents get eaten, then the floor of the forest may become congested with foliage. Extra foliage may, in turn, provide cover for new herbivores to enter the region, and thus life goes, in one endless cycle.

Another type of predator is a parasite. We’re not talking about tourist areas in Paris, France. These are little “bugs” that live on another life form. Bacteria and viruses are parasites, but they may become self-defeating parasites if they end up killing their host. Even so, there are myriads of “beneficial” bacteria that live in, or on, their host, and provide a positive, or symbiotic, relationship.

Ecosystems are ever-flowing, ever evolving. The life forms that inhabit them change over time. It may begin with a poorly-used area which attracts a hearty species that can tolerate the harsh conditions. Eventually, those life forms may actually improve the living conditions there, and new life forms are
attracted, that may drive out, or kill off, the original plant or animals. Given time, a climax is reached, where evolution pretty much comes to a stop, and it becomes a stable environment in equilibrium.

In summary, ecology, the study of ecosystems, is most valuable in helping us find out how to sustain desirable areas, and how to control exotic life forms. In the end, the Earth itself is one giant ecosystem, known as Biosphere.

Key Concepts and Terms
- birthrate
- carnivore
- death rate
- ecology
- ecosystem
- herbivore
- omnivore
- synergy

Questions
1. What happens when the birthrate exceeds the deathrate?
2. Compare and contrast carnivores, herbivores, and omnivores
3. What is an ecosystem?
4. Synergy refers to what?

SPACESHIP EARTH
(During this lesson, do Lab 4: The Fragile Earth)

The thin mantle of life that covers the earth is called the biosphere. This includes the lithosphere and the atmosphere. The lithosphere is the upper part of Earth’s solid part, including the crust and upper mantle.

The word “lithosphere” comes from two Greek words, lithos, which means “stone,” and sphaira, which means “ball-shaped object.” The element Lithium, Number 3 on the Periodic Table, also gets its name from lithos. Thus, “lithosphere” means a “ball of stone,” more or less. It is the ball-shaped upper shell of Earth’s globe, and extends from the surface down to about 100 kilometers.

The word “atmosphere” comes from two Greek words, atmos, which means “vapor” or “gas,” and, once again, sphaira, which means “ball-shaped object.” Therefore, “atmosphere” means a “ball of gas.” It is the thin shell, or envelope, of air just above Earth’s surface. It extends from the surface up to about 100 kilometers, although almost all of it is within 10 kilometers. Beyond that, the air is extremely thin.
In summary, the biosphere, meaning “ball of life,” is that region on Earth that supports life: the crust and soil, and the air. The planet Earth is essentially known as “Biosphere 1,” as there is a “Biosphere 2” mentioned in the next lesson.

A number of strategies are employed to put Biosphere’s regions into perspective. The vast areas of vegetation on Earth are labeled “biomes” which include both plant and animal. The word “biome” comes from a combination of the Greek words bio and some, meaning “life body.” Thus, biomes are “bodies of life,” or more precisely, areas of life forms. The most significant biomes are named for the most predominant plant life.

Biomes are affected by how far they are from the equator, altitude, elevation, and humidity. Biomes are also a function of geography, as tropic areas and arctic areas are quite different. Each geographical region contains its own variety of trees, grass, bushes, and even the dry desert.

We cannot exclude the bodies of water that are part of these biomes, which include lakes, rivers, streams, creeks, canals, ponds, and wetlands such as the Everglades. The aforementioned water sources are called “freshwater” regions.

Saltwater regions, such as marine environments, include oceans and seas, along with large, inland salt lakes (Salt Lake, Utah; Salton Sea, California; Dead Sea Israel, etc.). These areas are further divided into the shallow waters of these bodies, the deep waters, the various shorelines, the fluvial outflow areas (river deltas), and even tidal marshes.

Our planet Earth, however, is more than just a ball of rock, gas, and teeming life. It is in reality a spaceship. Yes, it’s a spaceship.

A typical spaceship is some kind of enclosed device that is sealed off from its environment, as is a submarine. In fact, a spaceship and a submarine are almost identical in many ways. One explores outer space. The other explores inner space, i.e., the ocean. Both must be self-contained, and carry their own food, water, and air. They must have highly-efficient recycling systems so as to preserve resources. Any water used must be purified, so as to be used again. Any air used must have a purification system, too. Plus, there must be adequate additional supplies of air and water on board. And, without a doubt, there must be enough food to last the entire voyage.

The National Aeronautics and Space Administration, or NASA, has been developing enormous space laboratories that can orbit Earth for thousands of years, or even take explorers to other worlds. For example, one particular unit is shaped like two immense doughnuts that are connected in the middle. The system rotates at a rate fast enough to create “artificial gravity” inside As long as one is in the right place inside the “doughnut,” it will seem just like gravity. The scientific name for such a doughnut is a “torus.” The tubes and tunnels connecting the two torus objects would have close to zero gravity.

Each torus could be made to resemble any Earth neighborhood, and the unit would be so large that clouds would form and it would rain inside. The
diameter of either torus would be 6 kilometers, so a person would not really be able to see the “top” ceiling of the torus structure. Each torus could hold millions of people.

Another proposal would be to have two large cylinders, each 30 kilometers long and 6 kilometers in diameter. The cylinders would be connected to each other via a tube tunnel, and the whole unit would rotate at a rate to simulate gravity. The effect would be the same as the double torus. And both the torus and the cylinder would be revolving about Earth, perhaps in a geosynchronous orbit that would enable it to remain above the same identical place on Earth all the time.

While all of these things sound fantastic, they are part of reality and can be done. We have created space stations already, and we are in the process of a never-ending project in space called the International Space Station. This unit is modular and more will be added to it over many generations.

Our planet Earth, though, also has only enough food, water, and air to sustain life as it is, for a period of time. If we pollute the air and water, kill off the food, and otherwise hurt Mother Earth, it will die, and like a spaceship that has run out of supplies, all its inhabitants will die, too.

Earth is rotating at a rate of one turn per day, or about 1,600 kilometers per hour at the equator. One might think that this is a very fast speed, and that we would be tossed off into space, but it is not fast enough to do that, as the gravitational force is far greater than the centrifugal force that may toss us off. The Earth would have to be spinning at a rate of once per hour, or about 38,000 kilometers per hour at the equator, to cause things to fly off. So, just like the torus or the cylinder, Earth is rotating.

Also like the torus and the cylinder, Earth is revolving. But our planet is revolving about our star, the Sun. It takes Earth one year, or 365 days to complete one cycle around the Sun. But how far is that, in kilometers? That’s almost a billion kilometers! Since there are about 31.7 million seconds in a year, that means Earth is traveling around the Sun at a rate of about 30 kilometers per second (or 108,000 kilometers per hour)! That’s really fast!

So, Earth is a self-contained unit, traveling through space at an incredible speed, as it orbits the Sun. But we are not even including that the Sun is revolving around the center of our Galaxy once every 240 million years. Relative to the center of the Galaxy, the Sun is traveling at about 500 km/sec, or 1.8 million kilometers per hour!

As mentioned in the previous lesson, we must pay careful attention to preserving the delicate ecological balances within our Earthen environment, if we are to avoid total extinction of all life forms on Spaceship Earth.
Key Concepts and Terms

- atmosphere
- biosphere
- centrifugal force
- lithosphere
- spaceship
- torus

Questions

1. What does biosphere mean?
2. What is Centrifugal force?
3. What is the lithosphere?
4. What kind of shape is a torus?

BIOSPHERE 2
(Field Trip to Tucson, Arizona)

In as much as humans and many other life forms have managed to survive on planet Earth, could this environment be duplicated on a small scale and be successful? The way to find out was to create a mini-Earth ecosystem called Biosphere 2.

In a way, Biosphere 2 was the largest greenhouse on the planet. While it is no longer an active research project, Biosphere 2 was a fabulously amazing experiment that endeavored to duplicate Earth’s environment in a closed ecological system.

Built at the foot of the jagged Santa Catalina Mountains in the Sonora Desert, the completed Biosphere 2 was “open for business” as a research experiment by late 1991. Much of what existed then is still intact.

Biosphere 2 contains two enormous mechanical "lungs" to circulate air. Its artificial rain forest simulates an Amazon jungle at a height of 30 meters. There are several savanna grasslands, and below that, two deserts. Plus, there is a swampland, a miniature ocean with ocean waves, a coral reef, tropical fish, and even a sandy beach. The air in the rain forest is very humid, and the temperature is quite warm. As one leaves the rain forest and enters a grassland, the change
of humidity is very startling. One moment you’re in a hot, humid jungle, and a few steps later, you’re in a dry, and slightly cooler, savanna. Then a few steps more, and you find yourself in a very hot and dry desert.

It’s uncanny. And, other than the tourists and tour guides, the only other animal life forms there are myriads of tiny ants, just about everywhere. And, yes, there are still fish in the ocean.

The facility itself, an enormous enclosed structure with a number of separate biomes and ecosystems inside it, was built on 250 acres of the southern Arizona Sonora Desert, just north of Tucson. Biosphere 2 contains an “ocean” with 900,000 gallons of water, a rain forest, a desert, many agricultural areas – and, of course - a human habitat. The Biosphere 2-unit building covers 3.5 acres on the larger tract of land.

Very much like a terrarium with a thyroid condition, Biosphere 2 was built to prove that self-sustaining ecosystems are possible, and / or to find out the reasons why they cannot survive. The name “Biosphere 2” was chosen for this project, since our planet, Earth, is the original Biosphere 1.

Biosphere 2 was built in 1990-1991, and cost about $150 million. Much of the funding came from a Texas oil billionaire named Edward Bass.

The project dates back to 1973, after Bass had dropped out of Yale to explore life and “find himself.” In the end, Bass ran into a brilliant, if eccentric, man named John Allen. A man of charisma, Allen was called a New Age visionary by some and a “cult leader by others. When Bass and Allen met, Allen was running a theatre group at a commune near Santa Fe, New Mexico. The location was called Synergia Ranch.

Some of the early planners for Biosphere 2 were interested in space travel and in the colonization of nearby planets. They felt that the construction of the sealed Biosphere 2 would help them understand what challenges could arise from living in a closed system. Therefore, in the fall of 1991, eight “Robinson Crusoe” – type characters began a two-year adventure aboard Biosphere 2.
However, where did Biosphere 2 get its start? Let’s go back to when Biosphere 2 was just a kernel of an idea inside the mind of John P. Allen, a scientist, ecologist, engineer, inventor, businessman – and New Age visionary.

John Polk Allen was born in Oklahoma during 1929 – just prior to the dust bowl epidemic that swept the Midwest.

He graduated with honors from high school, going on to study history, anthropology, and other subjects at a variety of universities. He eventually got a degree in metallurgy from Colorado School of Mines, and later an M.B.A. from Harvard University.

Much of his early career was spent working for organizations in mining or in ecology. During most of his life he served as a consultant for a great many corporations. From 1969 to 1974, Allen was the manager of a ranch in New Mexico whose prime purpose was to learn how to develop a synergistic relationship between man and nature through the drama of a theatre troupe. After having befriended Bass, he went from there to join a number of others in creating Ecotechnics Corporation and later Decisions Team, Inc., both of which were major participants in Biosphere 2.

Space Biospheres Ventures (SBV) was created in July 1984 as a co-equal joint venture between two organizations: Decisions Team, whose CEO was Margaret Augustine, and Decisions Investment, whose CEO was Edward Bass. Shortly after this, SBV purchased a large tract of land north of Tucson, and named it “SunSpace Ranch.” This is where they planned to build Biosphere 2. The location was picked, as it seemed ideal to gain the necessary sunlight to make the project succeed. And, of course, the desert southwest is well-known for its many days of sunshine.

John Allen was hired by SBV to head the research and development team, and to serve as the chair of that division. He was also an advisor to Edward Bass at the time.

In December 1984 SBV held a global conference and invited a number of well-known scientists and engineers. Their goal was to analyze a feasibility study regarding Biosphere 2. Overall, the sixty delegates were extremely supportive of Biosphere 2, and quite a few of them volunteered to sign on as consultants to help it along.

During the following year, prototype designs were drafted, and a mock Biosphere 2 was created to test some of the experiments. In preparation, two highly interactive international seminars detailed John
Allen's plan to develop the 7-biome, 3-acre “real thing,” and this allowed the interaction between the
engineers involved in ecology, and those involved in the design of the facility.

In 1986, systems tests began on the mock Biosphere 2 and on a series of greenhouses in advance of
creating the full unit. The next July, in 1987, another workshop was held by SBV – this time the topic
was about closed ecological environments. This workshop even attracted the attention of NASA
engineers, many of whom attended the London symposium. Before the end of 1987, the designs had
been finished, and a construction site was laid out. Further, scientists involved in the project began
collecting specimens of plants and animals from all over the world for insertion into Biosphere 2.

Humans were first inserted into a Biosphere 2-test program on September 10, 1988, when John Allen
himself became the first person to live in a sealed ecological system over a 3-day period. All of the air
and water were recycled, and all of the food he consumed had been grown within that environment.
The following March, a marine biologist named Abigail Alling repeated Allen’s human experiment
and remained five days in a sealed environment. She later became one of the on-board researchers.

Another global symposium on closed ecological environments was held in Russia in the fall of 1989.
This conference recognized a new science called “Biospherics” dealing with such closed systems.

On November 6, 1989, another scientist, Linda Leigh, began a stay of 21 days in the mock test sphere,
in which the necessary carbon cycle showed that it would become self-established. She, too, ended up
as one of the first aboard when the experiment began. With virtually all of the tests completed showing
positive results, SBV approved the start of the construction of the real Biosphere 2.

Construction on Biosphere 2 and the installation of all its interior parts continued at a fast pace all
through 1990, and well into 1991, when finally, it was ready for its maiden voyage in September 1991.

Crew members on a spaceship are called “astronauts.” Those who explore the depths of the ocean are
dubbed “aquanauts.” Therefore, what should those who were chosen to be the first ones aboard the real
Biosphere 2 be called? They were named “Biospherians.” The eight crew members came from 7
different nations. Each had specialized education and training over a two-year period prior to the
experiment, so as to prepare them. There were four men and four women among that first crew.

The eight members were Abigail Alling, Linda Leigh, Taber MacCallum,
Mark Nelson, Jane Poynter, Sally Silverstone, Mark Van Thillo, and Dr.
Roy Walford. Abigail Alling was a marine biologist. Linda Leigh was an
expert in surface biomes. Taber MacCallum was a systems analyst. Mark
Nelson was involved in communications, assisting Linda Leigh in biomes,
and he ran the recycling process. Jane Poynter was in charge of the crops
in the “field.” Sally Silverstone was a managing supervisor of the entire
program, and worked in agriculture and food systems. Mark Van Thillo
was the chief technician and assisted both Sally Silverstone in supervising,
and Dr. Walford as a paramedic. Finally, Dr. Roy Walford was the chief
medical officer, as he was an M.D., and the oldest of the eight
Biospherians.
The Biospherians entered Biosphere 2 shortly after sunrise on September 26, 1991, and, like Noah’s Ark, it contained a great number of plant and animal species. The beginning of Biosphere 2 was televised worldwide. The start of this grand experiment coincided with a related workshop on biospherics.

But almost from the moment they sealed the airlock, things began to go wrong. And, in reality, that’s okay, since these difficulties had not been foreseen, and lessons can be learned regarding subsequent types of experiments. That is, in essence, the scientific method. But many things went “right.” A brief synopsis of the good and the bad follows.

On October 11, 1991, bionaut Jane Poynter accidentally cut off the tip of one finger, and was removed from Biosphere 2 for surgery. She returned later that day.

Beginning that fall, the skies over southern Arizona were far cloudier during that two-year period than had ever been recorded in history. How can one predict that? As overcast skies contributed to a lower rate of photosynthesis, carbon dioxide levels increased to about 3400 parts per million. As a result, plants did not produce the oxygen that was originally expected.

In December 1991, a test of gas leaks was done. The test resulted in finding an annual leak-rate of less than 10% - which was 30 times better than any of NASA’s Space Shuttles.

Then, both the humming birds and the bumblebees started to die off. These were critical on the pollination of plants, especially crops. Thus, many of the food crops began to fail. The coffee plants that were grown were a bit meager, resulting in a yield that allowed about two cups of coffee per person each month.

However, some birds did not only survive, they even thrived. Some uninvited English sparrows somehow “sneaked into” Biosphere 2 before it was sealed up, and became “stowaways.”

One of the primate species brought aboard were galagos. In February 1992, a baby galago was born – a baby that had been conceived after the start of the experiment. This was a good thing.

In May 1992, Biosphere 2’s tightly sealed environment showed a decrease rate in oxygen of about 0.3% per month. This decline was neither expected nor predicted. Therefore, even something unexpectedly negative can have beneficial results in the field of research. That is why, in fact, Biosphere 2 came into existence – to find out things just like this.

Pigs, which had been brought on board as livestock, got loose and raided the vegetable gardens and, thus, decreased the human food supply. But before long, they died off, too.

The chickens seemed a bit “spooked” in their new digs, and laid only 256 eggs the first year. If all these eggs were consumed by the Biospherians, that would allow 32 eggs, per person, per year, or about 2 to 3 eggs per month for each human. Not surprisingly, the cockroaches were a hearty species and their population grew quite rapidly. In turn, they were captured and fed to the grateful chickens, who then increased their rate of egg production. Over time, 76% of the vertebrate species in Biosphere 2 became extinct.
Food production and diet were austere and low-calorie. For example, breakfast consisted of a grain gruel (rice, sorghum, or wheat) with herbal tea. Lunch included fruits and vegetables, often with beans and rice. Dinner had more food, but it was similar to lunch, with the addition of some bananas, beets, and yams.

According to the medical tests by Dr. Walford, the Biospherians were, indeed, getting healthier. But some complained of low energy levels. Jane Poynter, one of the “Elected Eight,” has been repeatedly quoted as having said, "Basically, we suffocated, starved, and went mad." Leigh apparently agreed with Poynter to a degree, acknowledging that the going was difficult, and that it seemed as if they were not getting enough food. Biospherians began to accuse each other of stealing and hiding food. As a result, the refrigerator got padlocked.

On September 26, 1992, the crew of Biosphere 2 observed one year of being sealed up. Meanwhile, some 6000 came to the site to join in on the celebration.

The crew’s physician, Dr. Roy Walford, reported that after one year, the crew’s health remained quite good. In fact, they were healthier after one year inside the module than they had been prior to their insertion. This may well have been due to a low-fat, low calorie diet, which was also rich in nutrients. After that first year, the mean loss in body weight averaged 16% per crewmember. For example, if a man had weighed 200 pounds upon entry to Biosphere 2, then after one year, he had lost 32 pounds, and was down to 168 pounds. For a woman who had entered at 125 pounds, she would then be down to 105 pounds. In reality, the men lost more weight on a percentage basis than the women did, but you get the idea.

After having made it to the one-year mark, the bionauts had a celebration of their own, away from the crowds. The adventurers collected several bunches of bananas that they had planned to dry. However, in the end, it was decided to ferment the bananas to make a banana liqueur. Apparently the alcoholic beverage wasn’t very tasty, but the inhabitants seemed to enjoy the after effects.

Even so, the members of the Biosphere 2 team were becoming depressed. Some thought it might be fun to go snorkeling in the mini-ocean. Others thought that having beach parties would lighten their spirits. Try as they might, nothing had a lasting effect on their dark moods.

Food, however, was not the big problem. They were running out of clean, breathable air. The oxygen levels dropped pretty far. Some Biospherians said that they began to have difficulty maintaining physical work levels. They had to stop too often to “catch their breath.” While it was a mystery at the time as to why the oxygen levels had decreased, it was later found out that, believe it or not, the structure's own concrete was absorbing some of the oxygen. In addition, there were tiny microbes in the soil that were also using the air supply.

Ever annoyed by constant hunger and always out of breath, the Biospherians became irritable. Arguments broke out over work assignments and food portions. In many cases, communication ceased among some of the Biospherians.
For a time, the group had divided into two “armed” camps. One side wanted more oxygen pumped in. The other team wanted to destroy some land areas to plant more crops. Of course, all of these concerns are valid for any “tribe” that may inhabit Earth.

Eventually, more oxygen was added, which improved morale. However, it created a pall of doubt over the project. On January 13, 1993 oxygen was added to Biosphere 2’s air to increase its level to 19%. Normal atmospheric oxygen at sea level is about 21%. The slow leakage mentioned above had continued until the level reached 14.5%, which is similar to the oxygen availability at 13,000 feet. As the level dropped rather slowly, the Biospherians were able to adapt to a good extent. After all, there are subsets of human society that live, and thrive, at very high altitudes on Earth, and through generations, they have been able to adapt to it. While there were times that the Biospherians felt as if they were “out of breath,” at no time were they in danger, and the results had given science new benchmarks for human adaptability in the exploration of external planets.

Up until February 1993, the Biospherians had been able to grow 80% of their own food to sustain their lives. The rest of their diet had come from food stores that had been grown previously in the system, and had been placed on board.

No matter. On September 26, 1993, the eight Biosphere 2 inhabitants exited their glass ark, and returned to Biosphere 1, albeit, a bit wiser, and a bit thinner. But not all of the excellent eight were eager to depart. Apparently, Botanist Linda Leigh wanted to stay longer, assuming that they could have solved some of the glitches. Leigh lamented the constant flow of “looky loos” who kept peering in, waving, and sometimes knocking on the glass panes. In some ways, Leigh felt like one of the primates in the experiment. Well, in fact, she was.

During a 6-month transition period, Mr. Bass decided to change the focus of the Biosphere 2 from a total system approach to a reductionist approach in ecology. The ensuing clash in the policies of the partners in Biosphere 2 led to a negotiation process resulting in a mutually agreed settlement and effectively dissolving the joint venture. It was decided that Decisions Team, Inc., would continue its work in biospherics elsewhere. So, on June 1, 1994, with the joint venture dissolved, Mission Two came to an end. The 7 new bionauts (5 men and 2 women) were removed from Biosphere 2, and it never again existed as a closed system.

Mr. Bass and his appointed President, Steve Bannon and the Scientific Committee, led by Wallace Broecker and Michael Crow of Columbia University, took over the operations. At this point, the project soon suffered scientific disdain and public ridicule.

On January 1, 1996, Mr. Bass entered into a 5-year lease with Columbia University for Biosphere 2. The University turned it into a world class educational center with reductionist ecosystems studies emphasizing carbon dioxide levels. Columbia University renewed its lease in 2000 for ten more years, but in 2003, the University ended its relationship with Biosphere 2 and Mr. Bass.

On January 1, 2004, Biosphere 2 Center opened its sealed doors to visitors as a hands-on, interactive science center. At that time, tourists were able to tour the apartments, kitchen, dining room, and other areas where the Biospherians worked and lived. From this area, visitors can also look out into the rain forest, ocean, desert, savanna and agricultural ecosystems that the Biospherians struggled to manage.
However, in 2005, Mr. Bass decided to sell Biosphere 2, and it is now actively on the market as of this writing.

**Key Concepts**
- biome
- bionaut
- biosphere 2
- extinction

**Questions**
1. What was Biosphere 2?
2. Why did they name it Biosphere 2, instead of just Biosphere?
3. How many bionauts entered Biosphere 2?
4. How long did the bionauts stay “on board”?
5. What did they learn having done this grand experiment?

**LIMITATIONS OF LIFE FORMS**

There are certain parameters for life to exist. Remarkably, however, life forms can exist in what seem the harshest conditions. Several life forms even exist in the frigid realms of Antarctica. But the harshest conditions on planet Earth are like heaven compared to those on the nearby planet, Mars. Thus, we ask ourselves, “Can life exist on Mars, or on some other planet in the Solar System?” The answers are both yes and no. How so?

**It is believed that at one time the red planet Mars was hospitable enough to support some type of life.**

**It is currently believed that there are some simple life forms within the atmosphere of Jupiter.** However, much more research is needed to verify such a theory.

Earth’s original primordial atmosphere of hydrogen, helium, and other gases eventually gave way to another atmosphere, mostly generated by volcanic exhaust. Volcanic gas is full of water vapor (about 57%), carbon dioxide (23%), sulfur dioxide (12%), nitrogen (7%), and other gases. Over time, the water vapor condensed out of the air and became the oceans, seas, lakes, rivers, and streams. The carbon dioxide combined with the ocean’s water and with the rocks and soil, as did the sulfur dioxide. But nitrogen is not very reactive, and it is pretty much still in the air.
Our final atmosphere contains nitrogen (78%), oxygen (21%), argon (1%), and variable amounts of carbon dioxide and water vapor. (The numbers are rounded). And some air pollution.

Eventually, on Earth, the formation of large amount of oxygen, $\text{O}_2$, from hydrolysis, changed the Earth’s air from a reducing atmosphere to an oxidizing (with oxygen) atmosphere. This was done by the Sun’s light supplying energy to water vapor hovering just above the ocean’s surface, by the reaction:

$$2\ \text{H}_2\text{O} + E_o = 2\ \text{H}_2 + \text{O}_2$$

where $E_o$ represents the Sun’s energy. Subsequently the hydrogen gas, $\text{H}_2$, being so extremely light, drifted to the top of the Earth’s atmosphere, and escaped into space. Oxygen, $\text{O}_2$, was too heavy to escape, so it continued to build up.

After a while, oxygen became so prevalent that it actually killed almost all of the existing life forms. How? By oxidizing, or burning, it. As adaptable as life is, some life forms evolved and survived, and created new life forms that used oxygen, and kept some life forms (plants) that gave off oxygen. Now we have a symbiotic, or synergistic, relationship on Earth: plants and animals help each other.

We have determined that the chemistry of all life forms, whether plant or animal, are identical on Earth. But that doesn’t mean other life forms elsewhere are the same as ours. They would most likely have to be carbon-based, but there may be types that are neither plant nor animal.

Each molecule of any compound has a certain shape. Whenever a molecule is created, the same shape occurs. For some simple molecules, like water or carbon dioxide, the shape looks and acts the same whether it is forward or backward – facing front or turned around.

**EXAMPLE**

Imagine looking at yourself in a mirror. Your image is not how you look. It’s very similar, but it is still the reverse of you. If you raise your right hand, your mirror image will raise its left hand. However, if you raise your right hand, and if your mirror image raises its right hand, I’d get out of the house really fast.

Meanwhile, if you put a carbon dioxide molecule in front of a mirror (pretend that you could see it; or imagine a scale model of it), then its reverse image in the mirror will be exactly the same. If, however, you were to put up a complex molecule, like glucose, $\text{C}_6\text{H}_{12}\text{O}_6$, it would not be identical. Its shape would be reversed, and one could see the difference.
Chirality

Interestingly, all organic compounds on Earth have one configuration, and one configuration only. We never find any reverse configurations in nature. In chemistry we call these organic molecules “right-handed.” The reverse image is called “left-handed.” Of course molecules don’t have hands, but, remember, your left hand is the mirror image of your right hand. And if you look at the image of your right hand in a mirror, the image is a left hand. Thus, we have adopted this type of phrase: “All organic life forms on Earth are right-handed.” If we were to find a life form that was left-handed, then we would know it did not come from Earth. The concept of “chirality” is the concept of whether the material is right- or left-handed.

Astronomers have been looking for such left-handed organic molecules in space. Biochemists, however, have been manufacturing man-made left-handed organic molecules in laboratories on Earth. Why would they do that? Well, the chemical and food industries have been searching for dietary plans to help overweight people become healthier.

EXAMPLES

Originally, chemists developed a sugar substitute called saccharin. Well, it is really sodium saccharine. “Sweet & Low,” and other “pink” packets are made of this. However, we now have many other sugar substitutes, like “Equal,” and other cyclamates; “NutraSweet,” and “Splenda,” among others.

While most sugar substitutes are merely different sweet-tasting chemicals, a way was developed to create a left-handed sugar. In chemical labs scientists began to create mirror images of glucose and sucrose.

What do our bodies do when we eat left-handed sugar? Nothing. While natural sugars are digested and absorbed into our bloodstream, left-handed sugars cannot be digested. They are no more nourishing than sand or sawdust. These left-handed sugars merely pass through our bodies and are excreted or flushed out. However, they are sugar. They just aren’t sugar that we are used to. And they don’t grow on left-handed sugar cane. Parts of some sugar substitutes contain left-handed sugar. And unlike some saccharines, left-handed sugars do not promote any form of cancer, as cancer is a right-handed organism!

In more recent years, chemists have developed a left-handed oil. Again, it does not get digested, and does not contribute to body fat or cholesterol, as they are all right-handed. A potato chip product was introduced using a left-handed oil called “Olustra.”

Eventually we expect that more types of left-handed foods will be made so people can eat all they want, but still maintain a healthy weight. The only side effect of left-handed foods seems to be dysentery, which makes sense, as none of the left-handed food is digested, but merely passes through.

And this brings us back to whether life can, or did, exist on other planets. The planet Mercury is the closest planet to the Sun. It has no air, and is extremely hot on the side facing the Sun – too hot for life.
And on the side – the one that’s in the dark, it is way too cold for life. Thus, scientists looking for life parameters realize that the ambient temperatures cannot be too hot, or too cold (just like Goldilocks found out when she tried the Bears’ porridge).

What about the planet Venus? Is it possible for life to have existed there? Surprisingly, yes, but before any simple life forms had a chance to evolve into more complex forms, such as into mammals, a “runaway” greenhouse effect turned the planet into a pressure-cooker cauldron with suffocating toxic gases. Any life there didn’t have a chance.

Mars, however, may have had a good chance of life. Smaller than Earth, and more distant from the Sun than our planet, Mars was not as hot as, say, Venus. Instead, it had cooler temperatures. For a time, the temperatures were still similar to those on Antarctica, and, therefore, able to support some simple life forms.

Mars is covered with what Percival Lowell believed were canals, but which were, in reality, channels. (Percival Lowell was an American astronomer of the late 19th and early 20th Centuries).

Fluvial planes crisscross this Martian world, showing what looks like rivers had once flowed, but later dried up. Recent research shows that there is still an abundance of water on Mars, albeit, locked in at the poles, and perhaps below ground level. Maybe there is even life that exists in some warm underground springs. Scientists are analyzing the latest data even now, as evidence suggests that life forms may have existed there a billion years ago. Some researchers feel that specimens that have been examined may actually be fossils. After all, what kind of life existed on Earth a billion years ago?

If life did exist on Mars at one time, what caused it to have the harsh conditions that it currently has? Well, about an aeon ago, Mars began to lose its once heavier and denser atmosphere. This was due to the low Martian gravity and its relative proximity to the Sun (as compared to the far out planets). Mars has a mass of about 1/10th that of Earth’s, and its gravity is about 37% as strong. While light atmospheric gases such as hydrogen and helium are able to escape Earth, heavier ones such as oxygen and carbon dioxide cannot escape. In a similar manner, oxygen was light enough to escape Mars.

So, does life exist on Mars? At this time, it probably does not, but we have not ruled it out. We will have to do some research there to confirm or deny the existence of Martians.

And what about the giant world, Jupiter? This planet has no surface, or, rather, no solid surface. However, while the core of Jupiter is an astonishing 10,000° K, the exterior cloud tops are only about 125 ° K. (0 ° Celsius is 273 ° K). This means, of course, that somewhere in between the temperatures must be “mild” enough to support life. And, indeed, about 100 kilometers beneath the upper clouds the temperatures hover around 300 ° K (27 ° C, or 80 ° F)

But if one of Jupiter’s cloud layers is, in fact, ideal in temperature and heat, is there enough raw material in that region to support Urey & Miller’s findings? Once again, the answer is “yes.” There are not only all the right raw materials there, DNA and RNA have been imaged by mass spectroscopy. Given the necessary energy and billions of years of time, one must conclude that life, does, indeed, exist within Jupiter’s atmosphere. Simple life forms, for sure, live there, but life nevertheless. Most likely, the life that may exist within the Jovian’s air are anaerobic bacteria. We would not be able to
communicate with such life forms, and it would be virtually impossible for us to go there and take a sample to prove it.

We can then imagine similar things on the further distant worlds of Saturn, Uranus, and Neptune, but no way to confirm it. Pluto, at over 5 billion kilometers from the Sun, receives less than 1/10th of 1% of the energy from the Sun that Earth does. It’s colder than a zombie’s heart, and thus, no life can exist there. Pluto has no air, but if it did, the gas would be so cold it would freeze into a solid.

In summary, the “life zone” of our Solar System ranges from a distance slightly closer to the Sun than Venus, and it extends to a region slightly beyond the planet Mars. There are some additional life “pockets,” in that we must consider specific areas within Jupiter’s atmosphere, and perhaps in others’ atmospheres. If and when we do find some life form, it may be “left-handed” and exist as the reflective twins of our organic chemistry.

One thing that we know for sure, Earth appears as a Garden of Eden relative to all the other planets in the Solar System, and most likely among the far away stars as well.

**Key Concepts and Terms**
- life
- intelligent life
- origin of life on earth
- other life forms in the solar system
- chances of intelligent life elsewhere in the universe

**Questions**
1. How many “races” of people are there? Name them.
2. How many people live on Earth?
3. Where did all the other hominids go that once walked the Earth?
4. Name a food that was created by science, not by nature
LESSON 3 STUDY QUESTIONS. FILL IN THE BLANK. CHECK YOUR ANSWERS.

1. An ________ is a “closed system” in which all the life forms within that environment interact in a synergistic way.
2. Plants and animals __________ to their physical and biological environments.
3. Ecosystems are marvelous examples of the __________ of nature.
4. It is most interesting to realize that nature wastes nothing, but just __________ all it has.
5. In the end, the Earth itself is one giant ecosystem, known as ________.
6. Earth is rotating at a rate of one turn per day, or about 1,600 kilometers per hour at the ________.
7. It is believed that at one time the red planet ________ was hospitable enough to support some type of life.
8. ________ was a fabulously amazing experiment that endeavored to duplicate Earth’s environment in a closed ecological system.
9. ________ is a self-contained unit, traveling through space at an incredible speed, as it orbits the Sun.
10. Biosphere 2 was built to prove that ________ ecosystems are possible.

ANSWERS TO LESSON 3 STUDY QUESTIONS.

1. ecosystem  6. equator
2. react  7. Mars
3. recycling  8. Biosphere 2
4. recycles  9. Earth
5. Biosphere 10. self-sustaining
LESSON 4

ADAPTABILITY OF LIFE

In this Lesson, you will learn how life can adapt and evolve to live in many environments.

The Lesson includes:

Life vs. “Leaky bag of enzymes”

Bacteria, Viruses, and other minute life forms

ExtraTerrestrial Life Forms

LEAKY BAG OF ENZYMES”

As we have learned so far, life is very complex. But it is different from just a bunch of organic goo.

In the 1980’s Carl Sagan explained, in a segment of the PBS Television series, Cosmos, that we can’t merely toss all of the components of a human into a test tube, shake, and end up with a fully-functional human.

The human body is composed of a number of elements from the Periodic Table of Elements. By percentage, that composition is:

As part of Organic Compounds
Oxygen 65%
Carbon 18.5%

In Various Salts
Calcium 1.5%
Phosphorus 1.0%
Potassium 0.4%
Sulfur 0.3%
Sodium 0.2%
Chlorine 0.2%
Magnesium 0.1%
Iodine 0.1%
Iron 0.1%

Trace Elements (total of all is less than 0.5%)
Chromium
Cobalt
Copper
About 70% of the body is water. The organic elements may come in many different forms. Salts and Trace Elements serve the function to keep the body in chemical balance, no matter what their concentration.

As we have read, enzymes are certain proteins that act as catalysts to speed up the biochemical reactions within cells.

Key Concepts and Terms
- body composition
- catalysts
- enzymes
- organic material

Questions
1. What is a catalyst?
2. What percentage of the body is water?
3. What is the most prominent element in our bodies?
4. Which salt is in the greatest concentration?
5. Numerous metals are in our bodies in trace amounts. Name two.

BACTERIA, VIRUSES, AND OTHER MINUTE LIFE FORMS

Bacteria
The ubiquitous bacteria are tiny little “germs” that are so small, one cannot see them without a microscope. By ubiquitous, it is meant that they are everywhere. There is not a place on Earth where it is devoid of bacteria. They are very resilient and have been around forever. Some are “good” and some are “bad.” The good ones help animals, like us, and the bad ones can kill. Of course, there are also some that are “neutral” and don’t impact us at all. The singular form is “bacterium,” the Latin phrase. It is a word derived from the Greek word baktron, which means “rod,” as the first bacteria observed were rod-like in shape.
A bacterium is a single-cell life form, but they are so little that they are measured in microns (µ). It takes a million microns to equal one meter. Sometimes a micron is called a micrometer (µm). A typical bacterium is about 1.0 µ in size, like the Anthrax bacteria at left.

While cells in animals and plants have nuclei which hold the DNA genetic material, bacteria don’t have a real nucleus, and their DNA just bobs around free inside the cell, which is protected by a strong wall.

Bacteria have been on Earth a lot longer than humans, or the humans’ forbears’. As the common human ancestor may have been Orrin Tugenensis, about 6 million years ago, these hardy little fellows have been around for over 3½ billion years! As Earth formed perhaps 4.6 billion years ago, that would mean that bacteria showed up on Earth maybe 1 billion years after Earth’s formation. Fossilized remains of such ancient bacteria have been discovered, confirming this amazing piece of information.

One can only imagine how Earth was 3.5 billion years ago. The air was super hot, the solar radiation was extremely intense, and there was no oxygen in the atmosphere at that time.

Over time, today’s bacteria have evolved from those original “tough” bacteria that could survive the extremely harsh conditions. Even so, there are some bacteria that even now can survive and flourish in super hot geysers, at temperatures in excess of 100°C. That’s hotter than boiling water!

Anaerobic bacteria die in an oxidizing atmosphere - like the one we live in. However, they can survive inside parts of our bodies, or in the goo lining the bottom of swamps. Some bacteria can handle radiation, some cannot. Even so, it is amazing to realize how bacteria can adapt and survive almost any environment.

The Importance of Bacteria

We often think that bacteria are bad and that they cause diseases. Well, they do. But some bacteria prevent diseases. These we have called the “good” bacteria. When we use anti-biotics to fight some “bad” bacteria, we are also killing off the “good” bacteria. When we used anti-bacterial hand soap, we are also killing any of the good bacteria that may be on our skin. Thus, we must strike a balance, since bacteria are good for our health.

The stomach flu and tooth decay come from bacteria. So, we want to do all we can to limit their negative influence on the body.

On virtually every surface of our skin, our mouth, nose, and linings inside our body, there are volumes of bacteria “towns” or groups. If and when any of these try to invade “forbidden” areas in the body, our immune system, the white blood cells, attack them and drive them out, or destroy them.

There is a popular phrase that states, “Whatever doesn’t kill us makes us stronger.” And that is true. If you are attacked by something or someone, and you survive, then you will be all the better, and more prepared, the next time. Another example is with disease. If you contract smallpox, and if you survive, then you are stronger, and you will never become ill with smallpox again. Essentially, you have become immune to the disease. The next time smallpox invades your body, your immune system “remembers” exactly what to do, and it kills off the disease rather quickly. This is why we often get
vaccinated with weak strains of diseases, so our immune system can “learn” how to deal with the real disease if, and when, it hits.

We can artificially “protect” a life form from any and all bacteria, but once that creature goes out into a real world, his immune system will be “stupid” and be attacked by many bacteria, resulting, most likely, in death.

People often suffer a variety of illnesses after they have moved from one city to another. Why? Well, if we live in one place a long time, our body gets used to all the local bacteria, and we become immune to them. Once we move to another place, we will encounter bacteria that we don’t “know” and they will invade our bodies, causing sickness. At least for a while; at least until our bodies overcome them and develop an immunity to them.

A good example is the rhinovirus, the common cold. But we will cover that in the next section.

Now imagine that you are generally healthy, but, for some reason, over a period of time, you “wear down” your immune system. How? Maybe not enough sleep, or not the proper type of food, or maybe you “catch a chill” in a cold environment. No matter. Whatever the reason, your immune system is temporarily weakened. When that happens, the bacteria in and around you can make great headway, and cause you to become sick.

The best way to keep yourself, and your immune system, healthy, is to eat properly (all the food groups, and make sure you get your vitamins, minerals, etc.), get enough rest (6 to 8 hours per day), drink plenty of fluids that have water in them (water, fruit juices, flavored water, etc.), and include regular aerobic exercise (walking, swimming, bicycling, etc.). This regimen won’t prevent everything, but it will go a long way to help.

Some not so typical bacteria, such as cholera and tuberculosis, can cause severe illness and even death. Cholera bacteria cause a person to lose most of his fluids and salts, resulting in dehydration. TB inflames the lungs, causing one to suffocate. One can get either of these bacteria from bad water, foods, or from an infected person. And then there are new diseases that show up. Well, they are really new forms of bacteria, and they have evolved, or mutated, from existing ones. The new bacteria, like the old ones, can be “good,” “bad,” or “neutral” as far as their impact on humans.

In 1975, a bacterium that lived in deer was transmitted to humans by ticks that lived on deer. This happened near the town Lyme, Connecticut, so it is called “Lyme disease.” This illness is a form of arthritis.

In 1976, a new form of pneumonia showed up, called Legionnaires’ disease, since it first appeared at a convention of members of the American Legion.

A recent illness has come forth as a variation of E. Coli. Normal E. Coli is a typical and common bacterium in our intestines. The new variation, though, causes severe illness, and on occasion, death. These bacteria thrive on raw meat, mostly raw beef. While some people enjoy eating steak tartare, or rare hamburgers, only thorough cooking kills the bacteria. That means “well done.” You may not like “well done” meat, but you will like it much better than death.
Immune systems are necessary for life forms like us to do battle against bad bacteria. We have some “standard equipment” to defend ourselves: the organic layer that covers our body (skin) is a natural barrier to bacteria, just as a moat was used as a barrier against invaders attacking a castle in medieval times. Most of us don’t realize that spit (saliva) and snot (mucus) are able to kill or stop some bad bacteria. As mentioned before, we strengthen our own immune system by allowing bad bacteria to invade us, and we “learn” how to defeat them.

Much of the time in our own immune system can attack and destroy an invasion of bacteria. That is what the immune system is designed for – to destroy invaders. And that will happen almost every time. However, once in a while, the immune system will destroy the invaders “too late,” in other words, the person dies before the invaders are vanquished. In those cases, our bodies can use some assistance from drugs or other treatment.

Antibiotics are great medical tools to help a person overcome a bacterial infection. However, as bacteria are very resourceful, they eventually become able to survive antibiotics. Thus, we must continue to do research to find new medicines to combat the “bad” bacteria. On the other hand, we can develop medications that teach our body how to fight such diseases. These are commonly known as vaccines.

One of the best ways to prevent bacterial infection is by the simple act of washing one’s hands. And not with antibacterial soap, which prevents one’s own immune system from working. However, in the most sterile environment, hospitals, bacteria are rampant, and many people die from diseases that they catch while in the hospital for something else.

We need bacteria, and we need to control bacteria. It is bacteria that turns milk into cottage cheese. And it is other bacteria that can spoil foods and make us sick. Bacteria inhale nitrogen, and in turn, these bacteria put nitrogen in to the soil. And that is good for fertilizer.

Bacteria are also used to break down waste (garbage) and allow things to be recycled. Bacteria are so important – and so interesting – entire courses and careers can be spent studying them.

Viruses
Viruses, like bacteria, are everywhere. They are made up of DNA or RNA, with a protein cover (called a capsid). Some viruses are surrounded by lipids and some aren’t. However, viruses are much smaller than bacteria. On average, a typical bacterium is 50 to 60 times larger. The size of the smallest virus is only about 30 nanometers (remember, it takes 1 billion nanometers to equal a meter).

The word “virus” comes from the Latin word virus, which means “toxic” (deadly). The plural of this word is “viri,” but most use the alternative “viruses.” Some scientists claim that a virus is a life form, and others do not. For example, a virus cannot replicate itself (reproduce) without a host. In other words, some believe that a
protein-covered DNA is not a life form, albeit, it has life-related aspects. Instead, they have “learned” how to share their genetic information with another cell in order to reproduce.

**Generally, viruses are not good. They are bad.** They hurt the cells that they invade. Many times, these host cells die. And if that were not bad enough, viruses can cause some cells to grow wildly, becoming a type of cancer. In most cases, there are no cures for these diseases. One example is the “common cold,” which is a rhinovirus. If we could find a “cure,” it would cure only that one particular rhinovirus, and, well, there are billions of versions of rhinovirus. Some time long ago an “original” rhinovirus evolved and mutated over many generations to form virtually an infinite number. The word “rhino” comes from the Greek word *rhino*, meaning “nose.” When one gets a cold, it is often centered in and around his nose.

**Classification**

**Viruses are classified in a number of different ways. First** of all, they are delineated by their genetic matter. **Second,** they are given to the way of reproduction. And finally, they are noted by their design or structure.

Viruses make their way into cells by hooking up with an existing molecule on the surface of the cell. But it must be a particular molecule. If the cell does not have this particular molecule, then the virus can’t do much.

However, if and when the virus binds to a cell, it must find a way to break through to the inside. After binding to an appropriate cell, a virus must cross the cell membrane. The techniques to get inside are many, but once inside, all “heck” breaks loose. The virus begins to reproduce itself at break-neck pace, taking only a few hours.

Sadly, some viruses cause the death of cells by causing severe damage to the cell. Other cells recognize the problem, and commit cell suicide to prevent the virus from completing its task. And, in some cases, a virus and its descendents may live forever inside the host cells – most of them harmless.

Yes, that’s right. Most viruses create no symptoms nor do they explode into a disease or sickness. But, then again, some viruses cause terrible consequences for most people who have them.

But how do viruses get into the body, anyway? Some viruses enter through cuts in the skin after contact with infected persons. Thus, it is good to wash one’s hands often. Some viruses get into the system from infected blood, such as re-using or sharing hypodermic needles with others. Bug bites and animal bites can transfer infected blood right into the bloodstream. So, don’t let the bedbugs bite. Other viruses, such as influenza, the rhinovirus, and chicken pox, can enter our bodies when we inhale infected air that has been exhaled by sick people – especially after the infected people cough or sneeze into the air. It is best to have tissue or a handkerchief handy so as to prevent the spread of such viruses.

And there are those viruses that enter our bodies by our eating **bad food**, such as the rotavirus, poliovirus, and hepatitis A. One can also get viruses, such as herpes, HIV, and the human papilloma virus, **by sexual contact**. Thus, it is important to limit sexual contact to healthy partners, and/or to use proper protection. There are even viruses that enter our bodies through the eye!
A sickness caused by a virus can be either **acute** or **chronic**. An acute illness is not one that looks “cute,” or that is pretty. Rather, it means that it doesn’t last very long, such as a “24-hour virus.” The word “acute” comes from the Latin word **acus**, which means “needle.” Thus, the practice of “acupuncture” means to stick a sharp needle into your skin. However, in this case, an acute illness is not one that may be acquired by a needle, but in this case, it means that the sickness comes and goes quickly, i.e., in which the patient recovers almost immediately.

A chronic sickness is one that may last a long time, or perhaps, forever. The word “chronic” has its roots in the Greek word **kronos**, meaning “time.” A chronic disease means that the virus is in the patient a long while, and / or the damage caused cannot be fixed.

If one contracts an acute illness, it may take 3 days – or more – before the disease is manifested (when symptoms begin to show up). Thus, you could be exposed to a person’s rhinovirus sneeze on a Monday, but not really start feeling sick until Thursday. However, just because you have inhaled a bad virus does not mean you will ever have symptoms. Why? Because within a few days, a healthy immune system may destroy the invader before it can do any damage at all. In other words, you may be sick, but not ever know it. And then, shortly thereafter, you are “cured” of an illness that you never knew that you had.

Chronic illnesses may take much longer before they “set in” and bring about symptoms. A person exposed to the human immuno-deficiency virus (HIV) may not exhibit acquired immune deficiency syndrome (AIDS) for 7 years or more. In other words, you may “catch” HIV, and then die of some other event long before you even know you have the disease.

Research has shown that viruses play a role in the onset of various cancers. Not all the data are in, so it is not yet known exactly how this happens.

**Fighting Viruses**

**Bacteria can be defeated by using antibiotics (meaning, anti-bacteria).** We can’t use antibiotics to fight viruses. We would need to use antivirotics or some other name for that medication. But we don’t have them. Instead, we must rely upon our body’s own immune system to fight off the bad viruses. We can do things to help our bodies to do this.

First of all, we can take all precautions to avoid getting a virus, as mentioned above (wash hands, etc.). Second, we can keep our bodies healthy (diet, exercise, rest). And we can drink plenty of water-rich fluids, including water, fruit juice, and so forth. NOT beer, wine, or liquor. One may prefer to be passed out drunk during an illness, but it’s a bad idea. We need to give our body all the “tools” it needs for a strong immune system.

As babies, we pick up millions of diseases, and as our bodies grow, our immune system grows. How many parents remember their young children always having a cold, or an earache, or some other malady. However, after the child reaches age 12 or so, they don’t get sick as much. By then, their bodies have had 12 years of experience in fighting diseases. Then, during some period in our lives, from about 30 to 60 years old, we are in the “golden age” of health, in which we rarely get sick at all, and when we do, it is mild. Only when old age sets in, and when our bodies can no longer keep up the rate of fighting illness, do we begin to become sick more often, almost as when we were babies.
Even so, when we get a virus, our bodies produce the “army cells” to go out and do battle. These are the white cells. Yes, there are other cells, too, involved, and altogether, they fight the good fight. Often times, the body turns up the heat, causing a fever. Having a fever is a good thing, as many viruses cannot survive in hotter environments. Of course, if the fever goes too high, not only will the viruses get fried, one’s brain will be burned, too, causing brain damage. So, there is a happy medium. Medical professionals usually urge people to prevent their body temperature to go higher than 105°F for any length of time. One can lower one’s body temperature by taking drugs (like aspirin) or by a cool (not cold) bath. However, the longer that one can tolerate a fever, the shorter the illness will be.

Well, what kinds of medicines can we take to help us defeat viruses? Only preventive medications will help, and they are called vaccines. Essentially, a vaccine is a medicine given to a person to prepare and strengthen his immune system “just in case” that bad virus comes around. A vaccine is typically a weak version of the real disease, so the body learns how to kill it off. When a strong version of that same disease arrives, the body has already “stockpiled” large reserves of white cells who know exactly what to do to kill off the disease.

In some cases, a single vaccination may last a lifetime, such as a smallpox vaccination. In the case of influenza viruses (also called “the flu”) these are like the common cold, in that they evolve and change from year to year, so that getting a flu shot one year may do little to prevent getting the flu the next year. And if you get a flu shot for “type A” flu, you may still get a “type B” flu and become sick. Even so, no matter what flu shot you get, it will make your immune system stronger, and whatever type of flu you contract, you won’t be quite as sick, nor will the disease last as long.

One interesting fact is that the element zinc plays a role in combating viruses. Taking over the counter pills that have zinc in them has been shown to lessen the severity of virus-related illness. A diet high in zinc may prevent a virus sickness altogether. Why? It seems as if the zinc compound “looks” just like the type of cell that viruses like. So, a virus invades the body, and attaches to a zinc compound. The zinc just flows through the system, and out the body. The virus is “trapped” on the zinc, and cannot reproduce itself, as zinc is not a living cell. A common commercial lozenge, “Cold-Eze,” is a typical form of this medication.

Vaccinating people against disease was accidentally discovered by an English medical doctor in 1796. Dr. Edward Jenner had been treating patients for smallpox, and he came to realize that women who milked
cows hardly ever came in for treatment. Now, what did milking cows have to do with preventing smallpox?

First of all, pox is a series of itchy skin eruptions that may leave small pits, or pockmarks after they heal. The word “pox” is the plural form of a word that came from the Old English word pocc, and in Middle English, the word was spelled pokke. This lead to the plural word pokkes, and then in more Modern English to pocks. Today it is spelled pox.

Anyway, Dr. Jenner visited several milkmaids and found out that a few of them had previously contracted a disease now known as cowpox. Fortunately for the milkers, cowpox is a rather mild viral disease, and the women who had suffered from it had a day or two of rest with fluids, and flu-like symptoms before fully recovering. Jenner concluded that there was a family of diseases known as “the pox diseases” and that one’s immune system can be greatly strengthened against any and all “pox diseases” if one survives only one of them. And that would include the relatively mild chicken pox.

Smallpox is often a deadly illness, but some people do survive, and when they do, they are immune, or protected, for life against smallpox. However, infecting people with live smallpox viruses seemed to be a death sentence, so Jenner began to infect people with cowpox. These patients got sick, but in a few days they were fine, and before long, all of London was rid of the smallpox epidemic.

In summary, viruses will always be around. We just need to keep ourselves ready for them.

Other Tiny Life Forms
While bacteria and viruses get all the headlines in diseases and such, there are also other life forms that are quite tiny. We won’t spend a great deal of time on them, but they include fungi (plural of fungus) and stuff like that, which will be covered in the next Lesson.

Key Concepts and Terms
- acute
- antibiotic
- bacteria
- capsid
- chronic
- disease
- immune system
- pox
- vaccine
- virus

Questions
1. What does the word “bacteria” mean?
2. What does “virus” mean?
3. What does “pox” mean?
4. How does an anti-biotic work?
5. How does a virus behave?
6. What is a vaccine?
EXTRATERRESTRIAL LIFE FORMS

We could speculate forever on what extraterrestrial life forms might look like, and how they might behave. But over all, if they are life, then they must be similar to what we know already about life here on Earth. Sure, there are probably some additional species out there that were never on Earth, but there are many here on Earth that have never been out there.

However, it may be more fruitful to ask ourselves what other intelligent life forms may be like. After all, it is those creatures that we would communicate with. But let’s start at the beginning.

**Exobiologists** seek out the right “formula” – or set of conditions - that a planet must have to increase the probability of the existence of life there. And that includes having a planet orbit a hospitable star. Most stars are too hot or too cold to allow life to occur on any nearby planets. Thus, in the end, one must understand what kinds of stars would be the ones to allow for the origin and evolution of life.

So far, we know that Earth, and its star, the Sun, are successful candidates. Thus, we can narrow our search to stars that are like the Sun. Astronomical research also shows that only about 20% of stars have planets of any kind. Thus, we have to look for Sun-like stars among only 20% of the Galaxy’s 400 billion stars. But even that is a huge number.

The only planet that we know for sure that has life is Earth. However, scientists suspect that bacteria live within Jupiter’s clouds, and that life once existed on the planet Mars. Neither of these life forms, however, are intelligent life forms.

**American astronomers Frank Drake, Carl Sagan, and David Menke** each independently developed mathematical relationships to give statistical estimates to how many planets in the universe have life forms. Plus, when we specify an intelligent life form, that number drops even more.

In spite of their different approaches, Drake, Sagan, and Menke all came up with very similar results: there are about 1,000 intelligent civilizations in the Milky Way. The only drawback is that, assuming random distribution, the closest one to Earth is about 1,000 light years away. And with our state of technology and education, there is no way we could ever rendezvous with them physically.

Exobiologists are participating more in NASA’s space travel plans, and are looking for the possibility of life forms on Titan, Europa, and other celestial orbs. More likely than not any life forms there will be single-cell.

It doesn’t seem reasonable to believe that intelligent life forms beyond Earth shall be found in the Solar System. Thus, we have had to turn some research to extra-solar locations. Unlike solar system research, which can be done relatively easily with robotic space probes, seeking life among the stars requires “listening” to radio waves for any intelligible signal. Even so, we have sent “information packages” on each spacecraft destined for regions beyond Pluto.

This is “just in case” in some distant future it lands on a planet with intelligent life, then “they” will know we exist. Maybe.

Exobiologists started to track the heavens for extraterrestrial radio signals in 1960. This initial adventure was called Project Ozma, deriving its name from the *Wizard of Oz*. Large radio telescopes
were trained in specific areas of the night sky in hopes of getting something, anything, of intelligent communication. But, after six months, it was abandoned, with no definitive results.

Another project was started in 1984 by astronomers Lou Friedman, Carl Sagan, and Dave Menke. Using a 28-meter (84-foot) radio telescope at Cambridge, Massachusetts, the Search for Extra Terrestrial Intelligence (SETI) program launched what has become the most energetic effort yet.

While Project Ozma had used just one single-channel receiver, SETI and NASA eventually developed the capability to monitor millions of channels simultaneously. On October 12, 1992, two large radio telescopes were added to the efforts: NASA’s 34-meter (112-foot) diameter radio telescope in Goldstone, California, and the National Science Foundation's 305-meter (1000-foot) telescope in Arecibo, Puerto Rico. Congress, however, canceled Federal Support in October 1993, and the effort once again fell to the private SETI Institute, which set up radio telescopes in Australia and later in Green Bank, West Virginia, which was the original home of Frank Drake’s Project Ozma.

In 1994, the SETI Project initiated the “SETI at Home” program, where any citizen with a home computer could monitor specific frequencies for radio signals. This on-going program has allowed SETI to explore all frequencies in almost every part of the sky all the time. So far, no conclusive evidence has come forth.

**Mass Interstellar Communications**

Let’s just imagine that there are other intelligent life forms out there who are capable of sending and receiving radio signals. On Earth, we began our ability to send sounds over wires with the telegraph, invented in 1844 by Samuel F.B. Morse, and later, Alexander Graham Bell’s invention of the telephone in 1876.

**Radio**

Radio signals were first detected by the German Physicist, Heinrich Hertz, in 1887, using a spark gap transmitter. Using this scientific technology, Italian inventor Guglielmo Marconi developed his own spark gap transmitter, with an antenna, and, on Christmas Day, 1894, he sent the first “wireless” message – to himself. Two years later, he applied for an international patent in London, England.

After Marconi’s work became known, further development of the radio went on rapidly. Canadian Reginald Fessenden invented a type of high-frequency radio in 1905 and the first voice transmission across the North Atlantic was done on December 24, 1906. Two independent inventors, Harold Arnold of AT & T, and Edwin Armstrong, developed radios that could broadcast long-range voice radio signals. Armstrong did it first in 1914, and Arnold’s device was the first to broadcast across the Atlantic Ocean from the United States to Britain, a year later in 1915.
BIOLOGY

The US Army liked Armstrong’s work, and offered him a commission as a Major in the U.S. Signal Corps during World War I. After the war, Armstrong sold his ideas to a company known as RCA, which had been formed in 1919. In 1933, Armstrong developed the first FM radio signals.

Meanwhile, an amateur radio operator, Charles Herrod, built his own “broadcast” radio station in San Jose, California, in 1912 – the first such in the world. Too bad that he didn’t “cash in” on it.

The first independent commercial radio station went on the air in Pittsburgh, Pennsylvania on September 30, 1920 – KDKA. And the “rest is history,” so they say.

Television
Meanwhile, the concept of sending images, or pictures, over a wire, or via electricity, had been researched long before 1900. In fact, in 1862, an Italian named Abbe Giovanna Caselli sent a still image over a wire. A cathode ray tube was developed in Boston in 1876, by George Carey and Eugen Goldstein, and this invention was improved upon by others. A mechanical way of broadcasting images was developed in 1884 by German graduate student Paul Nipkow.

At the Paris World's Fair in 1900, an international conference on electricity was held, and one of the delegates, Russian Constantin Perskyi, gave a paper about the new concept of sending images over wires, called it "television." That name has stuck. Following this, two divergent manners of sending images were followed: the electronic cathode ray tube, and the mechanical rotating disks. Following this, American Philo Farnsworth and Russian immigrant, Vladimir Zworkin develop an advanced type of cathode ray tube television with higher resolution. In 1923, Zworkin patented his device.

In 1927, the U.S. government, in cooperation with Bell Laboratories, transmits the first long-distanced television image. Later that year, Farnsworth patents a more advanced design. In 1928, the U.S. Government issues a radio broadcast license to American inventor Charles Jenkins. A year later, Scotsman John Baird opens the first television studio. In 1930, Jenkins broadcasts the first television “commercial.” That same year, the British Broadcasting Company began regular transmission of television programs.

Iowa State University opens its own station in 1933, and the Columbia Broadcasting System (CBS) begins in 1936. And “the rest is history.”

Of course, most people didn’t have access to simple televisions for regular commercial broadcasting and entertainment until after World War II. "Regular" television broadcasting in the United States began with NBC’s 1946 variety show “Hour Glass.” President Truman’s 1947 State of the Union Address was broadcast, and later that year came “Kraft Television Theater.” In December 1947 came a show with a wooden puppet called “Howdy Doody.” His human side-kick was Buffalo Bob. This program ran through September 1960, and again from 1976-1977.

The year 1948 was a big one for commercial television. Many new, and long-running, programs began, such as “Star Theatre,” with Milton Berle, which ran until 1981; “The Toast
of the Town,” later called “The Ed Sullivan Show;” Jackie Gleason’s “Honeymooners,” Sid Caesar’s “Show of Shows,” and William Boyd’s “Hopalong Cassidy.” And of course, the list goes on.

The whole point of making this short detour to overview the history of broadcasting is to point out that we humans have been broadcasting radio signals, in one way or another, at least since Hertz’s 1887 experiment, and non-stop and continuously since 1920. That means that, since light travels at 186,000 miles per second, the first radio signals left Earth in 1887, and have traveled well over 100 years at the speed of light into space – that’s 100 light years. And commercial radio programming has been broadcasting for over 80 years – since 1920. That’s more than 80 light years away. And television images, which are sent as radio waves, too, have been going out with regularity well over 50 years – out to a distance of 50 light years.

The closest star system to the Sun is “only” 4.3 light years away. This, the Alpha Centauri System, is now receiving radio and television signals from Earth that left just over 4 years ago. And there are hundreds of star systems – with possible life-sustaining planets – within 100 light years. Therefore, it is not inconceivable that somewhere, someone(s) have heard, or seen, our signals or images, and have already replied back, although those radio signals have not yet arrived here. Thus, the importance of programs like SETI. On the other hand, if the intelligent civilizations are randomly located, as mentioned earlier, the nearest society that would have the ability to communicate with us may be 1,000 light years away, and, thus, may not get any of our signals for another 900 years or so. We’ll just have to wait to find out.

The Chemistry of Biology
We realize that all life forms on Earth have the same chemistry, i.e., they are carbon-based. This means that carbon is the key element that bonds the various molecules and atoms together to “make things happen.”

An organic molecule in any animal can be removed and placed in any plant, and it will do just fine. While the biology of life on Earth varies, the chemistry does not.

Carbond is an element that is able to make endless bonds with itself, and with other elements. Thus, it is infinitely strong. But what other elements are in this same chemical “family?” Those elements include Silicon, Germanium, Tin, and Lead. Chemists have tried to “hook up” these other elements, as Carbon has been able to do, but they failed. In fact, only Silicon is able to form any type of bonding chain, but after seven links, it, too, breaks down. Thus, the imaginary creature known as the “Horta” in the science fiction TV series StarTrek (a rock creature that is Silicon-based) remains fiction.

On the other hand, we could mention the possibility of chirality, or “handedness,” as previously discussed. It is possible that some organic life forms exist elsewhere, but that are mirror images of our organic life forms. And, as also mentioned, perhaps some galaxies, or alternate universes, have anti-matter instead of matter, i.e., the protons are negative and the electrons are positive.
The Anthropology of Intelligent Biology

For the sake of interest, let’s “build” an intelligent life form that may exist elsewhere. What would he/she/it look like? What?, you say. How can we do that? It’s not that difficult. After all, what life form is the most advanced and most intelligent on Earth? And, why is it, anyway? And how is it “built?”

First of all, we’d have to assume that whatever life form is out there is carbon-based. All the other forms failed.

Then, the most important organ in the human body is the brain. Some may argue that the heart is, but, if one has a heart transplant, then he stays the same person. If someone has a brain transplant, then, well, he isn’t who he was at all.

And where is the brain? As far from the ground as possible. And it is protected by a hard “helmet” called the skull. If our brains were in our feet, we’d knock ourselves out every time we stubbed our toes. Therefore, any intelligent life form would have to have a brain (duh) and it would have to be protected, by both distance and by a shield.

The next most important organ is the heart. It is also far off the ground, but not as far. It is also protected by a shield, but not as hard as the skull. Rather, it has a rib cage for protection. After all, the heart is a muscle, and can sustain some “abuse.”

Humans are able to manipulate and build the most intricate items, since we have many fingers and opposable thumbs. And so would any intelligent life force. Dolphins and chimpanzees are smart, but they can’t build watches or take themselves to the Moon. Thus, building such a being would mean it would have to be similar to the android in “StarTrek Generations.” Humans are bi-pedal, allowing for sustained and rapid movement. Maybe not as fast as a cheetah, but we don’t need to be that fast.

We have eyes, but not in our toes, since then we couldn’t see anything but grass, unless we wore shoes and socks, then we’d see nothing. Our eyes are about as high as they can go – in the head. And we have two eyes for 3-dimensional viewing, allowing us to gauge depth and distance. Our two ears on each side of the head allows us to hear stereo sound, and thus, determine the direction of sounds. If we had our ears in our feet, we’d hear nothing but loud pounding when we walked. And our nostrils are in the head, near the brain, so as we can smell our food before eating it. If our noses were in our rear ends, it would always smell bad. And our mouth, used for communication and ingesting food, is also near the brain. All these major senses thus have very short pathways to the brain.

We can only assume that other intelligent life forms would look much like us. There may be some visual differences: color, amount of hair, height, mass, and so forth. But, overall, they can’t be too different. In fact, if one were to study the many kinds of humans that live on Earth today, some of these people, you may believe, are from other worlds!
Thus, in conclusion, extraterrestrial life forms most surely exist. And it is quite likely that intelligent life forms, like humans, are out there, too. We must conclude, though, that these other intelligent civilizations could be quite far away and impossible for us to have direct contact with.

Key Concepts and Terms

- Alpha Centauri
- exobiology
- extraterrestrial
- intelligent life forms
- light year
- Project Ozma
- radio signals
- SETI
- telephone
- television

Questions

1. What is the closest star system to the Solar System?
2. How far is a light year?
3. What was Project Ozma?
4. How were radio signals developed for broadcast?
5. What is an exobiologist?

LESSON 4 STUDY QUESTIONS. FILL IN THE BLANK. CHECK YOUR ANSWERS.

1. About _________ of the human body is water.
2. Enzymes are certain proteins that act as _________ to speed up the biochemical reactions within cells.
3. A _________ is a single-cell life form, so little that they are measured in microns (µ).
4. _________ bacteria cause a person to lose most of his fluids and salts, resulting in dehydration.
5. TB inflames the lungs, causing one to _________.
6. In 1976, a new form of pneumonia showed up, called _________ disease.
7. _________ systems are necessary for life forms.
8. _________ are great medical tools to help a person overcome a bacterial infection.
9. Research has shown that _________ play a role in the onset of various cancers.
10. Preventive medications will help against bacterial infections are called _____.
ANSWERS TO LESSON 4 STUDY QUESTIONS.

1. 70%  
2. catalysts  
3. bacterium  
4. cholera  
5. suffocate  
6. Legionnaires’  
7. Immune  
8. Antibiotics  
9. viruses  
10. vaccines
LESSON 5

PLANT KINGDOM

In this lesson, you will learn about the many types of plant life.

The lesson includes:

Fungi (Lab 5: Grow mushrooms)

Plants (Lab 6: Grow Flowers or Vegetables)

Form and Function of Plant Life

Plants and Animals Compared

 FUNGI
(During this lesson, do Lab 5: Grow Mushrooms)

Fungus

A fungus is neither plant nor animal, and it absorbs its food from its environment. Scientists have found evidence that fungi were around at least 550 million years ago.

The smallest fungus is too small to see without a microscope and the largest takes up about 30 acres! Some types of fungus live a long time. For example, lichens may be able to live for more than 4,000 years!

The existence of this unusual life form is necessary for all ecosystems. Fungi decompose organic matter, such as animal and plant parts, recycling their molecules and atoms.

Fungal medicines have been a real boon to keeping humans healthy. Some types of mold are excellent antibiotics and others help create medical hormones. The mushroom is a fungus, and it is often found in recipes. In fact, the eating of these mushrooms can enhance a person’s immune system.

However, don’t go out and eat all the fungi you find. Some are harmful, causing disease and death in both plant and animal. You have to know what is okay and what is not okay. In addition to the mushroom, yeast and most mildews are also fungi.
Animals take in nutrients by eating it. Plants get their energy from the Sun by using chlorophyll. However, a fungus doesn’t have a mouth to eat with, nor does it have chlorophyll to make its own food. Thus, the typical fungus settles in somewhere, excretes protein enzymes into its local surroundings which then pre-digests foods, and the fungus then absorbs the “food.”

DID YOU KNOW -
More British ships were destroyed by fungi than by American warships during the American Revolution? One type of fungus, the saprophyte, causes wood to rot very quickly.

DID YOU KNOW –
A major type of fungus, yeast, is used to make beer, wine, and even bakery products?

Key Concepts and Terms
- beer
- fungus
- mildew
- mold
- yeast

Questions
1. Which form of fungus is used to make beer?
2. What are some common forms of fungus?
3. What kind of fungus can you eat?

PLANTS
(During this lesson, do Lab 6: Grow Flowers or Vegetables)

There is a division of biology whose focus is plants. It is called “botany.” The word “botany” comes from the Greek word botanikos, meaning “fodder,” or food for animals. And, most animals do eat plants.

Plants are multiple-celled organisms that are able to create their own food supply by the chemical process of photosynthesis:

\[ 6 \text{CO}_2 + 6 \text{H}_2\text{O} + \text{E}_o = \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2 \]
BIOLOGY

where CO$_2$ is carbon dioxide, H$_2$O is water, E$_o$ is energy from the sun, C$_6$H$_{12}$O$_6$ is glucose, and O$_2$ is oxygen. Glucose is the food (a starch or sugar) that plants make to feed themselves. The numbers in front of the molecules give the required ratios to allow the reaction to move forward.

Bacteria, viruses, and fungi are not technically plants, as they don’t do photosynthesis. However, their study remains in the domain of botany.

The advanced intelligent civilization that we had mentioned earlier requires knowledge of plants: what to eat and what to avoid. How to plant and grow plants for food (crops). The care and “feeding” of plants. Evidence shows that humans have been agrarian for about 10,000 years (that means they have been planting and cultivating crops for about that long). However, wholesale agriculture has been around for maybe half that time.

The science of botany was seriously explored by the Greek thinker Theophrastus (372 BC – 287 BC), a pupil of Plato (427 BC - 347 BC) and a contemporary of Aristotle (384 BC – 322 BC).

After Aristotle, Theophrastus assumed the “mantle” of chief Greek Philosopher and advisor to Emperor Alexander the Great. Rather than being a ground-breaking scientist, he tended to be a teacher and “popularizer” of science. However, he did write two series of books about plants: *On the History of Plants* and *On the Causes of Plants*. The content was mostly a synthesis of what was already known at the time.

However, it was believed by the Greeks that all of the food that plants consumed came from the dirt, or earth, they were rooted in. It wasn’t until the mid-1500’s did further research began to give humans better understanding to the plant’s life.

Around 1620, a Flemish chemist and medical doctor, Jan Baptista van Helmont, decided to test the old Greek idea that plants got their food from the soil. He did this by planting a willow that weighed about 2.2 kilograms (5 pounds) into a large vessel containing about 90 kilograms (198 pounds) of dirt. Over the next five years, all the plant got from van Helmont was water. In 1625, he removed the plant and weighed it. After five years of “only” water, it had grown to weigh 76 kilograms (167 pounds)! “But, how could this be?”, he wondered. Van Helmont concluded that maybe the tree had depleted the soil, and, thus, the dirt should weight quite a bit less. He weighed the leftover soil and found out that it had dropped from the original 90 kilograms to 89.94 kilograms (197.9 pounds). Wow! The plant gained 74 kilograms (162 pounds), and the soil lost almost nothing. Van Helmont immediately concluded that the plant did not get its food from the ground, as the Greeks had believed. However, van Helmont was not yet ready to leap to the conclusion that the energy came from the Sun. That would be left to others.

Joseph Priestley, a British chemist, showed that plants give off oxygen, and Jan Ingenhousz, from Holland, figured out that plants need light to live. And that light was the Sun. These conclusions were made in the mid-1750’s.

Oddly enough, the well-known British physicist, Robert Hooke, suggested the existence of plant cells. Hooke was a contemporary of Isaac Newton, Edmond Halley, and Christopher Wren.
As mentioned in the Lesson 2, it was the Austrian botany expert, Gregor Mendel, who followed up on genetic traits of plants.

Many followed Mendel’s work, and a Swede, Karol Linnaeus, designed our modern hierarchy of plant classifications.

A hybrid science, paleobotany, helps modern biologists follow the historical record of plant evolution, through studying fossils. Research continues at all levels of understanding how plants live, survive, and even thrive, in such harsh places as the Mojave Desert. We will study plant classification in the next lesson.

Key Concepts and Terms

- botany
- glucose
- paleobotany
- photosynthesis

Questions

1. What does the word “botany” really mean?
2. How is glucose made by plants?
3. What do paleobotanists do?

FORM AND FUNCTION OF PLANT LIFE

Plant Classifications

Vascular plants are those that have a system of veins to allow fluids to circulate. Non-vascular plants have no such system. All plant classifications have the suffix –phyta, which means “plant” in Greek.

Vascular plants include ferns, club mosses, horsetails, gymnosperms and angiosperms. Non-vascular plants include liverworts, hornworts, and other mosses.

Gymnosperms are wood-type plants like trees and shrubs. They have seeds that are exposed, or “naked,” from the Greek word gymn, which means naked. (The ancient Greek gymnasiums were wrestling and work out areas for men and they wore nothing but a smile – or a frown) Gymnosperms include the conifers, pines, and similar.

Angiosperms include most trees, herbs, flowers, and shrubs. Angiosperms are the greatest source of the food that we, and other animals, eat. We also use many of these plants to supply us with raw materials for general use. Angiosperms have seeds that are enclosed, or “hidden” or “protected” such as flowering plants (fruits, vegetables, etc.). Some plants are poisonous, and should not be eaten. Watching other animals eat or avoid plants is a good way to find out. However, some birds can eat poisonous fruits that don’t affect them, as their digestive tract will not process the toxins before the waste is removed from the body. In this way, birds
can transfer seeds from one place to another, and the plant can avoid large animals eating the seeds first.

**Key Concepts and Terms**
- angiosperm
- gymnosperm
- phyta

**Questions**
1. How are an angiosperm and gymnosperm different?
2. List three examples of each of number 1.
3. What does the suffix “phyta” mean?

**PLANT AND ANIMAL SYNERGY**

At the beginning of Lesson 3, you learned that synergy means “working together”, like plants and animals do in a ecosystem. There is a symbiotic relationship between plants and animals. For example, animals eat plants. In turn, animals die and decompose, becoming nourishment for future plants. It’s one eternal round.

Another example was given at the end of the last lesson: birds that eat fruit and drop the seeds of that plant in some distant place, allowing the plants to reproduce and grow new plants elsewhere, thus preserving the plant life itself.

Animals eat plants, or other animals, or both. Herbivores are animals that eat only plants. Carnivores eat only meat. Humans tend to be omnivores, and eat both plant and animal. And we also eat fungi.

Overgrazing is not a good thing, as cattle or other livestock can eat all the grass and plants down to the roots, maybe the entire range could be destroyed. On the other hand, the animal droppings are a good source of nourishing fertilizer for plant life.

**Key Concepts and Terms**
- carnivore
- herbivore
- omnivore
- symbiotic
- synergy

**Questions**
1. What does it mean for plants and animals to have a symbiotic relationship?
2. Name two animals that are herbivores.
3. Name two animals that are carnivores.
4. Name two animals that are omnivores.
LESSON 5 STUDY QUESTIONS. FILL IN THE BLANK. CHECK YOUR ANSWERS.

1. A__________ is neither plant nor animal and it absorbs its food from its environment.
2. __________ may be able to live for more than 4,000 years.
3. __________ is the division of Biology that focuses on plants.
4. Plants are multiple-celled organisms that are able to create their own food supply by the chemical process of __________.
5. __________ plants are those that have a system of veins to allow fluids to circulate.
6. Joseph Priestley, a British chemist, showed that plants give off __________
7. Jan Ingenhousz, from Holland, figured out that plants need __________ to live.
8. __________ eat only meet.
9. Human tend to be __________.
10. There is a __________ relationship between plants and animals.

ANSWERS TO LESSON 5 STUDY QUESTIONS.

1. Fungus
2. Lichens
3. Botany
4. Photosynthesis
5. Vascular
6. Oxygen
7. Light
8. Carnivores
9. Omnivore
10. symbiotic
LESSON 6

ANIMAL KINGDOM

In this lesson, you will learn about the many forms of animal life.

The lesson includes:

The Science of Zoology

Water Animals vs. Land Animals (Lab 7: Evolution)

Arthropods

Fishes (Lab 8: Guppies and Tadpoles)

Amphibians (Lab 9: Frogs and Toads)

Reptiles (Including Dinosaurs) (Lab 10: Lizards)

Birds (Field Trip to a Bird Sanctuary or Aviary)

Mammals (Field Trip to a Zoo or Dairy Farm)

THE SCIENCE OF ZOOLOGY

Zoology is the branch of biology concerned with the study of creatures in the animal kingdom. This lesson discusses the history and concerns of that study.

Zoology is a series of projects designated for the analysis and classification of animals. About 2500 years ago, the Greek physician, Hippocrates, began to keep records of animal characteristics. Following him, it was Aristotle who created a format to classify the diversity of animals. Aristotle wrote a book, Historia Animalium that has correct descriptions of animal life forms that were alive in Greece and the nearby Middle East at the time.

The Roman Scholar Pliny the Elder (23 AD to 79 AD) was a “Natural Philosopher,” which later became known as a physicist. Even so, he wrote four books about zoology. Sadly, there were misconceptions in his work. Rather, the Greek physician Claudius Galenus (131 AD – 201 AD) did much more by actually dissecting animals and describing their features accurately.

Zoology didn’t begin to emerge as a true science until after the Middle Ages. One of the more influential scientists of that period was the German scholar Albertus Magnus (1193 – 1280), who resurrected Aristotle’s work. However, Leonardo’s research on anatomy was way ahead of his own time. Leonardo da Vinci’s (1452 – 1519) dissections and analysis of the human body and of other animals brought new revelations. Leonardo’s comments on the similarity among mammals were
brilliant. Too bad that hardly anybody during his life time cared. Rather, a Belgian scientist, Andreas Vesalius (1514-1564) was respected more for his rather ordinary theories.

Today’s modern zoological research is covered in Lesson 8.

**Key Concepts and Terms**
- Albertus Magnus
- Aristotle
- classification
- Claudius Galenus
- dissection
- *Historia Animalium*
- Leonardo da Vinci
- Pliny the Elder
- zoology

**Questions**
1. Who wrote *Historia Animalium*?
2. What was this book about?

**WATER ANIMALS VS. LAND ANIMALS**
*(During this lesson, do Lab 7: Evolution)*

Animals come in all shapes and sizes. And territories. Some animals live all their existence in the water, or beneath the surface thereof. Other animals don’t go near water at all, except to drink it. And there are those who do both. They live in or near the water and on the land. Some animals are born in the water, and then move on to the land to live, and vice versa.

Some water animals live in salt water (oceans, inland seas) and others live in fresh water (lakes and rivers). And some animal creatures live in both.

There are some animals that breathe air, but live in the water or under its surface. Other animals would die if they were either removed from the water, or if they were put in water. Some animals that live in salt water would die in fresh water, and vice versa.

Animals on land need some way to get around, so, many have feet. But not all of them. Animals in the water need some way to get around, so, many have fins. But not all of them. Some water animals are herbivores. Some are carnivores. And yet others are omnivores. Same for the land animals. It’s a fascinating, if not maddening, mix and blend of animals that we shall study.
Key Concepts and Terms
- fresh water
- land animal
- salt water
- territory
- water animal

Questions
1. Can a fresh water animal live in salt water? Why or why not?
2. Can a water animal live on the land? Why or why not?

ARTHROPODS

Arthropods comprise the most prolific group of animals on Earth – over a million species have been classified. Some scientists think that number may be closer to ten million!

The arthropod is an animal with a hard, outside skeleton (exoskeleton). It doesn’t have an internal skeleton like we humans do. Their bodies are jointed with various limbs. In fact, “arthropod” comes from the Greek word arthron and the Latin word pod, which means “joint” and “foot” respectively. In other words, they are the “jointed foot group.”

The arthropod group includes bugs and seafood creatures. By bugs, we mean insects and arachnids. Seafood creatures include crustaceans.

Insects include ants, beetles, flies, mosquitoes, and a million other types. Arachnids are best represented by spiders, but ticks and scorpions are also arachnids. Crustaceans are comprised of crabs, lobsters, and shrimp.

It is obvious that arthropods have been very resourceful and infinitely adaptive to just about any ecosystem. They are found in hot, parched deserts; in boiling hot springs; in snowy mountain ranges, and the barren Antarctic. They help pollinate plants, and they are food for many creatures.

Humans like to eat several types of arthropods, particularly the “fruit of the sea” or crustaceans. While this group is essential in the fabric of life on Earth, some of them, the insects in particular, have shown that they are able to be merciless pests. They consume agricultural crops, destroy wood, and are carriers of a host of diseases.

Arthropods are small creatures. Even so, there are always a few exceptions. For example, some crabs can be rather large and heavy - up to 4.0 kilograms (9 pounds) and the largest claw span has been measured about 1.5 meters (5 feet) wide.
Imagine what it would be like, as humans, if we had no skeleton. The muscles and tendons would have no place to connect to, in order to support us. We’d end up in a pile on the floor. Well, arthropods don’t have a skeleton inside, but they have an outer, armor-like shell. For us, it may be like wearing a suit of armor in the medieval sense. But these creatures are used to it.

These creatures’ body armor is not made of iron, but of dry cell fibers, glued together with protein, and on some arthropods, with a dash of calcium carbonate. Thus, this exoskeleton is protective for most things in the everyday world of the arthropod, but they aren’t strong enough, in most cases, to prevent being crushed by a human foot. Even so, the water-proof body suit helps them retain water.

One of the weak spots in the exoskeleton is that once it is made, it is permanent. So, if the creature grows, he either has to be crushed by his own skeleton, or he has to “remove it” and grow another one. During the interim period, the arthropod is “naked” and exposed to danger. Plus, the external shell can’t be too heavy, as then the little fellows wouldn’t be able to move very far. That is not a problem for sea creatures, as the water provides some buoyant support for heavy external shells.

Arthropods don’t really “breathe” like mammals, either. Some have small holes in their exoskeleton, and some have gill-like folds that allow air to pass through. Instead of having veins and arteries, the arthropod’s heart merely pumps blood en masse throughout the body, in waves. Only large spiders and crabs have a blood system that carries oxygen. The rest of the creatures get oxygen passed directly to the cells from the holes in the body armor.

The arthropodic brain is just bundles of nerves, and they sense their surroundings in a variety of ways. They sense light by tiny light-sensitive organs, or by simple eyes (like humans), or like compound eyes (like flies), or by antennae (similar to radios), and hair-like fibers here and there.

Arthropods used to have four subdivisions, but one of them, the Trilobites, became extinct some 250 million years ago. We have their remains in fossils, but we don’t know what caused their demise. In fact, it is quite puzzling, as virtually all arthropods can adapt to almost anything.

The remaining three types of arthropods are the Chelicerata (spiders, ticks, scorpions, mites, and horseshoe crabs), the Crustacea (crabs, lobsters, shrimp, and some zooplankton), and the Uniramia (centipedes, millipedes, and insects).

Sexual reproduction among these creatures is generally done by having the male “hand off” sacks of sperm to the female or “drop” the sack near the female, who will retrieve it. However, crustaceans, millipedes, mites, spiders, and some insects, have a type of physical intercourse where the sperm is directly, and personally, transferred.

Some of these creatures lay eggs, which later hatch. Others will keep the eggs inside their bodies, where they will hatch, and result in a “live birth.” Baby spiders look like tiny versions of mom & dad. But other bugs have to go through a longer process, like caterpillars change later into butterflies. Once
they have “grown up,” arthropods can live anywhere from a few hours (May flies) to many decades (like the tarantula).

The origin and evolution of arthropods is not yet definitive. An insect expert is called an “entomologist,” from the Greek word entomos, meaning, “cut in two,” because of the segmented body. See the lesson on research in Lesson 8 for a better understanding.

Key Concepts and Terms
- arthropod
- bug
- entomology
- exoskeleton
- insect

Questions
1. What is a bug?
2. How are insects different from arachnids?
3. What is an exoskeleton?
4. The study of insects and bugs is called what?

THE FISHES

“Fishy Fishy in the Sea, Fishy Fishy come to me,” goes part of a bedtime story, “The Fisherman and His Wife.” Well, in that story, there was a magical fish. There aren’t any such creatures. Even so, a great many people love to go out and try to catch one.

Fish are a varied and splendid genre of animals. They live in the water, generally below the surface, and they do breathe air, only that they do it much differently than we do. Interestingly, fish have an internal skeleton, although they don’t “stand” on ground. Most fish also have special swimming gear: fins, scales, and hydrodynamic styling for rapid movement. But I’ve never seen a fish smile. Maybe they aren’t happy. No matter.

The singular word, and the plural word, for fish is “fish.” But the term “fishes” is also used, mostly in describing a vast number of all fish everywhere. It is proper to say, “I caught a fish. Bob caught two fish.” However, if you plan to become an expert in fish, then you would “research the fishes of the world.” A man who is a fish expert is called an ichthyologist. And a woman who is a fish expert is called an ichthyologist. This word comes from the Greek ichthus, meaning, “fish.”

Fish provide an excellent food source for humans and other creatures. However, people either “love” or “hate” fish. Our English word “fish” comes from the German word, fische, which is pronounced the same as the way we do. In Old English the word was spelled fisc. In both modern Danish and Swedish, the word is fisk and in Norwegian, it is fisken. The Dutch version is vissen, which is pronounced like
“feesin,” and the Icelandic language has the word *fiskur*. Thus, we can see that virtually all the Germanic languages have the same word for fish.

Fish seem to be able to live in just about any underwater environment, including living in the freezing water under the North Pole, to desert hot springs. They are found in the mud of near-dry ponds, all the way to the bottom of the deepest part of the ocean.

How do fish exist if the water temperature is near freezing? Apparently, they have anti-freeze running through their veins. No kidding. Not the propylene glycol that cars use, but a particular combination of chemical molecules.

Meanwhile some fish live at temperatures over 40° C (104° F), and as the season causes the hot spring waters to dry up, these “hot fish” lay eggs, that stay there in the dry out. In some dormant state, the eggs do fine. When the spring rains come, they are “reconstituted” like orange juice concentrate, and go on to hatch and live for a season. And in the deep parts of the ocean where almost no light from the Sun can penetrate, some fish actually glow. That, again, is an internal chemical reaction. Also, fish that live at the bottom of the ocean live in a very high-pressure environment. If they were to try to come to the surface, they’d literally explode!

There are more than 25,000 species of fish, and more than 200 new species are being discovered through research, each year. Sadly, many are also becoming extinct at an alarming rate, as it is for many life forms. And, fish range in size from about 1 centimeter to about 12 meters in size. And we aren’t talking about the whale, which is a mammal, not a fish.

Fish may live in saltwater oceans, or in freshwater lakes. It is interesting to note that ocean’s waters contain 100,000 times the water found in rivers and lakes – but 40% of fish species are found in the freshwater areas.

Most of the ocean’s fish inhabit the continental shelves, which have abundant sunlight and nutrients from the nearby continents.

Did you ever wonder how fish “breathes”? They have unique organs called gills that help them get the oxygen that they need. There is some ambient oxygen dissolved in the water. This dissolved oxygen can actually pass through paper-thin gill membranes and enter directly into the fish’s bloodstream. So, they never really “breathe,” as they don’t have lungs.

Fish can sense changes in water movement pressure – before they can see anything – to determine if something is moving towards, or away from, them. This helps protect them from carnivorous predators. Like flocks of birds, many fish swim in close-knit groups (schools) for protection. Plus, they have a very good sense of smell. They can tell changes in chemicals when other fish, or humans, come near.
Some fish get food by chasing, capturing, and eating other fish. Other fish use an intricate "water suction" system that draws their meal, and all the water around them, down a black hole to their doom (the stomach).

Like insects, fish have a whole host of ways to reproduce. Some have only a few eggs, others have millions. Some fish just “dump” their eggs on the ocean floor, and hope some male will fertilize them. A few fish lay eggs and watch over them until they hatch. Some fish will move along side each other, and sperm will be released from the male at the same time eggs are released by the female. And in a few cases, the female accepts sperm directly from the male, and the eggs grow, and hatch, inside the mother.

Believe it or not, pipefish and sea horses do a reverse reproduction cycle. The female transfers her eggs to the male, and he carries them until they hatch. I bet that some human women would like their husbands to try that, at least once! Fish eggs have a gestation period of a day in some cases, or even a few months in other locations. There are a few humans that love eating fish eggs, or caviar. Caviar are typically the eggs of the sturgeon – of which there are freshwater and marine varieties. Generally, they are removed from the inside of the female sturgeon (which kills the fish) and seasoned before eating. The word “caviar” came to English from the an old Persian word, khayak, meaning “egg.” Later Persians spelled it khavyar, and in Turkish the word was havyar. Thus, caviar has been around a long while. And it is not originally from Russia, although it is very popular there – especially on their thin pancakes, called blini.

Humans have been relying on fish as a source of food protein since the beginning of time. The significance is not lost on the Judeo-Christian world, since fish are often mentioned in the Holy Scripture Writings of these faiths. Even Jesus of Nazareth used fish as a food, and as a lesson.

Are fish a threat to humans? Not really. Humans don’t live in the water, or under its surface. However, like with any animal, if humans wander into the wrong territory, the creature will defend itself. You can’t merely “talk reason” with the fish. And fish aren’t going to come after humans. They are not able to simply climb out of the water and chase a person down the road.

So, just a simple rule: avoid areas where dangerous fish can be. For example, it would be an unwise decision to walk around barefoot where the stonefish lives. It is very poisonous. It has a sharp, toxin-filled spine. One prick of this spine tip means certain and immediate death to humans.

Of course, sharks get a “bad rap,” as humans have ignorantly wandered into shark feeding grounds when the sharks have been hungry. Can you blame them? Humans are not on the typical menu for sharks. They prefer other foods. But, when you’re hungry, you have to eat.

We humans are a great danger to fish. For example, maybe a million sharks are killed by humans each year. On the other hand, perhaps 30 humans are killed by sharks per annum. Not a very fair war there.
Just like cattle and other livestock can overgraze a pasture, killing most of the grass, fishermen can overfish an area, and cause the disappearance of many innocent fish species for decades. And we aren’t even talking about the ecology disasters of polluted water, which kill untold numbers.

**Key Concepts and Terms**
- caviar
- fin
- gill
- ichthyologists
- scale

**Questions**
1. How do fish reproduce?
2. What is the science of the study fish?
3. Are fish dangerous to mankind?
4. How many species of fish are there?

**AMPHIBIANS**
*(During this lesson do, Lab 9: Frogs and Toads)*

An amphibian is an animal with damp, hairless skin through which water can pass in and out. Kind of like people at the beach. “Amphibian,” comes from the Greek words *amphi*, meaning “both,” and *bios*, meaning “life.” Both-life? What could that mean? Well, they live both in the water and on the land. It has the “best of both worlds.” The word “ambidextrous” has the same root, meaning “both hands.” In other words, a person who is ambidextrous can write, or throw, with either hand. The Roman amphitheatre was a theatre with two parts – one on the left, and one on the right. An expert in amphibians is a herpetologist, from the Greek word *herpein*, meaning “to creep.”

Amphibians spend their “youth” in the water and their adulthood on dry land. They only return to the water to reproduce. It is believed that amphibians are the natural ancestors of reptiles (next lesson), which in turn, are the ancestors of birds and humans (in future lessons).

Amphibians are either caecilians, frogs, or salamanders. Caecilians are not very common. They have no arms or legs, and look more like ugly snakes, or maybe earthworms. Like earthworms, caecilians live in the soil, and burrow into the dirt. Do not confuse these amphibians with Sicilians, who are people living on the Italian island of Sicily. Although, General George Patton’s army made an amphibious landing on Sicily in World War II.

Salamanders look like snakes with tiny legs and feet. Newts and mud puppies are salamanders. However, Newt Gingerich (a former Speaker of the U.S. House of Representatives) is not a salamander. Some salamanders are water-bound; some are land-locked. Others can’t make up their minds, and live some time in the water and some time on the land. Just like people who have beach houses.
Toads are part of the frog family, and together they are the most prolific of the amphibians. (Frogs have smooth, soft skin and long arms and legs. Toads have ugly, bumpy skin and little legs).

Amphibians live in almost every environment, except the polar regions, including in mountains, forests, savanna grasslands, rain forests, conifer forests, alpine areas, and even deserts. They need water to breed, but they have the uncanny talent of locating wetlands for that.

The giant Japanese salamander is the largest amphibian, about 1.5 meters (5 feet) long. The gold frog reaches only 1 centimeter (about 0.4 inch) in length.

Amphibians start life as fertilized eggs. Then when hatched, they live in the water and have gills at the sides of their heads that enable them to breathe underwater. At this point, they are called tadpoles (or pollywogs). They have a tail which is used in swimming. At this point, they are, for the most part, fish.

When tadpoles become frogs, they lose their tails and their gills. They live on land with powerful legs. Tails may hinder their jumping ability, so they go away. In many ways, human embryos look like tadpoles.

Maybe you have heard of cold-blooded killers, or perhaps evil and cold-hearted scumbags. In any event, saying that someone is “cold-blooded” evokes an image of a bad person. Well, amphibians are cold-blooded creatures, unable to generate their own body heat. We humans, and all mammals, have internal “thermometers” and heat engines that keep us at the right temperature. However, amphibians lack this control. Rather, they are the temperature of their environment. In warm weather, their systems are at full throttle. In cold weather, they slow way down, and may even “shut off” and hibernate.

Amphibians are seen in just about every color. This can help them to attract a mate, and it may help hide them from predators. Plus, amphibians breathe air and drink water through their skin. Yes, they have lungs and breathe that way, too. And they can drink water just like you and me. But they have this extra perk.

The skin of an amphibian is a veritable chemical factory. There are glands that release a type of mucous to protect the skin and to retain water. If they enter the water, these chemicals ensure that there is a proper salt concentration balance. On top of that, they can give off toxic chemicals to ward off predators, and even kill them.

Frogs and toads have no ears. Well, they do, but they are inside their bodies, not outside. Even so, they have a keen sense of hearing, and with a real vocal chord, they make a whole series of sounds, some for mating, and some for communications.
If you know Kermit the Frog, then you realize that frogs have large, bulbous eyes that stick out. This helps them scan their surroundings. Unfortunately, caecilians are blind. They do have eyes, but they have evolved to be useless, as caecilians live underground in the dark.

Amphibians are meat eaters, and love to catch bugs, worms, and even baby amphibians for their meals. Many amphibians have especially long tongues, so they can “cast it out” to capture an unsuspecting victim.

Frogs and salamanders seem to have showy courting habits. Male salamanders have their own “cologne” to attract females, and then, they use bright colors to “close the deal.”

At the right time, male frogs gather together and prepare for the courting season. And in doing so, they whistle, croak, and make all manner of noises to attract females.

Frogs mate in a most interesting way. The male climbs onto the female’s back, but he does not penetrate her as a mammal might do. Instead, he waits for her to begin to lay her eggs, and he then releases sperm that falls onto the eggs as she is dropping them. Some salamanders touch and have “direct deposit” while others drop sperm packages for the female to pick up.

The fertilized eggs are covered with a clear gel, and they must be in water, or in a very damp place. If dropped into water, the adults depart, and never return. Those that lay their eggs on land keep someone to guard the brood.

After hatching into a larval form, most amphibians undergo a dramatic change in anatomy, diet, and lifestyle known as metamorphosis, where meta means “trans” or “across,” and morph means “form” or “change.” So, the larva transforms into a different creature.

One can only imagine how long these creatures can live. Research of amphibians that have been kept “in captivity,” like in zoos or laboratories, has shown that salamanders can live over 20 years – a few have exceeded 50 years! Frogs have lived up to 10 years under human care, but some toads have survived in captivity for more than 30 years!

For a very long period of time, amphibians reigned as the prima animus on land – for more than 120 million years. Ironically, frogs, toads, salamanders, and caecilians were not among that select group of dominant animals.

For more than 300 million years amphibians have adapted and survived on this planet. However, recent and future changes in the Earth’s environment may spell their doom, and this causes alarm among scientists. Amphibian populations have been declining at the rate of 4% per annum for the past 50 years.

In as much as these creatures have permeable skin that allows just about anything to become absorbed, any changes in their habitat can impact them greatly.

Their declining populations may be caused by natural events, but, it is more likely than not that human action have caused the amphibian environment to change faster than they can adapt. While “progress”
has destroyed a number of natural amphibian habitats, and a preponderance of salamanders are vanishing, it is quite a mystery why some amphibian populations are decreasing or disappearing altogether, even though their habitats have not changed. For example, two types of Australian frogs have disappeared in the past two decades, even though their natural environment continues undisturbed. Another example is the golden toad of Costa Rica – vanished in the past 15 years from its almost “perfect” rain forest surroundings. And the red-legged frog that used to be “all over” the North American Pacific Coast is nowhere to be found. Maybe extraterrestrials are coming to Earth and kidnapping the frogs.

Recently, disturbing reports have come in about a large number of frogs with body abnormalities: extra legs or arms, or missing legs, or malformed body parts. What causes such things? Many possibilities exist: disease, global warming, ozone depletion, air and water pollution, acid rain, and many other things.

Let’s hope that we can have some control over these issues so as not to cause the death and destruction of the amphibians.

Key Concepts and Terms
- amphibian
- eggs
- frog
- herpetology
- Kermit
- metamorphosis
- tadpole
- toad

Questions
1. What are tadpoles?
2. What kind of animal is the puppet, Kermit?
3. Explain the difference between a frog and a toad.
4. What is a newt?
5. Explain metamorphosis.

REPTILES (INCLUDING DINOSAURS)
(During this lesson, do Lab 10: Lizards)

“Never smile at a crocodile” goes the song in Walt Disney’s “Peter Pan.” And “See ya later, alligator – after while, crocodile” is a silly refrain often used among pals. This is also the realm of the dinosaurs. This is the kingdom of the reptile. A reptile expert, one would think, would be a reptologist. But, no, the specialist is called a herpetologist, from the Greek word herpeton, “reptile.” Meanwhile, the Latin word for “to creep” is repere, so here we go again.
Reptiles don’t look very friendly. They have scale-covered skin that is tough and dry. Besides the aforementioned creatures, this area also includes snakes and turtles. Like amphibians, they cannot control their own body temperature, so they are cold-blooded.

Reptiles hatch from eggs which are laid on land, and the eggs have a protective covering – just like birds. They breathe air and have teeth – except for turtles. The reptile’s skin is a bit different than most other animals’. Like the toad, it is unpleasant and horny. But it’s dry, with scales. Their skin is not permeable. Water cannot pass through it. The skin is not damp. They don’t have feathers or fur or hair.

While reptiles have a fondness for warm regions – like the Tropics, and deserts, they can be found just about everywhere, except for the polar regions.

Reptiles are split into four subdivisions: Crocodilia (crocodiles, alligators, caimans, and gavials), Squamata (lizards, worm lizards, and snakes), Testudines (turtles, terrapins, and tortoises), and Rhynchocephalia (the tuatara). Crocs, lizards, snakes, and turtles make up the bulk of all reptiles. Caimans are a type of alligator, found in the American tropics. Gavials are a type of Crocodile found only near Thailand and Burma.

The “crocodilian” family live in the warm waters of the tropics, but American crocs and gators can also be found in some more temperate regions, such as along the Gulf of Mexico and along the Atlantic coastal areas of Georgia and South Carolina.

Most of the crocodile camp members are rather large and heavy. The most massive can exceed a ton. With their great bulk, it is not a surprise that they spend most of their lives in the more buoyant environment of water, where it is far easier for them to navigate their heavy forms.

The design of the creatures is most ingenious. If one looks carefully, one can see that their eyes and their noses project up above their head, so they can be completely underwater, and yet breathe and see. Their eyes are used like a submarine’s periscope. Therefore, foolish prey may accidentally glide by a hungry gator, and not realize that they have been eaten.

There are far more sauros (lizards) than any other type of reptile. With thin, long bodies, four legs and “hands & feet” that are similar to human hands and feet (except they have claws for toes), they wander the Earth’s surface, as they have for millions of years. The largest of the lizards were the dinosaurs, which comes from the Greek words deinos (monstrous) and sauros (lizards). However, with the demise of the “monstrous” lizards, the largest one around these days is the Komodo dragon, which can be 3.0 meters (9.8 feet) long and weigh 165 kilograms (363 pounds). While Komodo dragon is huge compared with most other living lizards, it still pales in comparison to such real monsters as Tyrannosaurus Rex (15 meters long and 9,000 kilograms) and the Brontosaurus – aka Apatosaurus (25 meters long and 36,000 kilograms).
The Komodo dragon is found only on Komodo Island, and other nearby islands of Indonesia. As a carnivore, it eats only meat – particularly live prey. The Komodo dragon charges and bites its victim, then turns and walks away. Why? Because the Komodo’s saliva contains a large number of deadly bacteria. (Imagine what kind of breath one of these has!) Once you have been bitten by a Komodo, you will die of disease. Meanwhile, the dragon will be nearby, waiting for the victim to kick the bucket, after which, he goes in for his meal. Since he lives with these deadly bacteria all the time, the Komodo is immune to it. The Komodo’s menu includes such animals as deer, goats, pigs, water buffalo, and even humans, including dead and decomposing humans who may have died in some other fashion; the Komodo isn’t picky. First discovered by European scientists in 1910, about a dozen humans have died from Komodo bites since that time.

Of course, most lizards are small creatures that live in or near trees, and eat bugs. If you don’t like bugs in your house, then invite these smaller lizards to take up residence. They will control your bug problem – without chemicals. If you have other pets, like cats or dogs, however, they will eat or kill the lizards.

The marine iguanas of the Galápagos Islands are the only lizards that routinely “go for a swim” in the ocean. These lizards feed mostly on algae rather than meat. And besides the Komodo, only two other lizards have poisonous saliva: the gila monster and the beaded lizard. Even so, their bites are not as lethal as that of the Komodo.

The iguana is a tropical lizard unique to the Americas. The gila monster is a desert creature, unique to the desert southwest of the United States, and is the largest American lizard.

Next we come to the “legless lizards,” or snakes, ranging in size from the 13-centimeter thread snake, to the 10-meter anaconda (which can be as much as 250 kilograms). As reptiles seem to have evolved from amphibians, so snakes seem to have come from the lizard family.

Like their ancestors, snakes can be found almost anywhere. However, as they are also cold-blooded, they stay away from the colder climes. Snakes have internal ears, and their “eyelids” are permanently closed, but they are transparent.

People are generally afraid of snakes, but they don’t have to be – most are harmless. Even so, some snakes do have poisonous venom to avoid: the vipers (rattlesnakes), cobras, and a member of the colubrid family – the boomslang.
Turtles are reptiles, too, but they live in a “tank” and carry their house with them. Their shell provides protection, but it is also rather heavy. It is common practice to call land turtles tortoises. The 11-centimeter American bog turtle is the smallest, while the leatherback turtle, known as a giant sea turtle, is as long as 2.4 meters weighing over 900 kilograms (1,980 pounds).

The shell of the tortoise is made of bones fused to the spinal cord and rib cage, and the outside is covered with tough scales. Water turtles don’t have hard shells like a military tank, but, rather, they are flatter, softer, with a leather-rubber-type of texture.

The last reptile for us to review is the so-called “living fossil,” the tuatara. They live only on a few islands near New Zealand in the South Pacific, and they are surely an anachronism. They should have died off long ago, but they are still around. First coming on Earth 225 million years ago – long before most dinosaurs - this creature has “overstayed” its time. Maybe someone should tell these old creatures that all their friends died off millions of years ago. Typically they grow to about 50 centimeters long, and live up to 100 years.

Reptiles have a well-developed brain, lungs, three-chambered hearts (except croc, which has four, similar to birds and mammals). In hot and dry environment, reptiles’ body wastes are sent to a special reservoir, where water is absorbed back into the body before the rest of the waste is excreted.

Reptiles have sharp senses, including special eyes, and a mouth “organ” to taste and smell. Snakes, and some lizards, have forked tongues that they use as a data-gathering tool. They can sense prey or predators and determine whether to follow a trail that they smell, or go the other way. One group of snakes, the pythons, boas, and pit vipers, have “night vision” like infrared sensing, being able to sense body heat of another animal.

When the weather cools off, reptiles may “hibernate” by retreating somewhere to hide, or go to the bottom of a pond. Turtles can actually stay for months under water (cold water) as their system slows way down, and their permeable membranes in parts of their skin can get the dissolved oxygen in the water.

Reptiles are delicious meals for fish or birds large enough to eat them. Some mammals or even other reptiles will also dine on them.

Most creatures have a “fight or flee” reflex, and reptiles are no different. They would rather run away, but if cornered they will fight, and even bite. While a bite from a tiny gecko is almost funny, remember, don’t mess with a Komodo. On the other hand, some reptiles use “military techniques” to confuse the enemy, like the element of surprise, or creating a diversion. For example the frilled lizard will run, stop, do an abrupt about face, open its mouth, and pop open a huge set of frills around its neck, like opening an umbrella. This usually scares any creature tracking it. The hognose snake makes a shrill hiss and does an impression of cobra, then it poops on itself, making it very offensive (like a skunk). Venomous snakes merely bite their attackers, or even “spit” at them with the poisonous fluid.
Reptiles have their version of dominance, courtship, and reproduction. Male turtles and crocodiles deliver sperm using a penis. Male lizards and snakes have two penises, called hemepenes, which they alternate each time they mate.

Reptiles lay eggs outside the body, and they incubate, like chicken eggs. A few reptiles lay only one or two eggs, while others may lay up to 150 at a time.

Most reptiles bury their eggs and move on. Pythons and crocodiles stick around to protect their eggs. After they hatch, the new reptiles are “all ready” and though young, “grown up” and on their own. Of course, small reptiles are easy targets for other creatures, in fact, few reptiles live to celebrate their first birthday. But, the longer that the live, the longer their life will be. Some live 100 years or more.

Of course, the ancestors of today’s reptiles were alive during the dinosaur period. What killed the dinosaurs gave impetus to the early croc and turtles to adapt and evolve. Even so, they are threatened today, and not by natural events. For the longest time, alligators and crocodiles were killed by hunters for their leather-like skin (for boots, shoes, purses, etc.) Now they are protected.

Turtles and their relatives have been hunted for many years, for all that they have to offer: food (eggs, meat, soup), fashion (shells, skin), and as pets.

International laws and agreements since 1975 have helped prevent the extinction of reptiles. However, poachers continue to illegally capture and kill them for financial gain.

**Key Concepts and Terms**
- alligator
- dinosaur
- iguana
- reptile
- snake
- warm blood

**Questions**
1. What does “hibernate” mean?
2. Name four reptiles
3. How do reptiles reproduce?

**BIRDS**
(During this lesson, please do if possible, the field trip to a Bird Sanctuary or Aviary)

Birds have wings and fly. Bats and bugs have wings and fly. Therefore, bats and bugs are birds. Nonsense. But at first the logic seems valid.

“Birdy, Birdy in the sky, don’t go poopie in my eye.” Birds are animals with feathers and wings. But not all birds fly. Really. Even so, flightless birds (ostriches, penguins, and others) had ancestors who could fly.
Birds are warm-blooded and can regulate their body temperature internally, like humans. They lay eggs, and hatch, just like reptiles, but with a warm heart, they can live almost anywhere. A scientist who studies birds is an ornithologist, from the Greek word *ornith*, meaning “bird.” Meanwhile, “bird” comes from Old English word, *brid*. That’s right – “brid.”

Birds fly above the highest mountains and over both poles. They can even live in hot, parched deserts, and bone chilling arctic regions. Some birds can dive into the ocean as far down as 250 meters! Some ocean-going seabirds have been seen by sailors, thousands of kilometers from land!

There has always been a symbiotic relationship between humans and birds. Of course, we humans get the better deal. We steal and eat their eggs, we capture and cook them, we use their feathers for bedding. And we were inspired long ago to learn how to fly.

The smallest bird is a **hummingbird**, about 5.7 centimeters long, weighing less than 2.0 grams. The ostrich is the largest bird, about 2.7 meters high and weighing about 156 kilograms. No wonder it can’t fly. The heaviest bird that can fly has a funny name: the great bustard. It weighs no more than 18 kilograms.

“Birds of a feather, flock together,” was a popular phrase long ago. This means, essentially, that you should stick to your “own kind.” So, don’t hang around with any orangutans. Anyway, birds have feathers that cover their bodies. Not fur. Not hair. Feathers. The bony structure of feathers is made of the same stuff that human fingernails are made of.

Feathers help in flight and as insulation against cold. They even make their own “body oil” that birds then spread on their wings to make them waterproof. Just like fingernails or hair, feathers are “dead.” They are not living tissue, so they need to be replaced when damaged. Dead tissue cannot repair itself as living tissue can. So, once in a while, birds will shed some of their feathers to make room for the new feathers coming in.

The muscles used to fly must be extraordinary, and they are. The muscles originate in the chest cavity and are hooked to the wings by tendons.

Birds have tails to assist them in flight, just like our airplanes. Their feet have four toes, one of which is a like an opposable thumb, so they can grasp branches and not fall off.

Birds don’t have any teeth. They have sharp bills or beaks that can take bites out of things. They don’t have lips, or any “fingers” either, in spite of many restaurant menus advertising “chicken fingers.”

Bird eyesight is top rate. Their ears are inside, but small openings near the eyes provide access to them.

If you hadn’t noticed, birds sing. They sing various songs. Some of them are lovely, and some of them are harsh to our ears. Never the less, birds have a type of “voice box” that allows them to make these sounds.
Are you a bird brain? Birds are brainy creatures, believe it or not. While they lack a developed cerebral cortex, they have a part of the brain that we don’t have. This part, called the hyperstriatum, helps them learn songs and other things that they need to know.

Interestingly, bird skeletons are super lightweight, maybe to help them stay aloft in flight. In fact, their bones are hollow. Another feature to help birds remain light, for flight, is that they have no teeth to grind their food. Instead, a special “stomach” called the gizzard does all the “grinding up” of the food. You may actually see, and eat, a turkey gizzard during Thanksgiving. They taste similar to liver. Plus, since females lay their eggs in a nest, they don’t have to carry the developing fetus around, as we humans do (well, female humans).

One may not realize it, but for birds flying requires a whole lot of energy. Really. It takes more energy for a bird to fly than it does for a human to run as fast as he can. So, birds need a great deal of energy. They must eat, non-stop, and their metabolism is always on hyperdrive. As a result, they have elevated body temperatures, like over 40° C (over 104° F). For humans, this could mean a violent reaction to a disease. But for birds, is it “normal.” Their biochemical reactions are then accelerated.

To keep this high rate of biochemistry going, besides the energy via food, birds need high rates of oxygen. Rather than breathing 30 times per minute, as humans do, they may breathe 300 times a minute, or more. And a bird’s heart beats faster than a speeding bullet: up to 1000 times a minute!

The circulatory system of birds also functions at high speed.

These creatures are multi-talented, as they can fly, walk, swim, and even dive. For example, loons, ducks, and penguins, to name a few, have webbed feet. And penguins utilize their wings to “fly” through water. One type of penguin is able to dive over 250 meters down (850 feet) and stay under water more than 10 minutes.

Just like us, birds eat, sleep, and reproduce. They also have to be on the lookout for other animals that may want to eat them. Long ago, humans spent a lot of time looking for food. That’s what birds do. But, since they can’t eat a large meal and go for long periods of time, they have to eat small amounts, almost constantly. If they could eat a lot of food, they would be too heavy to fly. Tiny birds must eat even more often that larger birds. For example, hummingbirds “pass out” at night, as they run out of internal energy. The only thing that stirs them the next day is the light of the Sun.

The bird diet includes bugs, fish, other small animals, seeds, nectar, and fruit. A few birds eat only meat. A few eat only fruits and vegetables. Sea gulls and crows are omnivorous, and will eat anything. As birds have no teeth, and no lips, they need something to chew their food, and, as mentioned before, that is the gizzard.

Didn’t we say that birds had brains? Some birds actually employ tools as part of their lives. The woodpecker finch uses tiny branches and twigs to remove bugs from hard to reach areas. And the
Egyptian vulture, who loves to dine on ostrich eggs, throws (drops) stones on the ostrich eggs to crack them, as ostrich eggs are pretty tough nuts to crack.

If you have any friends that don’t sleep much, maybe they are birds. You see, birds don’t need a lot of sleep. They stop to “rest” only to relax muscles and regain energy, and then they are off again. Sea birds hardly sleep at all. For example, one type of sea tern may stay aloft for years. YEARS! These terns are so adept at flying, that it takes like no energy at all for them. Can you imagine?

Birds are picky when it comes to finding a wife or husband. Did you know that most birds find a mate, and stay “faithful” to that mate, for their whole lives? We humans could learn something from birds there. Females pick the males that they find the most “attractive,” which means males who can sing loudest, or longest, or have a larger repertoire of songs. Plus, a male’s plumage can help. There are even some bird species in which males will provide a “house” as a dowry: the male will build an elaborate shelter for their future home. If the female “buys into it,” they will be mated for life. Cool, huh? And some people think birds are stupid.

Birds have excellent hearing and eyesight, which assists them to take quick action if necessary. Small birds are often attacked by snakes or by other birds, like hawks or falcons.

Did you ever hear of birds traveling long distances, back and forth, each season? Well, some birds do migrate, and they do so for a variety of reasons. They may want to move from a cold area to a warm area. They may want to find more fruitful areas for food.

The most famous birds are the aggressive, powerful ones, like eagles, falcons, hawks, and owls. These attackers have hooks on their beaks, sharp, powerful claws, and perfect vision and hearing. Favorite foods for these birds include rats and their relatives. They also like fish, and “fish from the air.” They will also eat bugs. Vultures and condors “attack” dead animals and eat them.

Birds who can’t fly are like track stars who can’t run. But, for some evolutionary reason, some bird species can no longer fly, such as ostriches and emus. Turkeys, chickens, and similar poultry have become “running birds” rather than flying birds.

Birds may have evolved from tiny dinosaurs or from flying reptiles. They learned to fly by either climbing up trees, then jumping off in an attempt to catch bugs; or by running along the ground and jumping up to grab flying insects. We aren’t quite sure yet. Even so, birds have been around for 140 million years or so, at least. Fossilized evidence supports these findings, as does recent DNA research. Ornithological evolution goes on. Some bird species have already become extinct, and more are vanishing each day.

Archaeological research has told us that our prehistoric ancestors ate birds and used their parts (like feathers) for fashion. Humans began to domesticate birds more than 5000 years ago. (That means that
they began to raise flocks of them, resulting in an evolutionary change over time). The ones most domesticated have included chickens, geese, and turkeys.

Birds have been used by people as indicators of our ecology. For example, in the 1800’s, coal miners routinely brought canaries into the mines with them. Canaries always sing, but if they stopped singing, then it meant something was wrong and they had to get out. For example, canaries are far more sensitive to chemical changes in the air than we are. When toxic gas was released in the mines, men may not even know about it. But if the canary died, then men would soon follow. And the gas wasn’t just poisonous. A spark could cause a huge explosion, causing many more people to be maimed and killed. This type of bird indicator was an active plan. But passive plans work, too.

In the 1960’s, ornithologists saw a decline in the population of peregrine falcons in the U.K., and a disappearance of carnivorous birds in the U.S. It was determined that certain insect killers, like DDT, were building up in the tissues of these birds, causing them to become sterile. Because of this, and other research, the use of DDT was banned, and other alternative, “nature friendly” pesticides were developed.

Some people like watching frogs jump. Others like watching men chase a ball all over a field. And yet others enjoy watching birds. These would-be amateur ornithologists go out in search of adventure, along with their bird guide books and their special binoculars. Even so, these amateurs often help the field of professional ornithology by keeping records of what they saw, where, and when.

Birds are not a threat to people. But, then again, some foolish humans blunder into a bird territory and get attacked, with one dying every so often. We are more dangerous to birds. Birds are more dangerous to us by being carriers of disease – and the bacteria-laden poop that they drop on our cars.

Some birds damage crops. Others fly unwittingly into jet engines, causing airline crashes. Overall, though, birds help rid farms of vermin, allowing the crops to grow.

Sadly, humans have hunted down many hundreds of bird types until they no longer exist. The best example is the dodo bird of the 1600’s.

Today, hunting birds to extinction has been outlawed, but we are still destroying bird habitats, which, in essence, also cause extinction. Sanctuaries for birds, known as aviaries, help to preserve those birds that are left. This word comes from the Latin word, avis, meaning “bird.” In the end, we will have to decide globally, not locally, about how we can best preserve birds, for their benefit as well as ours.

**Key Concepts and Terms**
- aviary
- bird
Questions
1. How do birds really fly?
2. Why are there birds that cannot fly? Name two.
3. What organ helps birds digest rough foods?
4. What is the study of birds called?

MAMMALS
(During this lesson, please do if possible, the field trip to a Zoo or Dairy Farm.
The field trip is described in the appendix)

Mammals raise their babies on milk – through mammary glands, or breasts. Mammals have fur or hair and are the most intelligent creatures on Earth.

Baby mammals are dependent upon their parents – mostly their mothers – for nourishment, and they remain in the nuclear family environment until they are “all grown up.” This creates strong interpersonal relationships between and among all family members.
Plus, the young can learn by observing their parents’ behavior.

It is believed that mammals came from a subset of reptiles, appearing some 200 million years ago.

Most mammals are land creatures that move on four legs. However, there are those that can travel on two legs, some that live only in the water, and others than can fly. Mammals range in size from 2 grams (a very small bat that lives in Thailand) to the blue whale, at more than 136,000 kilograms.

Some mammals live only about a year (shrew) while others can routinely surpass the century mark (humans).
As warm-blooded creatures, mammals can live almost anywhere – from the subzero weather in the arctic regions, to the oven-like temperatures of the hottest deserts. They are found thriving on top of the tallest peaks as well being able to survive more than a mile below the ocean’s surface.

One group of mammals actually lay eggs – like reptiles and birds. They are found only in the South Pacific land areas of Australia, Tasmania (right off the coast of mainland Australia), and New Guinea (not far from Australia). The duck-billed platypus lays a couple of eggs, and they are incubated in a special nest near the water. The spiny anteaters lay one egg, but then keep it in a special pouch of the
mother. One might think that after they hatch, that the mother would give them worms or other foods. Instead, they drink milk from the mother.

Another group, the **marsupials**, have live birth, but keep the babies in a pouch to continue their development. It is from there that they drink their mother’s milk.

Most marsupials live in – yes - Australia, Tasmania, or New Guinea. They include some interesting creatures, such as bandicoots, kangaroos, koalas, and wombats. The remaining marsupials live in America. The only marsupial in the United States is the opossum.

The largest of the mammal group are the placentals, which is what humans are. The babies are grown inside the mother’s womb, and are born fully developed – although not fully grown.

The largest subgroup are the rodents (from the Greek word, *rodere*, “to gnaw”), such as gerbils, guinea pigs, **hamsters**, mice, rats, squirrels, and similar creatures. Believe it or not, another large subgroup are the insect-eating bats. These mammals fly. The flying squirrel “flies,” too, but only in the sense that it can glide after jumping.

The carnivore mammals, such as lions and tigers and bears, eat almost nothing but meat. However, some bears will eat fruit and berries. The herbivore mammals, like antelope, bovines, porcines, the horse family, and pachyderms, eat almost nothing but fruits, vegetables, and grains.

Primates are omnivores, and will eat just about anything. That’s what humans are.

Marine mammals, such as manatees, seals, sea lions, walruses, love the water. Cetaceans (whales, **dolphins**, and their relatives) are expert at swimming and “fishing.” But these all must breathe air, as they have no gills.

Mammalian intelligence is related to brain size, but not entirely. In fact, there seems to be a greater relationship between the mass of the brain compared to the mass of the animal – the higher the percentage of the body’s mass for the brain, the more advanced the animal. For example, large whales may have brains with masses of 7 kilograms or more. Human brains are only about 1.4 kilograms in mass. So, whales have brains that are fives times as large. And yet, compared to the whale’s immense weight, its brain is only 2/10,000ths of its mass. In humans, the brain is 2/100th s of its mass – one hundred times more in ratio. So, in humans, the brain plays are far greater role than in whales.

That being said, mammals are very quick learners – either by trial and error, or by copying what they see from others. While mammals eat to stay nourished, they also eat to stay warm. The fatter they are, the more insulation that they have.
Carnivorous mammals, like canines (wolves, foxes, dogs) and felines (lions, tigers, kitty cats) are pre-programmed to hunt down their dinner. These animals have excellent eyesight, but even better hearing and sense of smell.

While mammals give birth to relatively few babies at a time, they make up for it by caring for them a long while, which increases the chances of their survival.

Female mammals typically give birth all by themselves, but with dolphins, elephants, and humans, other similar creatures often join in to help.

Milk produced in the mother’s mammary glands provides newborn mammals with water and important nutrients. Mammals are born with a strong sucking instinct that helps them feed immediately.

Before the young are finished with their mother’s liquid diet, they learn to socialize with their siblings, and to participate in the other family activities, including sharing the “kill” brought in by mom or dad. This teaches them invaluable experience for when they become adults.

Vocal signals have become important to monkeys, as they have certain warning calls for different predators. Skunks protect themselves by their putrid odor, and armadillos wear a suit of bone-plated armor. Some animals have antlers or horns that they use to ward off attackers. Other have needles, called quills, to prevent someone from trying to eat them. Besides that, they can use their claws, or teeth, or tusks, or even camouflage.

Mammals had been roaming earth by the time the reptilian dinosaurs came on the scene. The presence of dinosaurs curtailed the activities of mammals, as they were part of the dinosaur diet plan. But eventually, the dinosaurs went away, and mammals once again could multiply and replenish the Earth. To some extent, mammals have not changed much. They still have four legs, hair or fur, big brains, hearts with 4 chambers, and so forth.

The relationship between humans and other mammals has been well documented. They not only ate mammals and used them for tools and clothing, they also domesticated them to become partners in their existence. Humans trained dogs to help with herding, and have domesticated cats to help control pests (like rodents). Soon humans were “farming and harvesting” animals, such as cattle, sheep, goats, and other livestock. They were using oxen and horses for labor. And the list goes on.

Sadly, many mammal species are becoming extinct due to both chemical contamination and destruction of habitats. For example, a member of the horse family, the quagga, vanished in 1883. Before that, the bluebuck disappeared around 1800. Stellar’s sea cow, a type of manatee, was gone by 1768. More recently (1952) the monk seal died out. Several types of bats no longer exist; and a number of marsupials, have disappeared, including one called a thylacine, died in captivity in 1936. Over the past half century, almost all the black rhinoceros members have been killed off, and there are only about 5000 natural tigers in the wild that are left.
When “caught in time,” some species can be saved, as a whole, and nourished back into existence. For example, one group of ferrets, last seen in 1970, was thought to be extinct. However, biologists found a small natural colony still alive in 1981, and since then its population has grown.

While humans still have certain demands and needs, it is unlikely that any subset of humans desires to completely eradicate an animal species. It is just not in the best interest for humanity, the animals, or the planet Earth. Thus, we continue to design new methods to protect and promote all life forms, particularly mammals.

**Key Concepts and Terms**
- mammal
- mammary
- milk
- momma
- rodere

**Questions**
1. How do mammals reproduce?
2. Which rodent(s) can fly?
3. What do mammal females give their newborns to eat?
4. Name two mammals that have become extinct in the past 200 years or so.
LESSON 6 STUDY QUESTIONS. FILL IN THE BLANK. CHECK YOUR ANSWERS.

1. ________ is the branch of biology concerned with the study of creatures in the animal kingdom.
2. The ________ is an animal with a hard, outside skeleton (exoskeleton.)
3. Humans have been relying on ________ as a source of food protein since the beginnings of time.
4. ________ is an animal with damp, hairless skin through which water can pass in and out.
5. There are far more ________ than any other type of reptile.
6. International law and agreements since 1975 have helped prevent the extinctions of ________.
7. ________ are warm-blooded and can regulate their body temperature.
8. Sanctuaries for bids are called ________.
9. ________ are omnivores and will eat just about anything.
10. Many mammals’ species are becoming extinct due to both chemical ________ and destruction of habitats.

ANSWERS TO LESSON 6 STUDY QUESTIONS.

1. Zoology
2. Arthropod
3. Fish
4. Amphibian
5. Sauros (lizards)
6. Reptiles
7. Birds
8. Aviaries
9. Primates
10. Contamination
LESSON 7

HUMANS AND THEIR ANCESTORS

In this lesson, you will learn about the origin and evolution of humans.

The lesson includes:

Anthropology

Human Body (Lab 11: Self Examination)

Primates (Lab 12: Comparison of All Primates)

Apes (Lab 13: Types of Apes)

Hominids (Lab 14: Ancestors of Humankind)

Homo Sapiens (Lab 15: Study of Neandertals)

Cro-Magnons – Homo Sapiens Sapiens

ANTHROPOLOGY

In as much as Lesson 7 is all about humans and their ancestors, it is only proper to explain the science that studies humans: anthropology. This is a science that tries to find out as much as possible about humans, past and present.

The word “anthropology” comes from two Greek words, anthropos, meaning “human being,” and logos,” meaning “study of.” Other words that came from that Greek root include “android, philanthropist, philanderer, and polyandry.” An android is a “creature who is like a male human,” or more casually, “a human-like creature,” such as a human-looking robot. A “female robot” would be called a “gynoid.”

A philanthropist is a person who loves mankind, from the Greek philo, meaning “beloved,” and anthropos. A philanthropist is a person who is generous with his material possessions, and donates them to others to help them.

A philanderer is a person who engages in sexual love with many persons. This comes from philandros, meaning, “lover,” or one who engages in sex with many others. In today’s terms, it means a person who is an adulterer, and who engages in sexual activities with other people besides his or her spouse.
Polyandry means “many husbands,” in today’s language. It comes from the Greek poly, meaning “many,” and anthropos, “human males.” The opposite would be “polygyny” meaning “many wives.” The general term for plural spouses is “polygamy” from poly and “gamete.”

Meanwhile culture and society are critical in comprehending how humans are unique. Culture is inexorably connected with the human trait to be able to utilize linguistic talents to communicate – among other traits. Of course, our analysis of the evolution of humans can lead us to accurate conclusions regarding human social patterns and cultures.

Little has changed, biologically anyway, among humans over the past 100 millennia. Of course, 100,000 years ago it is likely that both homosapiens and neanderthals inhabited the planet.

To study the civilizations of the past, we invoke a branch of anthropology known as archaeology. This word comes from the Greek word arkhaios, meaning “ancient.” Archeology studies past, dead societies, rather than existing ones. As it is impossible to dig up the bones of a dead person and interview him about his life, artifacts are carefully examined. These artifacts include human remains, cities, structures, tools, cooking pots, and so forth.

Meanwhile, physical anthropology tries to make connections between the biological human and the society within his frame of reference. A subset of physical anthropology includes forensics, the study of scientific evidence for legal cases, such as in popular television shows such as CSI: Crime Scene Investigation.

**Forensic anthropologists** are often called upon to determine the age, gender, and / or the ethnic background of the remains of humans who have been found deceased at crime scenes, in addition to what may have caused their demise (through an autopsy if possible). In this vein, forensic anthropologists and medical examiners (also known as coroners) are virtually identical. Physical anthropologists have also exhumed mass graves to determine the cause of death of the unfortunate victims. This is particularly common during war times, such as during the Holocaust or in Bosnia. Such anthropologists provide evidence which is used in war crimes trials to convict individuals, such as Saddam Hussein.

**Anthropologists attempt to understand human uniqueness especially among other primates.** For example, humans have a large and complex language, while other primates do not. Humans regularly use fire, while other primates are scared to death of it. Humans wear clothes, while all other animals loathe the idea. Humans also wear jewelry and have body markings – something that no other life form would do. Humans manufacture a variety of items for personal use and export, while no other animal does that. And humans have personal beliefs about an afterlife, a god, or similar kinds of things.

Even so, humans and other primates have almost identical characteristics, such as big brains, hands that can grab, sharp binocular vision with depth perception, and sharp teeth able to consume a number of different foods.

Recent research has confirmed that all humans are closely related. All humans share a common ancestor who lived 150,000 years ago. We are also related to all apes with a common ancestor of some 6 million years ago.
Anthropologists create genealogies to see how people are related to each other, how people divide into groups, and how those groups interact with each other.

Key Concepts and Terms
• android
• anthropology
• archeology
• genocide

Questions
1. What do anthropologists study?
2. What separates primates from other animals?
3. How does archeology differ from anthropology?

HUMAN BODY
(During this lesson, do Lab 11: Self Examination)

The human body is an amazing work of art and science. As we have already alluded to, the human body has a huge number of parts. To name a few, we can list them. We have a head, which is protected by a skull. In that head, we have the brain, eyes, ears, nose, mouth. We have a heart and all our necessary organs in the main body cavity, protected by a rib cage. The intestines work to help us get nourishment, after food has left our stomachs. We have several limbs to help us pick things up and to walk. Our hands have fingers and opposable thumbs.

Like other primates, we have hair, but that varies from person to person. Otherwise, we are very similar to all the other apes. Our bodies have an immune system to ward off disease. We are omnivorous, and eat virtually anything. Humans, like primates, reproduce in an “intimate” way, with personal contact. However, in humans, the sexual act is usually connected with some type of emotional bond, unlike most other animals.
The human body is composed of:

A. Organic
   Oxygen (65.0%)
   Carbon (18.5%)
   Hydrogen (9.5%)
   Nitrogen (3.2%)

B. Salts
   Calcium (1.5%)
   Phosphorus (1.0%)
   Potassium (0.4%)
   Sulfur (0.3%)
   Sodium (0.2%)
   Chlorine (0.2%)
   Magnesium (0.1%)
   Iodine (0.1%)
   Iron (0.1%)

C. Trace (totals less than 0.5% altogether)
   Chromium (trace)
   Cobalt (trace)
   Copper (trace)
   Fluorine (trace)
   Manganese (trace)
   Molybdenum (trace)
   Selenium (trace)
   Tin (trace)
   Vanadium (trace)
   Zinc (trace)

96.2% of body weight comes from "organic elements" present in many different forms. DNA, RNA proteins, lipids and sugars are all composed of primarily O, C, H and N. Also, Water (H₂O) and carbon dioxide (CO₂) as well as other small molecules involve these elements. 3.9% of body weight comes from elements present in the form of salts, which are very important for the maintenance of homeostasis (meaning "well balanced organism").

Calcium is a major component of bones and teeth. Iron is necessary for oxygen transport by red blood cells. Sulfur is present in most proteins and potassium keeps your heart beating smoothly and regularly.

The trace elements compose less than 0.5% of total body weight but then again, they are essential for homeostasis. Some of these elements are cofactors of critical enzymes in the body (meaning that without them, enzyme cannot work at all and that even low concentrations of them can make the enzyme work very well.)
In as much as the examination of the human body is a sensitive and private matter in many people’s lives, it is suggested that further research be done individually, such as seeking out books, or an internet search engine, to delve into human anatomy as much as desire. For example, go to http://www.innerbody.com/htm/body.html, 01/16/2006 and to http://www.bartleby.com/107/, 01/16/2006 and also, http://www.madsci.org/~lynn/VH/, 01/16/2006 among other places.

**Key Concepts**
- anatomy
- chemical composition
- physiology

**Questions**
1. Write a brief essay on the marvels of the human body.
2. What is the difference between anatomy and physiology?

**PRIMATES**
*(During this lesson, do Lab 12: Comparison of All Primates)*

We humans are not only animals and mammals, but we are also primates. Primates also include animals such as apes, monkeys, tarsiers, lorises, and lemurs. “What?!” you ask. Well, there are some animals that are not common household names. The word “primate” means “the first.” In other words, “we’re number one!”

As primates, we humans share a common ancestor with all primates. For this, and other reasons, primates have fascinated us. Why? Well, primate physical features, their society, how they behave, and their fossils give us some idea how our ancestors were. And we mean our distant ancestors, not our grandparents. Although, in some cases, our grandpa may have been quite an ape.

All primates evolved from ancestors that lived in trees. No wonder I like tree houses. While some of us more advanced primates prefer walking on the ground, we still have some characteristics which are connected to our elevated ancestors. For example, we have arms and legs that can move more freely than those of most other mammals, as if we have universal joints. We also have flexible digits (fingers and toes), that help us make tools, watches, spaceships, and so forth. Our eyes face forward and we have binocular vision (we can see three dimensions).

Primates can live almost anywhere, but they like warm climates. A few have been able to survive in the mountains and colder regions, such as the Japanese macaque and Sasquatch. Of course, the Sasquatch may be as real as the Loch Ness Monster, the Abominable Snowman, and the Unicorn. However, it is an area of interest, and, if real, the Sasquatch (also known as “Bigfoot”) may be a link between humans and other apes. Or not.

All primates, whether in the forest or out in the open, instinctively climb trees for safety. Even humans. We humans are quite sociable creatures, and most primates are, too. Primates live in groups, and come in tiny (about 30 grams in mass) to gigantic (over 200 kilograms in mass) sizes. The pygmy mouse
lemur is the smallest, while one type of gorilla is the largest. This does not take into consideration a few humans who have eaten themselves to masses far exceeding the gorilla.

While there are over 200 species of primates, they are divided into two groups: the prosimians and the anthropoids. (Do not confuse anthropoids with arthropods). The prosimians are the “pre” primates, and include galagos, lemurs, lorises, pottos, and tarsiers. The anthropoids are the “true” primates, as they are “human-like” and include apes and monkeys.

Prosimians are generally small and have cat-like whiskers. They can hear and smell quite well, and have pointed snouts.

The anthropoids, or “humanlike” group, have flat faces and a relatively poor sense of smell. Baboons on the other hand, have quite a 3-D face. Anthropoids are active during daylight and locate their food by using their eyes. Monkeys are found on both hemispheres of the planet. Those from Central and South America are known as New World monkeys, those from Africa and Asia are known as Old World monkeys. Those in my home are called “Menkes.”

The ape family includes chimpanzees, gorillas, orangutans - and - humans. With the exception of humans, apes are found only in Africa and Asia. They have no tails, and their arms are longer than their legs. Hey – wait – maybe you know some people who are like that!

Most mammals have “lost” their collarbones, but primates have not. Our collarbones are utilized it in conjunction with shoulder joints. This allows primates to swing from branch to branch, among other things. It has created a type of “universal joint”. Primates are the only mammals that can support themselves by hanging by one arm. And how often have you seen a giraffe doing “pull ups”?

Primates have a full set of digits, unlike many other mammals. This adds to the flexibility and dexterity of the creature, and it helps in the building of tools. Pigs don’t built houses of straw, sticks, or bricks, in spite of the nursery rhyme.

Most mammals with fingers and toes are able to bend all of them in the same direction at the same time. In primates, one of each 5 digits is opposite the other four, allowing the ability to grasp and hold on to things. These opposite digits are called “opposable thumbs.” All apes, except humans, have opposable big toes, too. But you can train yourself, if you’d like.

One immediately noticeable difference between monkeys and apes is that monkeys have tails; apes do not. Tails are used by monkeys to wrap around tree branches, making the tail a type of extra hand or foot. It is interesting to note that most humans, when they see a chimpanzee, will immediately say, “monkey.” Since chimps are apes and have no tail, they cannot be a “monkey.”

Each of the primate’s two eyes has its own field of view. Even so, a large portion of each field overlaps with the other. Both eyes are focused on the same object, which gives them binocular, or stereo, vision. This is important for depth perception. Some primates are carnivores and some are herbivores, but most are omnivores.
BIOLOGY

Manly animals give birth to a large number of “children,” such as spiders, and dogs, and cats. However, primates have usually only one baby at a time. On rare occasion, they may have “twins,” but typically, they have only one child per pregnancy.

The gestation (pre-birth) period for primates is rather long – much longer than for a rat. And once the young are born, there is a long period of childhood (humans have the longest childhood; even when they grow up, they still act like kids), which enables complex patterns of behavior to be passed on from one generation to another.

The mating practices of primates vary slightly. Solitary primates (like orangutans) have relatively simple mating behavior.

Each male orangutan controls his own “turf,” and one may find several adult females living on that “turf.” Of course, each female has her own portion of real estate. When the male feels that it is time to mate, he checks with one or more of the females living on his “turf,” and if any are receptive, mating will occur. Gorillas practice “plural mating,” or, in other words, the male has several females that live with him, as do all of his/their children. It’s almost as if gorilla families are living the plural marriage concept of the early Mormon Church. (No disrespect to the Mormon Church, as they don’t adhere to this practice currently).

Female chimpanzees are not very selective, as they will mate with just about any male chimpanzee. However, as her “season” of mating winds down, a female chimp may seek out the most powerful chimpanzee in the group to be near.

Primates have the most highly developed brains in the animal kingdom, rivaled only by those of dolphins, elephants, and whales. Some animals have larger brains, but that doesn’t necessarily make them more advanced in intelligence. As previously mentioned, the primate brain takes up a higher percentage of the primate’s mass than any other animal’s ratio. More brainpower has helped primates to develop tools. This is particularly routine with chimpanzees and even more so with humans. All primates, and some non-primates, use tools. But the ability to make tools is generally the domain of humans and chimps. (Remember that more than 98% of a chimp’s DNA is identical to a human’s).

The day-to-day existence of primates is full of social interaction. They actually know who their relatives are, and who their friends, and enemies, are. And primates are very much into grooming – each other. This is a bonding moment for two primates, as they groom each other to make themselves cleaner and healthier.

Primates are pretty adept at ways of communicating with each other. If they don’t see each other, they may “track” each other by scents left behind. The prosimians are a bit more primitive at this method, but apes and monkeys use both audio and video tools.

Did you ever “make a face” in reaction to something? Perhaps there was something that smelled bad, or tasted bad, or something that you saw didn’t appeal to you. It is natural for humans to make a “face” for almost every situation. All apes and monkeys are that way.
We humans talk, whisper, whistle, sing, and do many other things to make sounds in order to communicate with our fellow humans (or even to communicate with our domestic pets, like pet dogs). So, it is not a surprise that all apes and monkeys do similar kinds of sound making. For example, grunts, roars, songs, clicks, and other noises come rolling off the tongue of primates. Primates use sounds to keep track of each other, for mating, to warn about dangers, and to scare off enemies. Hey, we do all that, too!

There are not a lot of fossilized remains of primates. Why? Because they were stolen by a crime ring from back East. No, that’s not it. It’s because primates vaporized and turned into gas. No, that’s not it either.

It’s because they were kidnapped by extraterrestrial aliens, and taken to another planet. No, not true either. Rather, most primates are born, live, and die in forests and wooded wildernesses. When a primate “kicks the bucket,” it merely drops dead. Humans are the only primate that buries their dead, and only homo sapiens at that. Thus, when a primate dies and collapses to the ground, all their relatives and friends run away. Scavenging predators come along and eat the dead (or dying) creature. Any bones that may be left over end up being scattered hither and yon.

Even so, a few primate fossils have been located - the earliest indicated the existence of primates living on Earth about 65 million years ago – when dinosaurs were here. However, these really early primates were prosimians, and not very large. Of course, when the dinosaurs died out, these prosimians survived.

Trying to figure out where apes and monkeys came from is a bit more of a challenge. There is but one fossil dating to 38 million years ago. Whatever this creature was, it was probably related to the Old World monkeys and the apes. New World monkeys evolved from the Old World ones, as recent DNA research has shown. How they got from the Old World to the Western Hemisphere is a matter of speculation.

Of greatest interest for examination are the ancestral lines of humans. For example, it has been theorized that orangutans evolved in a different direction from the other apes about 12 million years ago. A number of years later, the chimpanzee and the human line split. This was about 6 million years ago.

Nevertheless, modern-day humans, in their infinite curiosity, have tried a number of different experiments in order to communicate with other apes. As all apes are really intelligent, it was first believed that one could teach chimps, gorillas, or orangutans to speak. Unfortunately, their anatomy made it difficult for them to make recognizable sounds.

Instead, scientists began to try using sign language – and achieved remarkable success! For example, in 1968, a chimpanzee was trained to learn some 130 signs. In 1980, a gorilla had been trained to use 500 signs and to recognize another 500! But research found out that these apes were not merely copying the signs that they were taught. They evolved beyond that, and created new, related, hand signs to communicate with humans! Recent research showed that chimpanzees can be trained to use
computer keyboards. In addition, chimps have demonstrated an intellectual talent to relate real objects with abstract symbols!

Because the anatomy and physiology of apes is almost identical to ours, they are very valuable in medical research. We try new medicines and types of surgery on them, before we take such steps with humans. The animals most used are the chimps, baboons, and rhesus monkeys. What medical research has learned from these procedures has become extremely helpful in increasing human health. Of course, using any type of animal for research has come under scrutiny. Some people feel it is cruel punishment for such creatures, especially since over 100 primate types are threatened with extinction. Thus, primates are extremely at risk for many reasons.

Deforestation has been the greatest threat to primates. In a recent international research project, it was determined that the nation of Brazil is destroying primate habitats at an alarming rate. Each hour, an area the size of New York City’s Central Park is deforested in Brazil. Pretty soon, we’re going to run out of forests, and end up causing the extinction of many species of animals – and probably us humans will be among them. Other parts of the world which are rapidly destroying rain forests and other animal habitats include Madagascar, Southeast Asia, Uganda, Rwanda, and the Democratic Republic of the Congo.

International groups have banded together to stop exportation of primates, and to stop the destruction of forests. But many nations “don’t care” and continue doing it. Without voluntary preservation of these natural habitats, most primate species are headed for extinction.

**Key Concepts and Terms**
- anthropoid
- binocular vision
- opposable thumb
- primate
- prosimian
- tail

**Questions**
1. Compare and contrast the mating practices among primates.
2. Which primates have tails, and which do not?
3. What is a prosimian?
4. What does it mean to have binocular vision?

**APES**
*(During this lesson, do Lab 13: Types of Apes)*

Apes are extremely intelligent primates, with large brains. Apes include chimpanzees, gorillas, gibbons, orangutans – and – humans. And maybe such creatures known as sasquatch and “chorilla.” But more on them later.
Some people confuse apes with monkeys. However, unlike their smaller primate counterparts, apes do not have tails and their arms are usually longer than their legs. Except for humans, apes live in tropical woodlands and forests of Africa and Asia. Well, humans live there, too. Despite sharing similar habitats, different ape species show striking differences in behaviors and ways of life.

At one time, apes were classified as a single group of primates, but today most zoologists divide them into two distinct families: the lesser apes, such as gibbons, and the great apes, such as chimps, gorillas, orangutans, and humans.

Gibbons are similar to monkeys, with lithe, slender bodies and extremely agile movements. Gibbons spend all of their lives in trees, using their hands like hooks to swing arm-over-arm between branches. This method of locomotion is so fast that gibbons can easily overtake a person running on the forest floor.

Most great apes (except the pygmy chimps, aka bonobos) are bigger than gibbons and also much less acrobatic. However, they are still good climbers. While orangutans spend most of their life in trees, where they use their long arms and dexterous hands and feet to grasp branches and vines, chimpanzees frequently come to the ground to feed.

Gorillas are primarily terrestrial, but even fully grown adult males have been observed clambering among tree branches more than 15 meters (49 feet) up. Chimpanzees and gorillas - the apes that spend the most time on the ground - normally walk on all fours, clenching their hands so that their knuckles take their weight.

From physical and fossil evidence, biologists know that apes and humans share a common ancestry. In recent years, biochemical analysis has shown just how close this link is - chimpanzees and humans differ significantly in only 2 percent of their DNA genetic material. This evidence suggests that humans and chimps diverged from a common ancestor 6 million years ago – *Orrorin tugenensis* – and he shall be discussed later.

Meanwhile, chimps and gorillas inhabit dense tropical forests in Africa. There is one problem with that: the forests are vanishing. There is also a strange part, as far as humans are concerned: these apes are covered with thick hair, and thus must be hot all the time.

Orangutans and gibbons live in the rain forests of Southeast Asia. Again, as rain forests disappear, these apes do, too.

As mentioned, most apes are covered with thick hair or fur. All ape skeletons and skulls are designed to allow a big brain, and all of us apes have no hair on a large portion of our faces (and even less, after we shave). This gives us the opportunity to make faces at each other, as previously stated.
Apes can live a long time. Some gorillas live to age 35, and chimps can live about 50 years. Apes in captivity often live longer, as they have all that they need. **Humans** in captivity can live over 100 years.

Apes are quite social and live in groups, or clans. Only the orangutans are anti-social. Families of gorillas are very stable, and may have the same leader for years. Chimps are more like us humans, with shifting power bases, alliances, and routine battles.

Like humans, chimpanzees are omnivorous and will often travel long distances to find just the “right” food. Chimps also hunt in groups so they can improve their chances at being successful. And so do human men. Gorillas, as mighty and powerful as they are, eat vegetables and other foods typical of herbivores. Thus, groups of gorillas do not need to band together to sneak up on a patch of **broccoli**.

Apes breed all year long. Orangutans couple, then go back to where they were before. This would be like some guy named “Joe” from Brooklyn having a “one night stand” with a lady named “Susan” who lives in Baltimore, and then going back to his life in Brooklyn. Their courtship is quite short, and, as ever, each orangutan lives a solitary life.

**Gibbons**, on the other hand, get **“married”** and stay faithful to each other all their lives. This would be like some man named “Bob” falling in love with a lady named “Barbara” and then marrying her, and remaining with her to raise their children all their lives. As one can see, human mating behavior runs the spectrum of what other apes do.

Female apes – including human women - give birth to one child after a pregnancy of 7 to 9 months. Yes, once in a while an ape will have twins or more, but that is not typical. Gibbon mothers breastfeed their babies for about 2 years, and chimp moms will breast feed 4 years or more.

There are some **human woman who also breast feed** their children for 4 or more years, although the average is about one year. Infant care is generally the mom’s job, but in some cases, the “dad” will take the new ones after about a year.

Gibbons, gorillas, and orangutans are endangered. And if we don’t take care of mother Earth, humans will be, too. In spite of laws against capturing orangutans, some are kidnapped and sold off as pets – after some dastardly person has killed the young ape’s mother.

We shall learn later about the extinction of some of our ancestors. And it is a sad story. Meanwhile, let’s examine the chorilla and the sasquatch.

**Chorilla**
A new subspecies of gorilla, **gorilla gorilla uellensis**, was identified in 1927, but has since “disappeared.” Where did they come from? Where are they now? And are they gorillas, or chorillas?
An officer in the Belgian Army, stationed in the Congo, had collected a series of gorilla skulls while on duty, near the village of Bili, Democratic Republic of the Congo (DRC), along the Uele River. [This river runs from the northwestern DRC town of Bondo all the way to the northeastern DRC town of Aba].

Upon his return home to Belgium in 1908, the officer visited the Belgium's Royal Museum for Central Africa in Tervuren, and decided to donate the skulls to the Museum. It took nearly 20 years, but in 1927, the chief anthropologist, and Museum’s director finally classified the skulls as this new subspecies.

Colin Groves, an Australian anthropologist, became curious about the skulls in 1970, and decided to examine them himself. His analysis differed from the Museum director’s some 43 years earlier and no new specimens from that area have been uncovered.

In 1996, the Swiss conservationist and nature photographer, Karl Ammann, decided to begin an adventure to find these “lost” gorillas. Almost ten years have past, but Amman has yet to find this particular gorilla. Even so, he has collected a great deal of information about the nesting habits, hair samples, and feces of certain local creatures. More recently, an ape that resembles a large chimpanzee and behaves more like a gorilla has been spotted and legitimately photographed.

By mid-2005, data analysis of the samples had not yet been completed. Meanwhile, an independent primate behavior specialist from Atlanta, a one Ms. Shelly Williams, concluded, "at the very least, we have either a new culture of chimps that are unusually large or hybrids with unusual behaviors." Williams had spent two months in the north part of the Democratic Republic of Congo in 2004 trying to determine what Amman was also looking for: validity.

Enter Colin Groves. He has decided to join both Williams and Amman in this quest to find this usual “chorilla,” or “gimp.”

Since 1996, Ammann has visited Bili area where he found a skull which had both characteristics of a gorilla and a chimp. Sadly, a civil war in the Democratic Republic of Congo curtailed further research. Ammann, not wishing to be arrested and shot, hired a local bush man from nearby Cameroon, and asked him to visit and photograph the areas. The bush man shot pictures of gorilla ground nests in that area – just north of Bili.

A gaggle of gorilla enthusiasts joined Amman in 2000 to search for further evidence in the area of Bili. No specimens were found, but they did find several well-worn ground nests in swamp - infested riverbeds. Local natives told Ammann and his retinue about two kinds of chimpanzees in the region – the “normal” chimps, aka "tree-beaters," which are easily killed with poison darts shot at them by the local hunters. However, they said, there exists another, bigger “chimp” that does not climb trees and that is immune to the poison darts. The locals call the larger chimp a "lion killer."

Ammann took a photo of the cadaver of a giant chimp next to the local hunter who killed it. The skull resembled the earlier one that Ammann had discovered in 1996 and confirms a huge body size.

Colin Groves concluded, "Giant chimpanzees occasionally occur here and there in the central and eastern subspecies, but evidence so far indicates that Karl Ammann may have [found] a population of
‘giants’ in his area. Presumably their giantism is relevant to their ground nesting behavior."

It has been decided that this “giant chimp” is a unique culture of chimps. "Work has started on habituating one of the ground nesting chimp groups. This is done by provisioning them with sugar cane," Amman said, as he embarked on further research.

DNA analysis of hair samples and feces will help to determine if what they have is indeed a new subspecies of chimpanzee or simply a unique culture. "Discovering an isolated group of apes exhibiting unusual cultural behaviors is just as important as identifying new DNA profiles. That's why continuous observation, habituation, and surveying are so important," explained Williams. And it is still hoped that living specimens will be located.

The apes nest on the ground like gorillas but have a diet and features characteristic of chimpanzees. Gorillas make ground nests, while chimps prefer to be off the ground, and sleep in trees. However, a dietary analysis (examining the feces) that whatever these creatures are, they eat fruit and nuts, a diet characteristic of chimpanzees, but not gorillas. Therefore, these apes are probably a subset of chimps, which are overly large, and show behavior more like that of their cousins, the gorillas. Esteban Sarmiento, from the American Museum of Natural History in New York said, "It is a chimpanzee. There are presently three recognized subspecies of common chimpanzee Pan troglodytes and it could represent a fourth subspecies or change our present understanding of where to draw the divisions between subspecies. I would think there is a strong possibility that south of Bili on the other side of the Uele River there may be gorillas, and this would seem an important area to turn our attention to," said Sarmiento.

Thus, the Uele River may have become a physical boundary, causing an evolutionary bifurcation leading to a new, fascinating creature.

Sasquatch

The sasquatch is allegedly a type of ape, more advanced than a chimp or gorilla, but less intelligent than a human. As of this date, there is no scientific confirmation of such a creature, but there has been a great deal of research on it. And here is how the story goes.

In June 1884, an animal - similar to what a sasquatch may be - was allegedly captured by a railroad engineer crew in British Columbia. Dubbed "Jacko" by its captors, it was reported that he was about 1.4 meters tall and had a mass about 58 kilograms. From what we have learned about the sasquatch, the size of this particular animal would be way too small for an adult, but maybe not for a child or youth. It was reported to be covered with brown hair and it ate berries and milk. Those that had captured him had planned to take him to London, but the creature somehow miraculously escaped. Interesting story, but of no scientific value.

About 40 years later during the 1920’s, a Canadian schoolteacher from British Columbia, J.W. Jones, decided that it would be a good idea to publish some of the stories that he had been hearing over the years about such a creature that was apparently living in the northwestern wilderness regions. Thus, the
teacher began to write down accounts from a host of people that lived in the area that he interviewed. The Native Americans called these creatures 'sokqueatl' and 'soss-q'tal', so, after a number of these anecdotal reports, Mr. Burns created an English word similar to the native language, "sasquatch."

The stories of Mr. Burns created much interest in folklore, but no real research. In 1929, *MacLean's Magazine* printed part of Burns’ publication, and it included the word "sasquatch." While the article generated more interest in this subject, it was not until the late 1950’s that the concept of a real sasquatch was taken seriously.

The seriousness of the subject was because a group of Californians allegedly had spotted a similar creature in Humboldt County (northwest California). Some of the extant “evidence” from that sighting included very large footprints. Thus, this hairy “beast” was given the name “bigfoot.” At first, people were wondering if there were two different species of animal, but after extensive comparisons, it was concluded that “bigfoot” and “sasquatch” were one and the same.

Some of the additional “evidence” included photographs and amateur movies. For example, on October 20th, 1967, two men, Roger Patterson and Bob Gimlin, were exploring the Bluff Creek Riverbed area in Northern California while on horseback. Their plan was to document the sasquatch habitat – not to film a specimen. At one point along the trail, the horses reared, and eventually Patterson was tossed off. Before he fell, however, Patterson was fortuitously able to grab the 16mm camera from the saddlebag.

At first, Patterson thought that the horses reared because of a cougar or bear, and decided to film whatever the animal was. Panning about, the men were startled when they came upon a large, dark, hairy animal, crouching in the riverbed ahead. Patterson instinctively pointed the camera at the creature, only to have the being stand up and walk away. Undaunted, Patterson began walking, then running, after the animal. Gimlin was too shocked to take any action himself. Instead, Gimlin held his horse and watched in awe struck silence as the sequence unfolded.

It turns out that Patterson filmed what has become – allegedly - the most convincing film “evidence” ever obtained of what may have been a live sasquatch. The scenes at the start of the film are shaky (Patterson is a bit nervous and unsure) but it becomes more stable toward the end where some sort of animal can be clearly seen. Whether it was Sasquatch, a large man in a costume, or something else, we will never know.

Since one of the nicknames for *sasquatch* has been “bigfoot,” footprints are a lot more common to use as evidence than other items. Trying to relate footprints to sasquatch-type beings has been a stretch so far. However, the footprints apparently have been made by an animal that walks on two feet – more similar to an Australopithecine.

Quite a few of the footprints have been found in areas that are not common for human bare foot traffic. Even so, footprints are relatively easy to fabricate, so one must not leap to conclusions.

Meanwhile, hair and fecal samples have been collected and analyzed, and found to be of an unidentified member of the ape family. Since gorillas, chimps, and orangutans do not inhabit the
northwestern part of the America, the evidence that was collected must be of some other ape, perhaps a sasquatch. These "northwestern apes" apparently have developed flat, human-like feet that are much larger than those of humans or other apes.

**A theory on the origins of the Sasquatch**

Some 500,000 years ago, “giant apes,” the *gigantopithicus* and the *meganthropus*, resided in Asia. As later, more advanced hominids (such as the homo ergaster and neanderthals) began to increase in number, the giant apes saw their habitat shrinking. Some became extinct. Others crossed the “land bridge” between Siberia and North America (where the Bering Sea is now, between the Aleutian Islands and Russia) and ended up in the northwestern part of North America.

Upon arriving in North America, they confronted hominids (ancestors of Native Americans?) who also became their enemy.

To survive, the sasquatch had no choice but to hide and be “invisible,” as legends tell. Eventually descendants of Europeans and others arrived and began to develop the land, forcing the sasquatch into even more remote areas for breeding and raising young.

As such, the “modern” sasquatch – assuming they exist and that there are any - reside primarily in the Pacific Northwest Cascade Mountain Range from Northern California north to British Columbia, Canada.

The sasquatch are nomadic wanderers constantly foraging for food which consists of the same type of diet as the gorilla: vegetables, fruits, berries, nuts, some roots, saplings, with maybe occasional insect grubs, and maybe fish now and then.

The life span of a sasquatch is probably more that 40 years, as other apes. When they die, however, they are similar to other wild animals - they seek a place to die where their body will not be discovered. Once they are dead, the body is quickly consumed by predators (other animals, insects, and bacteria) and thus returns to the food chain.

Eyewitnesses have given varying descriptions of the sasquatch, but generally they are about 2.5 meters (8ft) tall, with broad shoulders, and strongly-built. It has small eyes, accentuated eyebrows, and a small, pointed, low-set rounded head. Apparently, the creature appears to be ape-like and bi-pedal. And they stink.

Nosewitnesses claim that their acrid odor easily offends the most congested nose. Some have described its smell as a mixture of raw sewage, animal poop, and terrible human body odor. If the size won’t scare you off, the smell will.

Earwitnesses have claimed to have heard high-frequency voice sounds alternating with deep guttural grunts.
The Sasquatch may be just as real as the Easter Bunny, the Loch Ness Monster, the Abominable Snowman, the Unicorn, and other fictional creatures. Or it may be a lost link. But there is one thing for sure – real or not, it generates interest.

Key Concepts and Terms
- chimpanzee
- chorilla
- gibbons
- gigantopithicus
- gorilla gorilla uellensis
- gorillas
- orangutans
- sasquatch
- tree beaters

Questions
1. What is a chorilla?
2. Compare and contrast the hunting habits of gorillas and chimpanzees
3. What is a gigantopithicus?

HOMINIDS
(During this lesson, do Lab 14: Ancestors of Humankind)

In late 2004, it was announced that a new ape species, *Pierolapithecus catalaunicus*, had been classified. The remains had been discovered in the Spanish province of Catalonia, and testing showed it to be approximately 13 million years old. *P. catalaunicus* may be the oldest common ancestor to all living apes, of which humans are a part.

From the fossil research, the body is that of an ape, with fingers of a chimpanzee and the upright posture of humans. This particular ape may bridge a gap between older apes and humans. This newest ape species is important enough to push back the research on ancient human forbearers.

Researchers have anxiety over labeling this a “missing link.” However, they do agree that if this is not the “link,” then it is closely related to it.

David Strait, an anthropology professor, said that the find was "spectacular," but added, "'Ancestor' is a loaded term. It's very hard to identify ancestors in the fossil record."

Only one of these hominids was found in this area close to the city of Barcelona. But other fossils nearby have been unearthed. F. Clark Howell, a retired UC Berkeley professor, exclaimed, "This is a remarkable find. It indicates a diversity in hominids." The research team in Spain gathered over 80 bone fragments from a male adult. It has been determined, that this ape didn't swing through trees with the curved fingers of an orangutan. Nor did it knuckle-walk on four limbs with the
horizontal trunk posture of a chimp. Instead, it was adept at climbing, which kept it erect.

The great apes living today, which include humans, chimps, gorillas, and orangutans are believed to have diverged from the lesser apes about 15 million years ago.

Meanwhile it was announced during the year 2000 that the fossilized remains of what could have been another, more recent common ancestor of man, had been discovered. “He” was given the name *Orrorin tugenensis* - or, more familiarly, *Millennium Man*, because his discovery was announced in the year 2000. Apparently, then, he is a true human ancestor.

Previously, a creature known as *Ardipithecus* was believed to be the oldest ancestor. However, Ardipithecus is nothing more than a monkey's uncle or a chimp's great-great-grandfather, anyway. No one disputes that Millennium Man – the competing ancestor of Ardipithecus – is 6 million years old and thus more ancient than the 5.8-million-year-old Ardipithecus. What's still to be proved is that it's a hominid.

The overall picture looks pretty straightforward from about 6 million years ago to the present. After Millennium Man came *Ardipithecus ramidus kadabba* (ARK). Then, more than a million years later, its descendant, the newly renamed *Ardipithecus ramidus*, appeared. After that comes a new genus, called *Australopithecus* (where a famous female specimen called “Lucy” belongs), and finally, about 2 million years ago, the first members of the human genus Homo.

But, as we are near the end of this textbook on biology, let’s review the scheme of life. In the chain of Human Evolution we first have life itself divided into plants and animals (and the other odd group of fungi). The Animal Kingdom, of which Mammals are a part, are broken down into many types. Primates (Monkeys, Apes, etc.) are Mammals. The Hominidae (Apes) are Primates, of which the bipedal and upright Homininae (aka Hominines) are a subgroup. Among these are the Australopithecus (Australopithecines) that lived from about 5 Million BC to 1.5 Million BC.

In this sub-category of Australopithecus, we have traced the existence of three distinct types: the *Anamensis*, the *Afarensis*, and the *Africanus*. The Anamensis Australopithecines lived around 4 Million BC in or near present-day Kenya. The Anamensis Australopithecines eventually became extinct or moved to Mars. The Afarensis Australopithecines lived from about 3 to 4 Million BC, in or near the present-day region of Afar, Ethiopia. They didn’t use tools. The Africanus Australopithecines lived from 2.5 to 3 Million BC in southern Africa and had evolved from the Afarensis Australopithecines. But they, too, did not use tools as far as we know.

Out of the Australopithecus Africanus group evolved the *Homo Australopithecus Africanus*, also known as Homo Africanus. This group of people lived from 1.5 to 2 Million BC in what is now Kenya and Tanzania. And there are three sub-groups of Homo Africanus: Homo Ergaster, Homo Erectus, and Homo Habilis. Homo Ergaster lived in Africa from about 1.9 Million BC and used tools. Homo Erectus lived in Asia about 1.7 Million BC, used tools and had fire. The Homo Erectus fellows were hunters. The Homo Habilis lived in Africa around 1.5 Million BC, used tools, and ate meat. For unknown reasons, both the Homo Erectus and Homo Habilis groups vanished.
Maybe they didn’t like the neighborhood. It is also possible that these groups conjoined, or competed with each other, until one became extinct.

Evolving from Homo Ergaster were three different lines: the Homo Robustus, the Homo Boisei, and the Homo Sapiens. The Homo Robustus of southern Africa became extinct about 1.5 Million BC. These groups keep dying off, don’t they? The Homo Boisei of eastern Africa also became extinct about 1.5 Million BC. Note that these last two vanished about the same time as did the Homo Habilis. Maybe extraterrestrial aliens kidnapped them.

And that leaves us with the immediate direct ancestor humans: the Homo Sapiens. And that is where we go next.

**Key Concepts and Terms**
- africanus
- ardipthecus
- Boise
- erectus
- habilis
- hominid
- homo
- millennium man
- orrorin tugenensis
- pierolapithecus catalaunicus

**Questions**
1. What is a pierolapithecus catalaunicus, and where was he discovered?
2. Who is the Millennium Man?
3. When was the discovery of Millennium Man done?
4. What are the three distinct types of the Australopithecus?
5. Who is “Lucy” and what type does she belong to?

**HOMO SAPIENS**
(During this lesson, do Lab 15: Study of Neanderthals)

The Homo Sapiens appeared about 300,000 BC. But they were not confined to central, southern, or eastern Africa. We find their remains even in Europe. The Homo Sapiens were apparently the first ones that buried their dead. Up until that time, a hominid would just be left behind to die.

There are two subcategories under Homo Sapiens: *Homo Sapiens Neanderthalensis* and *Homo Sapiens Sapiens*. The Homo Sapiens Neanderthalensis, also known as the Neanderthals (or Neandertals, named for the Neander Valley in Germany where one of the earliest skulls was found) occupied parts of Europe and the Middle East as early as 120,000 years ago until about 30,000 years ago, when they, too, “disappeared.” The features of the Neanderthals are a low, sloping forehead, a large brow ridge, and a large face without a chin. You may know some people like this.
In any event, the Neanderthals were adept with tools, fire, construction, and with hunting. There is also evidence that they traveled far and wide, and even traded. It is common for people to associate the proverbial “cave man” with the Neanderthal: a short, stocky man, with a club over his shoulder and bare feet. He may be wearing an animal skin. Not too far from our estimates. It is likely that the Neanderthals were the first hominids to wear some sort of clothing or covering of the body, so as to increase the range of habitat.

According to many anthropologists, Neanderthals are too primitive for them to be considered the ancestors of modern humans. Instead, the Neanderthals are believed to be on a side branch of the human evolutionary tree that became extinct. In effect, that would make them “cousins” to modern humans at best.

In 1997 a team of scientists added strong evidence to support this view. They managed for the first time to analyze mitochondrial DNA (a DNA form inherited only from the mother and particularly useful for determining ancient ancestral relations) from a Neanderthal skull. The analysis showed that the lines leading to Neanderthals and the more modern Cro-Magnons began to diverge over 500,000 years ago.

There is no evidence that Neanderthals and Cro-Magnons interbred. In addition to some fragmentary fossil finds from southern Africa, support for the theory of the extinction of the Neanderthals comes from comparisons of mitochondrial DNA taken from women around the world, representing a worldwide distribution of ancestors. These studies suggest that humans derived from a single generation of Cro-Magnons in sub-Saharan Africa or southeastern Asia.

Key Concepts and Terms
- burial
- cave man
- Cro-Magnon
- Homo sapien
- Neanderthal

Questions
1. Are the Cro-Magnons descended from Neanderthals? Why or why not?
2. How early do scientists think Neanderthals came upon the land?
3. How are the homosapiens different from their predecessors?
4. When did the Neanderthal disappear, and why?

HOMO SAPIENS SAPIENS – THE CRO-MAGNONS

The Homo Sapiens Sapiens, also known as Cro-Magnons, showed up some time in western and southern Europe during the last glacial age – after 90,000 BC but before 40,000 BC. The Cro-Magnon people were taller and leaner than the Neanderthal, but had a more advanced and larger brain. They were able to domesticate animals and raise them for food and for clothing. Cro-
Magnons also domesticated plants, having done agricultural farming of crops. The name Cro-Magnon is derived from a rock shelter of that name in the Dordogne Department in southwestern France, where the first skeletal remains were discovered in 1868.

Artifacts attributed to the earliest period of Cro-Magnon culture, the Upper Paleolithic Aurignacian (100,000 BC to 8000 BC), demonstrate clearly that they had mastered the art of fashioning many useful instruments from stone, bone, and ivory. The Cro-Magnons wore fitted clothes and decorated their bodies with jewelry and ornaments of shell and bone. Hey, we do that now! It would seem that the Cro-Magnons were able to create a period of leisure time unknown to any life form before. They seemed to have time for “culture.” A number of colored paintings left on the walls of caves is evidence of art, and other aspects of their interesting and complex culture.

The Cro-Magnons’ physical characteristics include a high forehead and a well-defined chin. Cro-Magnons appear to be the ancestors of the living peoples of southern and western Europe.

Note that for a time, both the Neanderthals and Cro-Magnons inhabited the planet. This occurred from about 90,000 BC until about 30,000 BC. That means for approximately 60,000 years these two groups of homo sapiens co-existed. Eventually, the Neanderthals died out and became extinct. Or maybe their extinction was accelerated by the Cro-Magnons. Or maybe they all drowned in a tsunami, or their habitat changed and their food sources all died, or maybe they caught the flu, or who knows?

Thus, our current human race is really a member of the Primate Hominidae Homininae Australopithecus Africanus Homo Ergaster Sapiens Sapiens group – the Cro-Magnons. They walk the Earth today. But anthropologists have subdivided this further into five subgroups or races: Caucasians, Mongolians, Ethiopians, Americans, and South Asians.

<table>
<thead>
<tr>
<th>The <strong>Caucasians</strong> include western Asians (like those in the Middle East and India), northern Africans, and Europeans (except for the Saami and Finns).</th>
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<td>![Caucasian Person]</td>
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<th>The <strong>Mongolians</strong> are from eastern Asia, which include Chinese, Japanese, Koreans, Vietnamese, Filipinos (Philippines), Indonesians, Malaysians, and Thais. These eight groups have sometimes been called Mongoloids, meaning &quot;like Mongols.&quot; These groups are also called Oriental, meaning &quot;of the east&quot;. Others of the Mongolian category are the Finns, Saami, and the Inuit &amp; Aleut (Eskimos) of the Arctic regions. The Saami of northern Scandinavia are also called Lapps or Laplanders.</th>
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<td>![Mongolian Person]</td>
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The **Ethiopians** are the native peoples of Africa, except the northern Africans. They are also as Blacks and were formerly known as Negroes.

The **Americans** include all aboriginal New World peoples (except the Inuit), such as all the Native American Indian groups.

Finally, the **South Asians** are Australian and Oceanian Peoples – aborigines of Australia; the Melanesians on and near New Guinea; the Micronesians north of New Guinea; the Polynesians in the outer reaches; and the Hawaiian Islanders.

Returning to the Millennium Man, he may have been “Adam,” or the first man, or just the common ancestor of all Hominids. More research is needed. If, as religions say, Adam lived about 6,000 years ago, then he was clearly a Cro-Magnon.

**Key Concepts and Terms**
- American
- Caucasian
- Ethiopians
- Homo sapien sapien
- Mongolian
- South Asian

**Questions**
1. How many subdivisions are there under homo sapien sapiens?
2. Name each of the subdivisions in #1
3. Who was the common ancestor of all living humans?
4. When did Cro-Magnons appear?
5. During what period did both Neanderthals and Cro-Magnons co-exist?
LESSON 7 STUDY QUESTIONS. FILL IN THE BLANK. CHECK YOUR ANSWERS.

1. _________ is the study of humans.
2. _________ is the study of civilizations of the past.
3. _________ of body weight comes from “organic elements” present in many different forms.
4. _________ is a major component of bones and teeth.
5. _________ has been the greatest threat to primates.
6. _________ are similar to monkeys, with lithe slender bodies and extremely agile movements.
7. _________ appeared about 300,000 B.C.
8. Homo Sapiens Sapiens are also known as _________.
9. The _________ were adept with tools, fire, constructions and with hunting.
10. Anthropologists have divided humans into _________ subgroups.

ANSWERS TO LESSON 7 STUDY QUESTIONS.

1. Anthropology
2. Archaeology
3. 96.2%
4. Calcium
5. Deforestation
6. Gibbons
7. Homo Sapiens
8. Cro-Magnons
9. Neanderthals
10. five
LESSON 8

RESEARCH IN BIOLOGICAL SCIENCES

In this lesson, you will learn about the main branches of the biological sciences.

The lesson includes:

Research in Biology
Research in Anthropology
Research in Paleontology
Research in Zoology
Research in the Medical Sciences

RESEARCH IN BIOLOGY

In as much as this entire textbook has been devoted to the science of biology, you, as the student, already have a great idea about what is on the front lines of biological research. Of course, the largest area of research now is in microbiology.

But let us try to understand the nature of research, and what it means to do research following the “scientific method”. It is the same in all the sciences, including biology, and all the other ones that we will mention briefly hereafter.

The acronym TPEPDREQ stands for the 8 subdivisions of the scientific method:

1. Title
2. Purpose
3. Equipment
4. Procedure
5. Data
6. Results
7. Error Analysis
8. Questions

When one undertakes research, he must first begin with a title of what he is going to do. Sure, it can be a “working title,” and it may be changed later, as the project goes on to completion. However, it is important to give the idea a name, otherwise you have no idea what you are going to do.
As an example, let’s say you wanted to do research on how birds fly. Then you may give your project a name, or title, called “How Birds Fly.” After that, it is not likely that you will go on to study the social habits of professional baseball players.

Next, you want to determine the purpose of the project. In other words, why are you doing this research? Nobody starts a research project on, say, how birds fly, but then has no idea why he is doing it. How many people roll out of bed one day and say, “I’d like to find out how birds fly because it’s Tuesday,” or “because ice cream has no bones.” And you can’t put down the reason as, “I want a good grade in a class.”

After you know what you are doing and why, you have to think about what you need in order to complete your project. One cannot simply sit on a hillside and admire birds in flight, then write a research project on it. One must determine if you will need binoculars, camera, cages, measuring devices, and so forth.

Then you will have to map out a procedure for what you will do. Make a list and check it twice. What will you do, and in what order will you do it? You don’t want to catch and kill a bird to study it, and then throw it into the air to see how it flies. Dead birds don’t fly.

Now you are ready to get to work. This is when you gather your data, make your observations, calculate your answers, and so forth. You may include photos, sketches, tables of data, or whatever.

When you are all done gathering your information, you sit down and study what you have. Can you draw any conclusions? What kind of results did you have? Were you successful? If so, or if not, why do you think? If it were a miserable failure, what could you do next time to make it better? And stuff like that.

Surely some errors in your research occurred, somewhere. What were they? What caused them? How can you avoid them in the future? What would you recommend to another researcher who is planning to do research in the same area? And other things like that.

Finally, there may be a series of questions that you wanted answered. So, answer them, if you can. Or maybe the research created more questions than there were before. Write them down, and use them the next time you do research.

To find out the latest research going on in biology, go to a website near you, such as this one: www.genomebiology.com, 01/16/2006.

Questions
1. What is the scientific method (8 steps)?
2. What is the acronym for the scientific method?
3. What is a hypothesis?
4. How do you prove, or disprove a hypothesis?
RESEARCH IN ANTHROPOLOGY

So far you have learned a lot about anthropology, and TPEPDREQ applies here too. For the latest information on research in this area, check out this website: www.lib.utah.edu/ResGuides/anthropology.html, 01/16/2006.

RESEARCH IN PALEONTOLOGY

So far you have learned a little about paleontology, and TPEPDREQ applies here too. This science is a branch of geology that studies the fossils of animals that have been dead a long time – like dinosaurs. For the latest information on research in this area, check out this website: www2.nature.nps.gov/geology, 01/16/2006. From the Explore Geology menu on the left side of the opening page, choose Paleontology, then research.

RESEARCH IN ZOOLOGY

So far you have learned a great deal about zoology, and TPEPDREQ applies here, too. This science studies animals. For the latest information on research in this area, check out this website: www.hcl.harvard.edu/research/guides/zooloogy/basics.html, 01/16/2006.

RESEARCH IN THE MEDICAL SCIENCES

So far you have learned a little about the medical sciences, and TPEPDREQ applies here, too. This science does research on how to cure diseases and help people stay healthy. For the latest information on research in this area, check out this website: www.msrp.med.ufl.edu/msrpfellowsips.shtml, 01/16/2006.
COURSE OBJECTIVES

The purpose of this course is to provide exploratory experiences and laboratory and real-life applications in the biological sciences. Topics covered in this course will include the nature of science, matter, energy, and chemical processes of life, biology, reproduction, and communication. The student will:

- Know that investigations are conducted to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories.
- Know that from time to time, major shifts occur in the scientific view of how the world works, but that the more often, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge.
- Understand that no matter how well one theory fits observations, a new theory might fit them as well or better, or might fit a wider range of observations, because in science, the testing, revising, and occasional discarding of theories, new and old, never ends, and lead to an increasingly better understanding of how things work in the world, but not to absolute truth.
- Know that scientists in any one research group tend to see things alike that therefore scientific teams are expected to seek out the possible courses of bias in their design of their investigations and in their data analysis.
- Understand that new ideas in science are limited by the contest win which they are conceived, are often rejected by the scientific establishment, sometimes spring form unexpected findings, and usually grow slowly form many contributors.
- Understand that in the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism and that in the long run, theories are judged by how they fit with other theories, the range of observations they explain, how well they explain observations, and how effective they are in predicting new findings.
- Understand the important of a sense of responsibility, a commitment to peer review, truthful reporting of the methods and outcomes of investigations, and making the public aware of the findings.
- Know that scientists assume that the universe is a vast system in which basic rules exist that may range form very simple to the extremely complex but that scientists operate on the belief that the rules can be discovered by careful, systematic study.
- Know that scientists control conditions in order to obtain evidence, but when that is not possible, for practical or ethical reasons, they try to observe a wide range of natural occurrences to discern patterns.
- Know that performance testing is often conducted using small-scale models, computer simulations, or analogous systems to reduce the chance of system failure.
- Know that scientists can bring information, insights, and analytical skills to matters of public concern and help people understand the possible causes and effects of events.
- Know that funds for science research come from federal government agencies, industry, private foundations, and that his funding often influences the areas of discovery.
- Understand how knowledge and energy is fundamental to all the scientific disciplines (e.g., the energy required for biological processes in living organisms and the energy required for the building, erosion, and rebuilding of Earth).
- Understand that there is conservation of mass and energy when matter is transformed.
• Know that the total amount of usable energy always decreases, even though the total amount of energy is conserved in any transfer.
• Know that the body processes involve specific biochemical reactions governed by biochemical principles.
• Know that membranes are sites for chemical synthesis and essential energy conversions.
• Understand that biological systems obey the same laws of conservation as physical systems.
• Know that the chemical elements that make up the molecules of living things are combined and recombined in different ways.
• Know that complex interactions among the different kinds of molecules in the cell cause distinct cycles of activity governed by proteins.
• Know that cell behavior can be affected by molecules from other parts of the organism or even from other organisms.
• Understand the mechanisms of asexual and sexual reproduction and know the different genetic advantages and disadvantages of asexual and sexual reproduction.
• Know that every cell contains a blueprint coded in DNA molecules that specifies how proteins are assembled to regulate cells.
• Understand how genetic variation of offspring contributes to population control in an environment and that natural selection ensures that those who are best adapted to their surroundings survive to reproduce.
• Know of the great diversity and interdependence of living things.
• Know that body structures are uniquely designed and adapted for their function.
• Know that separate parts of the body communicate with each other using electrical and/or chemical signals.
• Know that organisms respond to internal and external stimuli.
• Know of the great diversity and interdependence of living things.
• Understand how the flow of energy through an ecosystem made up of producers, consumers, and decomposers carries out the processes of life and that some energy dissipates as heat and is not recycled.
• Know that the chemical elements that take up the molecules of living things are combined and recombined in different ways.
• Know that layers of energy-rich organic materials have gradually turned into great coal beds and oil pools (fossil fuels) by the pressure of the overlying Earth layers and that humans burn fossil fuels to release the stored energy as heat and carbon dioxide.
• Know that changes in a component of an ecosystem will have unpredictable effects on the entire system but that the components of the system tend to react in a way that will restore the ecosystem to its original condition.
• Know that the world ecosystems are shaped by physical factors that limit their productivity.
• Understand that the amount of life any environment can support is limited and that human activities can change the flow of energy and reduce the fertility of Earth.
• Know the ways in which humans today are placing their environmental support systems at risk (e.g., rapid human population growth, environmental degradation, and resource depletion).
• Know that changes in Earth’s climate, geological activity, and life forms may be traced and compared.
• Know that Earth’s systems and organisms are the result of a long, continuous change over time.
• Understand the mechanisms of changes (e.g., mutation and natural selection) that lead to adaptations in a species and their ability to survive naturally in changing conditions and to increase species diversity.
• Know of the great diversity and interdependence of living things.
• Understand how genetic variation of offspring contributes to population control in an environment and that natural selection ensures that those who are best adapted to their surroundings survive to reproduce.
• Understand the interconnectedness of the systems on Earth and the quality of life.
• Know that technological problems often created a demand for new scientific knowledge and that new technologies make it possible for scientists to extend their research in a way that advances science.
• Know that the value of a technology may differ for different people at different times.
• Know that scientific knowledge is used by those who engage in design and technology to solve practical problems, taking human values and limitations into account.