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Module #1: Biology, The Study Of Life

Introduction

In this course, you're going to take your first detailed look at the science of biology. Biology, the study of life itself, is a vast subject, with many subdisciplines that concentrate on specific aspects of biology. Microbiology, for example, concentrates on those life forms and biological processes that are too small for us to see with our eyes; biochemistry studies the chemical processes that make life possible, and population biology deals with the dynamics of many life forms interacting in a community. Since biology is such a vast field of inquiry, most biologists end up specializing in one of these subdisciplines. Nevertheless, before you can begin to specialize, you need a broad overview of the science itself. That's what this course is designed to give you.

What is Life?

Well, if biology is the study of life, we need to determine what life is. Now to some extent, we all have an idea of what life is. If I were to ask you whether or not a rock is alive, you would easily answer "No!" On the other hand, if I were to ask you whether or not a blade of grass is alive, you would quickly answer "Yes!" Most likely, you can intuitively distinguish between life and non-life.

Even though this is the case, scientists must be a little more deliberate in defining what it means to be alive. Thus, scientists have developed several criteria for life. If something meets all of these criteria, then we can scientifically say that it is alive. If it fails to meet even one of the criteria, it is not alive. These criteria are:

1. All life forms contain deoxyribonucleic acid (DNA).
2. All life forms have a method by which they extract energy from the surroundings and convert it into energy that sustains them.
3. All life forms can sense changes in their surroundings and respond to those changes.
4. All life forms reproduce.

When put together, these criteria define life, as far as science is concerned. Now if you're not sure exactly what each of these criteria mean, don't worry. I will discuss each of them in detail.

DNA and Life

Our first criterion states that all life contains DNA. Now I'm sure you've at least heard about DNA. It is probably, however, still a big mystery to you at this point. Why is DNA so special when it comes to life? Basically, DNA provides the information necessary to take a bunch of lifeless chemicals and turn them into a living system. You see, if I were to analyze an organism and determine every chemical that made up the organism, and if I were then to go into a laboratory and make all of those chemicals and throw them into a big pot, I would not have made something that is alive. I would not have even made something that resembles the organism I studied. Why?

In order to make life, we must take the chemicals that make it up, and we must organize them in a way that will promote the other life functions mentioned in our list of criteria for life. In other words, just the chemicals themselves cannot extract and convert energy (criterion #2), sense and respond to changes (criterion #3), and reproduce (criterion #4). In order to perform those functions, the chemicals must be organized so that they work together in just the right way. Think about it this way: suppose you went to a store and bought a bicycle. The box said "some assembly required." When you got it home, you unpacked the box and piled all of the parts on the floor. At that point, did you have a bicycle? No, of course not. In order to make the bicycle, you had to assemble the pieces in just the right way, according to the instructions. When you got done, all of the parts were in just the right place and worked together with just the right parts. This makes your bike.

In the same way, DNA is the set of instructions that takes the chemicals which make up life and arranges them in just the right way so as to produce a living system. Without this instruction set, the chemicals that make up a life form would be nothing more than a pile of goo. However, directed by the information in DNA, these molecules can work together in just the right way to make a living organism. Now of course, the exact way in which DNA does this is a little complicated. Nevertheless, in an upcoming module, we will spend some time studying DNA and how it works in detail.

Energy Conversion and Life

In order to live, organisms need energy. This is why our second criterion states that all life forms must be able to absorb energy from the surroundings and convert it into a form of energy that will sustain their life functions. This process is called **metabolism**.

Metabolism - The process by which a living organism takes energy from its surroundings and uses it to sustain itself, develop, and grow

How is metabolism accomplished? It's a long process that actually begins with the sun.

Almost all of the energy on this planet comes from the sun, which bathes the earth with its light. When you take chemistry, you'll learn a lot more about light. For right now, however, all you need to know is that light is pure energy. Thus, the light that comes from the sun is, in fact, the main energy source for all living organisms on our planet. Green plants (and some other things you will learn about later) take this energy and, by a process called **photosynthesis**, convert that energy into food for themselves.

Photosynthesis - The process by which a plant uses the energy of sunlight and certain chemicals to produce its own food. Oxygen is often a byproduct of photosynthesis.

Now we'll be looking at photosynthesis in great detail towards the end of the course. Thus, if the definition is a little confusing to you, don't worry about it. What you need to know at this point is that photosynthesis allows plants to convert the energy of sunlight into food.

If plants absorb their energy from the sun, where do other life forms get their energy? Well, that depends. Some organisms eat plants. By eating plants, these organisms take in the energy that plants have stored up in their food reserves. Thus, these organisms are indirectly absorbing energy from the sun. They are taking the energy from plants in the form of food, but that food ultimately came from sunlight. Organisms that eat only plants are called **herbivores**.

Herbivores - Organisms that eat plants exclusively

So you see that even though herbivores don't get their energy directly from sunlight, without sunlight, there would be no plants, and therefore there would be no herbivores.

If an organism does not eat plants, it eats organisms other than plants. These organisms are called **carnivores**.

Carnivores - Organisms that eat only organisms other than plants

Even though carnivores eat other organisms, their energy ultimately comes from the sun. After all, the organisms that carnivores eat have either eaten plants or have eaten other organisms who have eaten plants. The plants, of course, get their energy from the sun. In the end, then, carnivores also indirectly get their energy from the sun.

Finally, there are organisms that eat both plants and other organisms. We call these **omnivores**.

Omnivores - Organisms that eat both plants and other organisms

Ultimately, of course, these organisms also get their energy from the sun.

Think about what we just did in the last few paragraphs in this module. We took all of the organisms that live on this earth and placed them into one of three groups: herbivores, carnivores, or omnivores. This kind of exercise is called classification. When we classify organisms, we are taking a great deal of data and trying to organize it into a fairly simple system. In other words, classification is a lot like filing papers. When you file papers, you place them in folders according to similarities that they have. In this case, we have taken all of the organisms on earth and put them into one of three folders based on what they eat. This is one of the most important contributions biology has made in understanding God's creation. Biology has taken an enormous amount of data and has arranged it into many different classification systems. These classification systems allow us to see the similarities and relationships that exist between organisms in God's creation. Figure 1.1 illustrates the classification system you have just learned.

FIGURE 1.1
Herbivores, Carnivores, and Omnivores

Horses eat only plants. We therefore call them herbivores.

Lions eat only meat. This makes them carnivores.

Humans eat both plants and meats. Humans are omnivores.

In biology, there are hundreds and hundreds of different ways that we can classify organisms, depending on what kind of data we are trying to organize. For example, the classification system we just talked about groups organisms according to what they eat. Thus, organisms that eat similar things are grouped together. In this way, we learn something about how energy is distributed from the sun to all of the creatures on earth.

This is not, however, the only way we can classify organisms to learn how energy is distributed from the sun to all of the creatures on earth. We could, alternatively, classify organisms according to these groups: **producers, consumers,** and **decomposers.**

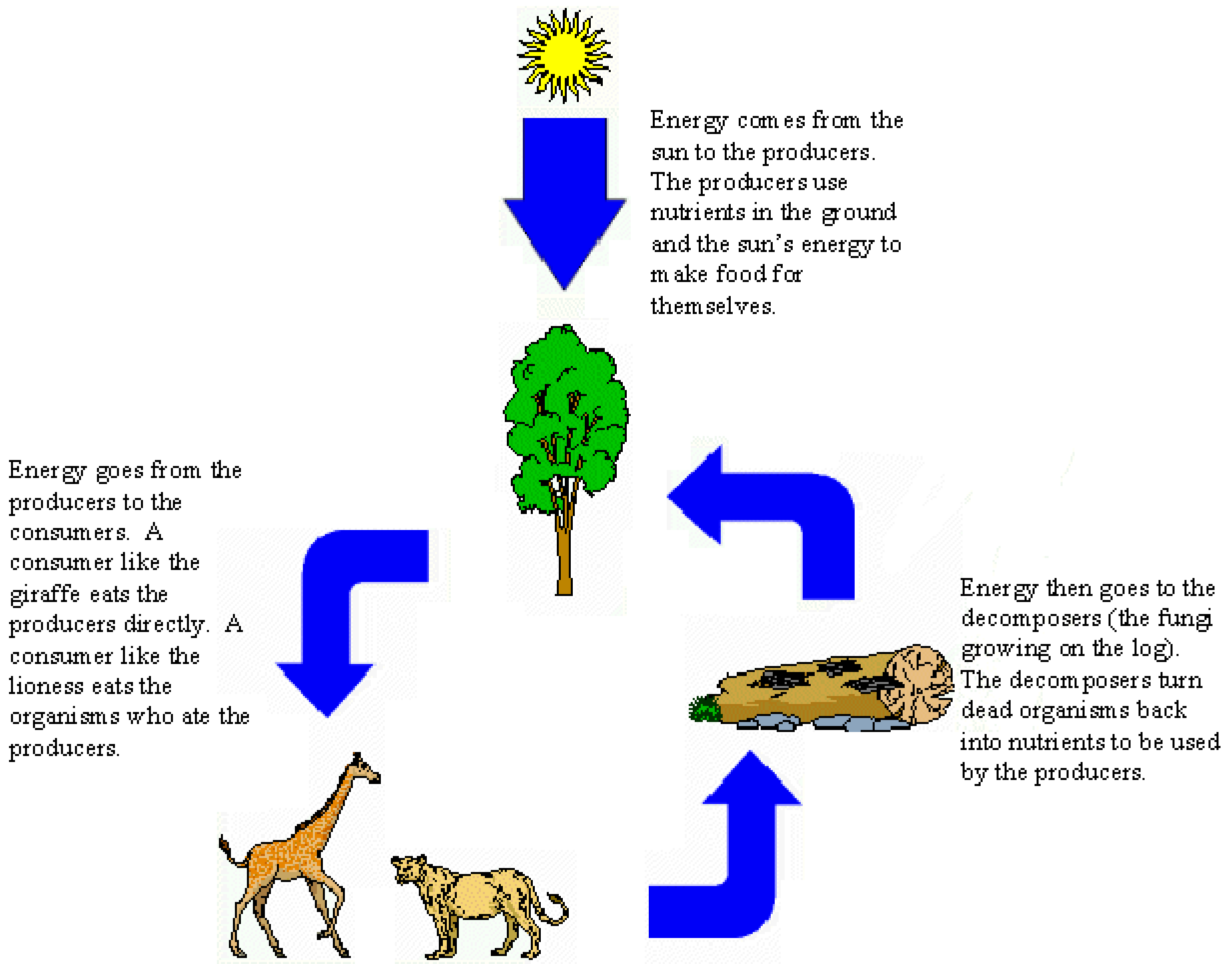
Producers - Organisms that produce food directly from sunlight

Consumers - Organisms that eat living producers and/or other consumers for food

Decomposers - Organisms that break down the dead remains of other organisms

In this system, plants are producers because they make their food directly from the sun's light. Omnivores, herbivores, and carnivores are all consumers, because they eat producers and other consumers. Certain bacteria and fungi (the plural of "fungus"), organisms we'll learn about in detail later, take the remains of dead organisms and break them down into simple chemicals. Thus, these creatures are the decomposers. Once the decomposers have done their job, the chemicals that remain are once again used by plants to start the process all over again. This, classification scheme, illustrated in Figure 1.2, gives us a nice view of how energy comes to earth from the sun and is distributed to all creatures in God's creation.

FIGURE 1.2 Producers, Consumers, and Decomposers



There are, of course, differences between this classification (producers, consumers, and decomposers) system and the one you learned previously (omnivores, herbivores, and carnivores). The first difference you should notice between this classification scheme and the one you just studied is that, in this case, we include plants, bacteria, and fungi in the classification. In the previous classification system, we could only classify organisms that ate plants or ate other organisms. There was no grouping in which to put the plants, the bacteria, or the fungi. Does this mean that the second classification system is better than the first? Not really. They each tell us different information. For example, if I need to look at the differences that exist between animals, then the first classification scheme is best. Some animals are herbivores (cows, for example), some animals are carnivores (tigers, for example), and some animals are omnivores (humans, for example). In the second classification system, all animals are consumers. So the second classification system doesn't tell us much about the differences that exist between animals. If, however, we want to study how energy flows from the sun to every creature in Creation, the second classification system is the one to use.

As a point of terminology, producers are often called **autotrophs**, because they make their own food. Consumers and decomposers, on the other hand, are often called **heterotrophs** because they have to eat other organisms for food.

Autotrophs - Organisms that are able to make their own food Heterotrophs - Organisms that depend on other organisms for their food

In a little while, these two terms will become very important, so you need to know them.

Before you go on to the next section, answer the "on your own" questions below. These questions will be scattered through out the modules in this course. They allow you to reflect on the things you have just read about, cementing the concepts into your mind.

ON YOUR OWN

1.1 Classify the following organisms as herbivores, carnivores, or omnivores:
a. tigers b. horses c. humans d. sheep
1.2 Classify the following organisms as producers, consumers, or decomposers: a. flowers b. yeast (a fungus) c. lions d. humans

Sensing and Responding to Change

Our third criterion for life is that it senses and responds to change in its surroundings. It is important to realize that in order to meet this criterion, an organism's ability to sense changes is just as important as its ability to respond. After all, even a rock can respond to changes in its environment. If a boulder, for example, is perched on the very edge of a cliff, even a slight change in the wind patterns around the boulder might be enough for it to fall off of the cliff. In this case, the boulder is responding to the changes in its surroundings. The reason a boulder doesn't meet this criterion is that the boulder cannot sense the change.

Living organisms are all equipped with some method of receiving information about their surroundings. Typically, they accomplish this feat with **receptors**.

Receptors - Special structures or chemicals that allow living organisms to sense the conditions of their surroundings

Your skin, for example, is full of receptors. Some allow you to distinguish between hard and soft substances when you touch them. Other receptors react to hot and cold temperatures. Thus, if you have your hand under a stream of water coming from a water faucet, your receptors react to the temperature of the water. The receptors send information to your brain and you can then react to the temperature. If the water is too hot or too cold, you can remove your hand from the stream to avoid the discomfort.

A living organism's ability to sense and respond to change in its surrounding environment is a critical part of survival, because God's creation is always changing. Weather changes, seasons change, landscape changes, and the community of organisms in a given region changes. As a result, living organisms must be able to sense these changes and adapt, or they would not be able to survive.

All Life Forms Reproduce

Our final criterion for life says that all living organisms reproduce. Although the necessity of reproduction for the perpetuation of life is rather obvious, it is truly amazing how many different ways God has designed the organisms on earth to accomplish this feat. Some organisms, for example, can split themselves apart under the right circumstances. The two parts can then grow into wholly separate organisms. This is called **asexual reproduction**.

Asexual Reproduction - Reproduction accomplished by a single organism

Other organisms, however, require a male and female together in order to reproduce. This method of reproduction (which occurs in most of the life forms with which you are familiar), is called **sexual reproduction**.

Sexual Reproduction - Reproduction that requires two organisms, a male and a female

As we go along in this course, we will be studying both of these methods a bit closer, because there is a great deal of variety among the different means of sexual and asexual reproduction.

Reproduction always involves the concept of **inheritance**. Although this word has several different meanings, in biology the definition is quite specific.

Inheritance - The process by which physical and biological characteristics are transmitted from the parent (or parents) to the offspring

In asexual reproduction, the characteristics and traits inherited by the offspring are, under normal circumstances, identical to the parent. Thus, the offspring is essentially a "copy" of the parent. In sexual reproduction, under normal circumstances, the offspring's traits and characteristics are, in fact, some mixture of each parents' traits and characteristics. Of course, the organism's parents' traits and characteristics are a mixture of each of their parent's traits and characteristics, and their parents' characteristics are a mixture of each of their parent's traits and characteristics, and so on. In the end, then, the inheritance process in sexual reproduction is quite complicated, and leads to offspring that often can be noticeably different than both parents.

Notice that in describing inheritance for both modes of reproduction, I used the phrase "under normal circumstances." This is because every now and again, offspring can possess traits that are incredibly different than the offspring's ancestors. These incredibly different traits are called **mutations**.

Mutation - An abrupt and marked difference between offspring and ancestor

As we will see in a later module, this is actually not the best definition for mutation, but we'll use it for right now. The study of mutations is quite interesting, and we will focus on it strongly in upcoming modules.

ON YOUR OWN

1.3 A biologist studies three organisms: a parent and two offspring. They are all identical in every possible way. Do these organisms reproduce sexually or asexually?

Life's Secret Ingredient

Well, now that we have a good idea of whether or not something is alive, another question should come to mind. What gives life the characteristics that we learned in the previous sections? As I said before, if we chemically analyzed an organism, gathered together all of the chemicals contained in it, and threw them in a pot, we would not have a living organism. Those chemicals would be basically useless without the information stored in the organism's DNA. However, even if we were able to isolate a full set of the organism's DNA and were to throw it into the pot as well, we would still not have a living organism.

You see, life is more than a collection of chemicals and information. There is something more. Scientists have tried to understand what that "something more" is, but to no avail. The secret ingredient that separates life from non-life is still a mystery to modern science. Of course, to Christians, that secret ingredient is rather easy to identify. It is the creative power of God. In Genesis 1:20-27, the Bible tells us that God created all creatures, and then He created man in His own image. Think about it this way. Suppose you had a bunch of engine and metal parts and you also had instructions that led you through all of the steps necessary to take those parts and make a working motorcycle. Could you just throw the parts and the instructions into a pile and make a motorcycle? No, of course not. Even though you had all of the necessary parts as well as all of the instructions, you still need to exercise some of your own creative power to follow those instructions and make the motorcycle.

If we were talking about a living organism instead of a motorcycle, we could say that chemicals are the "parts" that make up the organism and DNA is the instruction set that contains the information necessary to assemble the parts properly. Nevertheless, if you just threw the chemicals and the DNA into a big pot, you would not make a life. Some creative power must be exercised in order to take lifeless chemicals and use the information in DNA to make a living organism. Of course, only God has such creative power, and that is why all life comes from Him.

So you see, science will never be able to uncover the "secret ingredient" that makes life possible. At some point in the future, scientists might be able to catalog every chemical that makes up a living organism. At some farther-off point in the future, scientists might even decode the information stored in DNA and determine all of the instructions necessary to form those chemicals into a living organism. Even after those incredible feats, however, science would be no closer to creating life. Without the creative power of God, lifeless chemicals will never become a living organism.

This little discussion brings us to probably the most important thing that you will ever learn in your academic career: science has its limitations. I say that this is probably the most important thing that you will ever learn because I know a great many scientists whose lives have been ruined because they put too much faith in science. They think that because of all the wonderful advances we have made in recent years, science has no limitations. As a result, they live their lives looking to science as the ultimate answer to every question. This leads them down a path of spiritual destruction. Had they only placed their faith in God, who has no limitations, they would have lived fulfilling lives and spent eternity with the ultimate Life-Giver! Read the next section carefully, so that you will understand the limitations of science.

The Scientific Method

Real science must conform to a system known as the **scientific method**. This system provides a framework in which scientists can analyze situations, explain certain phenomena, and answer certain questions. The scientific method starts with **observation**. Observation allows the scientist to collect data. Once enough data has been collected, the scientist forms a **hypothesis** that attempts to explain some facet of the data or attempts to answer a question that the scientist is trying to answer.

Hypothesis - An educated guess that attempts to explain an observation or answer a question

Once he or she forms a hypothesis, the scientist (typically with help from other scientists) then collects much more data in an effort to test the hypothesis. If data is found which are inconsistent with the hypothesis, the hypothesis might be discarded, or it might just be modified a bit until it is consistent with all data that has been collected. If a large amount of data is collected and the hypothesis is consistent with all of the data, then the hypothesis becomes a **theory**.

Theory - A hypothesis that has been tested with a significant amount of data

Since a theory has been tested by a large amount of data, it is much more reliable than a hypothesis. As more and more data relevant to the theory gets collected, the theory can be tested over and over again. If several generations of collected data are all consistent with the theory, it eventually attains the status of a **scientific law**.

Scientific Law - A theory that has been tested by and is consistent with generations of data

An example of the scientific method in action can be found in the life of Ignaz Semmelweis, a Viennese doctor who lived in the early-to-mid 1800's. He was put in charge of a ward in Vienna's most famous hospital, the Allegemeine Krakenhaus. He noticed that in his ward, patients were dying at a rate which far exceeded that of the other wards, even the wards with much sicker patients. Semmelweis observed the situation for several weeks, trying to figure out what was different about his ward as compared to all others in the hospital. He finally determined that the only noticeable difference was that his ward was the first one that the doctors and medical students visited after they performed autopsies on the dead.

Based on his observations, Semmelweis hypothesized that the doctors were carrying something deadly from the corpses upon which the autopsies were being performed to the patients in his ward. Thus, Dr. Semmelweis exercised the first step in the scientific method. He made some observations and then formed a hypothesis to explain those observations.

Semmelweis then developed a way to test his hypothesis. He instituted a rule that all doctors had to wash their hands after they finished their autopsies and before they entered his ward. Believe it or not, up to that point in history, doctors never thought to wash their hands before examining or even operating on a patient! Dr. Semmelweis hoped that by washing their hands, doctors would remove whatever was being carried from the corpses to the patients in his ward.

Well, the doctors did not like the new rule, but they grudgingly obeyed it, and the death rate in Dr. Semmelweis' ward decreased to the lowest in the hospital! This, of course, was good evidence that his hypothesis was right. You would think that the doctors would be overjoyed. They were not. In fact, they got so tired of having to wash their hands before entering Dr. Semmelweis' ward that they worked together to get him fired. His successor, anxious to win the approval of the doctors, rescinded Semmelweis' policy, and the death rate in the ward shot back up again.

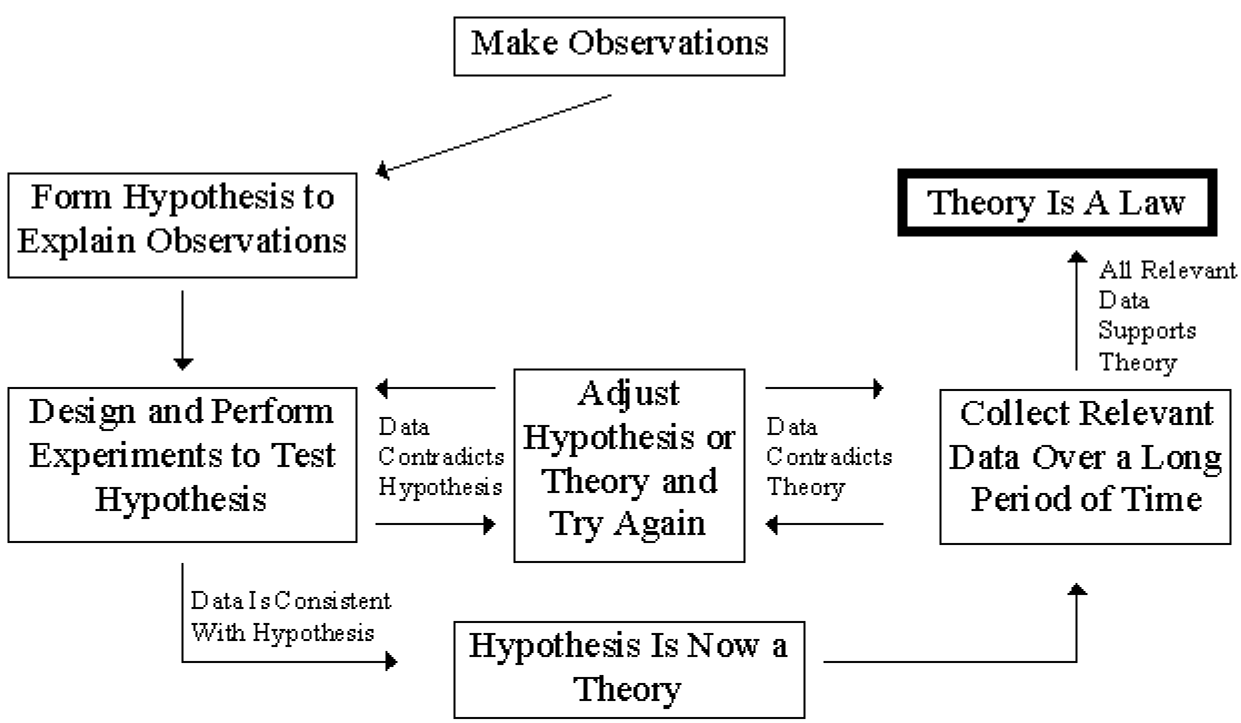
Semmelweis spent the rest of his life doing more and more experiments to confirm his hypothesis that something unseen but nevertheless deadly can be carried from a dead person to a live person. Although Semmelweis' work was not appreciated until after his death, his hypothesis was eventually confirmed by enough experiments that it became a scientific theory. At that point, doctors began washing their hands before examinations and surgery.

As time went on, more and more data was gathered in support of Semmelweis' theory. With the advent of the microscope, scientists were finally able to see the deadly bacteria and germs that can be transmitted from person to person, and Semmelweis' theory became a scientific law. Nowadays, doctors do all that they can to completely sterilize themselves and their instruments before performing any medical procedure.

Before we leave this story, it might be interesting to note that the Old Testament contains meticulous instructions concerning how a priest is to cleanse himself after touching a dead body. These rituals, some of which are laid out in Numbers 19, are more effective than all but the most modern methods of sterilization. In fact, Dr. S. I. McMillen, a medical doctor and author of None of These Diseases, states that "In 1960, the Department [of Health in New York State] issued a book describing a method of washing the hands, and the procedures closely approximate the Scriptural method given in Numbers 19." This, of course, should not surprise you. After all, God knows all about germs and bacteria: He created them. Thus, it only makes sense that He would lay down instructions as to how His people can protect themselves from germs and bacteria. If only doctors would have had the sense to follow those rules in the past centuries. Countless lives would have been saved!

So you see, the scientific method (summarized in Figure 1.3) provides a methodical, logical way to examine a situation or answer a question. If a theory survives the scientific method and becomes a law, it can be considered reasonably trustworthy. Even a scientific theory which has not been tested enough to be a law is still pretty reliable, because it is backed up by a lot of scientific data.

FIGURE 1.3
The Scientific Method



ON YOUR OWN

1.4 When trying to convince you of something, people will often insert, "Science has proven..." at the beginning of a statement. Can science actually prove something? Why or why not? 1.5 A scientist makes a few observations and develops an explanation for the observations that he or she has made. At this point, is the explanation a hypothesis, theory, or scientific fact?

Limitations of the Scientific Method

At the end of the previous section, I said that if a theory survives the scientific method and becomes a scientific law, it is "reasonably trustworthy." Why did I say "reasonably?" Aren't all scientific laws completely trustworthy? If a hypothesis survived scientific scrutiny and became a theory, and that theory went on through more significantly scientific scrutiny and became a law, isn't it 100% reliable? No, not at all. You see, in order to test hypotheses and theories, scientists must gather data. In order to gather data, they must perform experiments and observations. Since these experiments and observations are designed and performed by imperfect humans, the data collected might, in fact, be flawed. As a result, even though there might be an enormous amount of data supporting a scientific law, if the data is flawed, the law is most likely wrong! In addition, it is simply impossible, even after centuries of experimentation, to test all implications of a scientific law completely. Thus, even though years and years of experimentation exist in support of a scientific law, some clever person somewhere might devise an experiment in which the data contradict the law. So we see that scientific laws can be demonstrated false when the experiments that support them are shown to be flawed or when someone finds a new kind of experiment that contradicts the law. Both of these situations occur frequently in the pursuit of science, and they are best studied by example.

Scientific laws are constantly being overthrown due to the fact that it is impossible to completely test them. For example, prior to 1938, it was considered scientific law that the coelacanth (a bony fish) was extinct. After all, many, many fossils of the fish had been uncovered, but no live specimen had ever been found. Many biologists and paleontologists (those who study fossils) exhaustively searched for living coelacanths. Since almost 100 years of searching for this fish never turned up a live specimen, the hypothesis that it was extinct was eventually accepted as a theory and then as a scientific law. All scientists agreed: the coelacanth was extinct. Imagine their surprise when, in 1938, a fisherman who was fishing off the coast of Africa in the Indian Ocean caught a live specimen! It turns out that the coelacanth is relatively plentiful in the Indian Ocean; thus, a scientific law was overthrown due to the fact that it is impossible to test a law completely. One would think that since 100 years of careful searching for the coelacanth had never turned up a live specimen, the law stating that it was extinct should be rather reliable. However, no one had looked carefully enough in the Indian Ocean off the coast of Africa, and therefore a scientific law turned out to be quite wrong!

Other scientific laws are overthrown because the experiments that support them are flawed. For example, in about 330 BC, the famous Greek philosopher Aristotle observed that if one left meat out in the open and allowed it to decay, maggots would appear on the meat within a few days. From that observation, he formed the hypothesis that living maggots were formed from non-living meat. He called this process "spontaneous generation," and he postulated that this is where many life forms originate. He made many other observations that seemed to support his hypothesis. For example, he showed that eels have a similar smell and feel as the slimy ooze at the bottom of rivers. He considered this evidence that eels spontaneously formed from the ooze.

As time went on, many more experiments were performed that seemed to support the hypothesis of spontaneous generation. As a result, the hypothesis was quickly accepted as a theory. Of course, the experimentation did not stop there. As late as the mid-1600s, a biologist named Jean Baptist van Helmont performed an experiment in which he placed a sweaty shirt and some grains of wheat in a closed wooden box. Every time he performed the experiment, he found at least one mouse gnawing out of the box within 21 days. Think about it. A hypothesis that was formed in 330 BC was quickly accepted as a theory due to the fact that all experiments performed seemed to support it. Experiments continued for a total of 1900 years, and they all seemed to support the theory! As a result of this overwhelming amount of data in support of the theory of spontaneous generation, it became accepted as a scientific law.

About that same time, however, Francesco Redi, an Italian physician, questioned the law of spontaneous generation. Despite the fact that this law was universally accepted by the scientists of his day, and despite the fact that his fellow scientists laughed at him for not believing in the law, Redi challenged it. He argued that Helmont could not tell whether the mice that he supposedly formed from a sweaty shirt and wheat grains had gnawed into the box or out of the box. He said that in order to really test this law, you would have to completely isolate the materials from the surroundings. That way, any life forms that appeared would have to have come from the materials and not from the surroundings. He performed experiments in which he put several different types of meat in sealed jars and allowed the meat to decay. No maggots appeared on the meat. He claimed that this showed that maggots appear on meat not because they are formed by the meat, but instead because they crawl onto the meat.

Of course, the scientists of his day said that by sealing the jars, Redi was cutting off the air supply, which would stop the maggots from forming. Thus, Redi redesigned his experiment. Instead of sealing the jars, he covered them with a fine netting. The netting was fine enough to keep maggots out but allow air in. Still, no maggots formed on the meat, even long after it was decayed. What these experiments showed was that the previous experiments which purportedly demonstrated that maggots could form from decaying meat were simply flawed. If one were to adequately isolate the meat from the surroundings, maggots would never form.

These experiments sent shock waves throughout the scientific community. A scientific law, one which had been supported by nearly 1900 years of experiments, was wrong! Of course, many scientists were simply unwilling to accept this. Yes, they agreed, perhaps maggots did not come from decaying meat, but surely there were some types of organisms that could spontaneously generate from non-living things.

Anton van Leeuwenhoek thought he had found such organisms. In 1675, he reported that he had fashioned a homemade lens which magnified whatever was observed through it. As a result, he discovered the world of **microorganisms**.

Microorganisms - Living creatures that are too small to see with the naked eye

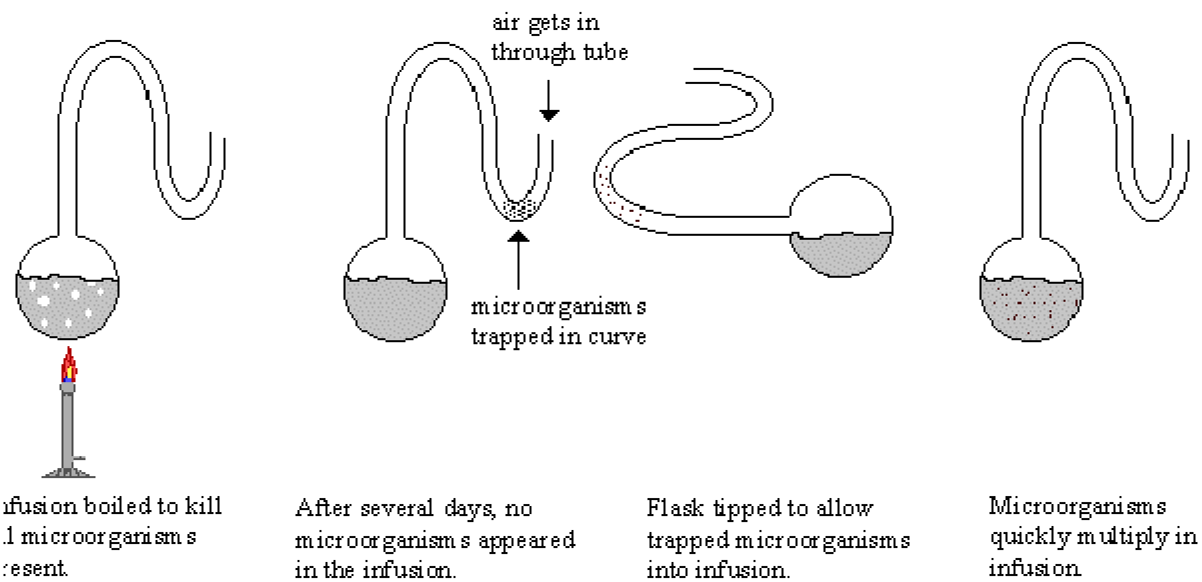
In the next module, we will begin studying this fascinating world in more depth. For right now, you just need to know that because these creatures cannot be seen without the aid of a magnifying lens, scientists prior to 1675 had no idea that they existed.

Leeuwenhoek and many others showed that these microorganisms did, indeed, seem to generate spontaneously. For example, in the mid-1700's John Needham did experiments very similar to Redi's. Needham made a liquid broth of nutrient rich material such as mutton gravy. He called these broths "infusions." He showed that if you boiled an infusion for several minutes, you could kill all microorganisms in it. Then, if you put the infusion in a jar and covered it with a net like Redi did in his experiments, microorganisms would appear in the infusion within a few days. Needham concluded that since he had covered the jar with a net just as Redi had, the infusion was isolated from the surroundings. These experiments were hailed as support for the beleaguered law of spontaneous generation.

Lazzaro Spallanzani, a contemporary of Needham, did not like Needham's experiments. After all, he said, since we cannot see microorganisms with our eyes, perhaps they can be transported by the air, making their way through the nets that covered Needham's infusions. Spallanzani repeated Needham's experiments, but Spallanzani covered the jars with an airtight seal. In these experiments, no microorganisms formed. Of course, those who still held on to the law of spontaneous generation argued that once again, without air, nothing could live. Thus, by making an airtight seal, Spallanzani cut off the process of spontaneous generation.

In the mid-1800's, however, the great scientist Louis Pasteur finally demonstrated that even microorganismsms cannot spontaneously generate. In his experiments, illustrated in Figure 1.4, Pasteur stored the infusion in a flask that had a curved neck. The curved neck allowed air to still reach the flask, but if microorganisms were present in the air, they would be trapped at the bottom of the curve. When Pasteur repeated Needham's experiments in the curved flask, no microorganisms appeared. In a final blow, Pasteur even showed that if you tipped the flask once to allow any microorganisms that might be trapped to fall into the infusion, microorganisms would appear in the infusion. Thus, Pasteur showed that even microorganisms cannot spontaneously generate. As a sidelight, he also showed that these microorganisms can be transported through the air.

FIGURE 1.4
Pasteur's Experiment



The point to this rather long discussion is simple. Even though a scientific law seems to be supported by hundreds of years of experiments, it might very well still be wrong because those experiments might be flawed. All of the experiments that were used to support the law of spontaneous generation were flawed. The scientists who conducted the experiments did not adequately isolate them from the surroundings. Thus, the life forms that the scientists thought were being formed from non-living substances were, in fact, simply finding their way into the experiment.

These two discussions, then, show the limits of science and the scientific method. First, even scientific laws are not 100% reliable. I am certain that some of the things which you learn in this book will someday be proven to be wrong. That is the nature of science. Because it is impossible to fully test a scientific law, and because laws are tested by experiments that might be flawed, scientific laws are not necessarily true. They represent the best conclusions that science has to offer, but they are nevertheless not completely reliable. Of course, if you are working with something that is a theory, it is even less reliable. Thus, putting too much faith in scientific laws or theories will end up getting you in trouble, because many of the laws and theories that we treasure in science today will eventually be shown to be wrong.

Well, if scientific laws are not 100% reliable, what is? The only thing in the universe that is 100% reliable is the Word of God. The Bible contains truths that will never be shown to be wrong, because those truths come directly from the Creator of the universe. So much misery and woe has come to this earth because people put their faith in something that is not reliable, like science. In the end, they are spiritually deprived because what they believe in is, to one extent or another, wrong. Those who put their faith in the Bible, however, are not disappointed, because it is never wrong.

If science isn't 100% reliable, why study it? The answer to that question is quite simple. There are many interesting facts and much useful information that is not contained in the Bible. Thus, it is worthwhile to find out about these things. Even though we will probably make many, many mistakes along the way, finding out about these interesting and useful things will help us live better lives. Because of the advances made in science, wonderful technology like the television and the computer exist. Thus, there is nothing wrong with science. It is a good and useful endeavor. The problem occurs when certain people who are enamored with science end up putting too much faith in it. As a pursuit of flawed human beings, science will always be flawed. Because the Bible was inspired by One who is perfect, the Bible is perfect. As long as we keep this simple fact in mind, our study of science will be greatly rewarding!

Spontaneous Generation: The Faithful Still Cling to It!

After that long story, it might surprise you to learn that there are those scientists who still believe in spontaneous generation. Now of course, there is no way that they can argue with the conclusions of Pasteur's experiments, so they do not believe that microorganisms can spring from non-living substances. Nevertheless, they still do believe that life can spring from non-life. These scientists believe in a new theory known as **abiogenesis**.

Abiogenesis - The theory that, long ago, very simple life forms spontaneously appeared through random chemical reactions

In this theory, some scientists say that since all life is made up of chemicals, it is possible that long ago on the earth, there was no life. There were just chemicals. These chemicals began reacting and, through the random reaction of chemicals, a simple life form suddenly appeared.

As we go through this course, you'll see how such an idea is simply inconsistent with everything that we know about life. At this time, however, I want to make a simple point regarding abiogenesis. Back when scientists believed in spontaneous generation, they had experiments which backed up their claim. Even before Pasteur's authoritative refutation of spontaneous generation, these experiments were shown to be flawed. Rather than giving up on their law, however, those who fervently believed in spontaneous generation just said, "Well, okay, these experiments are wrong. However, look at these other experiments. Although we now know that life forms which we see with our own eyes cannot spontaneously generate, microorganisms can."

Do you see what the proponents of spontaneous generation did? Because they wanted so badly to believe in their theory, they simply pushed it into an area in which they did not have much knowledge. The whole world of microorganisms was new to scientists back then. As a result, there was a lot of ignorance regarding how microorganisms lived and reproduced. Because of the ignorance surrounding microorganisms, it was relatively easy to say that spontaneous generation occurred in that world. After about 200 years of study, however, scientists began to understand microorganisms a little better, and that paved the way for Louis Pasteur's famous experiment.

Well, nowadays, scientists have pushed the theory of spontaneous generation back to another area that we are rather ignorant about. They say that although Pasteur's experiments show that microorganisms can't arise form non-living substances, some (unknown) simple life form might have been able to spontaneously generate from some (unknown) mixture of chemicals at some (unknown) point way back in earth's history. Well, since we have very little knowledge about things that happened way back in earth's history; and since we have only partial knowledge about the chemicals that make up life; and we have no knowledge of any kind of simple life form that could spring from non-living chemicals, the proponents of spontaneous generation (now know as abiogenesis) are pretty safe. The fact that we are ignorant in these areas keeps us from showing the error in their theory.

Of course, there are a few experiments that lend some support to the theory of abiogenesis. We will discuss them at length in another module, so right now let me just say that they are not nearly as convincing as the ones that van Helmont and Needham performed. In fact, they do not even produce anything close to a living organism, as van Helmont's and Needham's experiments seemed to. They just produce some of the simplest chemicals that are found in living organisms. Nevertheless, those who cling to the idea of spontaneous generation casually disregard the flaws that can be easily pointed out in these experiments and trumpet their results as data that support their theory. However, if you look at the track record of spontaneous generation throughout the course of human history, it is safe to conclude that at some point, the version of spontaneous generation known as abiogenesis will also be shown to be quite wrong. In a later module, you will see why these authors think that such a case has already been made.

Biological Classification

Now that we've spent considerable time on the limitations of science, it's time to turn our attention to some of the strengths of science. One of the greatest things that science can do is classification. In the study of biology, we uncover many, many facts. For example, there are many, many organisms on the earth and they have many, many properties and characteristics. Some of their characteristics they have in common with other organisms, and some of their characteristics are unique. All of these facts comprise a huge volume of data that, by itself, would be hard to understand and virtually impossible to use. Much like we have split this book into modules and have further split the modules into sections, "on your own" problems, study guides, and review questions, we need to take all of the data in biology and split it up into an organized system.

Now there are many different classification systems in biology. You have already seen that all organisms can be split into three groups: producers, consumers, and decomposers. You have also seen that we can split consumers up into herbivores, carnivores, and omnivores. Those classification systems were rather simple. They took many, many different organisms and lumped them into only a few groups. Now we need to get more detailed. We need to learn a classification system that takes all organisms and splits them into several groups. The number of groups that we split the organisms into must be large enough so that we are not grouping incredibly different organisms into the same group. At the same time, however, there cannot be too many groups, because the classification system must make the data easier to understand than it was originally. With too many groups, the classification system becomes almost as complex as the data itself.

The classification system that we will use most frequently is multi-leveled. It starts by splitting all organisms up into five different groups known as kingdoms. The organisms within each kingdom can then be further divided into different groups called phyla (the singular is phylum). Each phylum can be further divided into classes, which can be further divided into orders. Within an order, organisms can be divided into families, which can be further divided into genera (the singular is genus), which can finally be broken down into species. This multi-leveled (often called "hierarchical") classification scheme is summarized in Table 1.1.

TABLE 1.1
A Hierarchical Biological Classification Scheme

Classification Groups (In Order)
Kingdom
Phylum
Class
Order
Family
Genus
Species

To make sure that you can remember the names and orders of this classification system, you can use the following mnemonic:

King Philip Cried Out, "For Goodness Sake!"

Since the first letter of each word in this sentence can stand for a group in our classification system, you can use it to remember the order in which we place these groups. It is important to note that the classification of organisms is so complicated that we often split these groups into subgroups. Thus, do not be confused if you run across a term like "subphylum." A subphylum is simply used to split organisms in a phylum into smaller groups before they are split into classes. There are also subclasses, suborders, and subfamilies. Another annoying fact is that some classification schemes use "division" instead of "phylum" for kingdoms Monera, Fungi, and Plantae. Although we will not do that, you need to be aware that others might.

Now that we know the groups and their respective orders, it's time to see how we use this system to classify organisms in nature. As we mentioned before, we generally split all of the organisms in nature into five separate kingdoms. In fact, there are some applications of this classification system that use as little as three kingdoms, but most biologists use five, so that's what we'll use. The names of these kingdoms are ***Monera, Protista, Fungi, Plantae, and Animalia***. The proper names of all our classification groups are Latin, and when we use those names, we italicize and capitalize them to emphasize that these are proper classification names.

How do we know what organisms go into what kingdom? Well, we group organisms together based on similar characteristics. Since the first step in classification deals with placing organisms in kingdoms, the common characteristics that organisms in the same kingdom share are pretty basic.

ON YOUR OWN

1.6 Suppose you chose two organisms at random out of a list of the members of kingdom Plantae, then you chose two organisms at random out of a list of the members of family Pinaceae. In which case would you expect the two organisms to be the most similar? 1.7 You compare several organisms from different orders. You then compare organisms from different classes. In which case would you expect the differences to be greatest?

Characteristics Used to Separate Organisms into Kingdoms

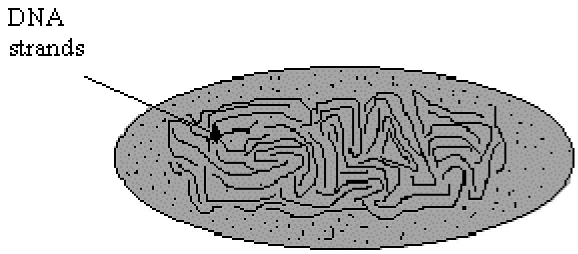
The first and most basic distinction that we make between organisms is based on the number and type of cells that the organism has. Now you have probably learned a few things about cells from your earlier studies in science. You probably learned that all living creatures are made up of at least one cell, and that cells are the basic building blocks of life. We will be making a detailed study of cells throughout the next few modules, so for right now, we don't want to spend a lot of time on them. The only thing that we want to concentrate on right now is the fact that cells come in two basic types: **prokaryotic** and **eukaryotic**.

Prokaryotic Cell - A cell that has no distinct, membrane-bound organelles
Eukaryotic Cell - A cell with distinct, membrane-bound organelles

Now of course, these definitions mean nothing unless you know what **organelles** are and what "**membrane-bound**" means. You see, in order to live, a cell must perform certain functions. As one of our criteria for life says, living things must have an energy conversion mechanism as well as reproductive capacity. In order to carry out these functions, cells must complete many different tasks. In eukaryotic cells, the individual tasks needed to complete the functions of life are carried out by distinct structures within the cell. These structures are called organelles. In order to stay distinct, they must be surrounded by something that separates them from the rest of the cell. We call this a membrane. Thus, a "distinct, membrane-bound organelle" is simply a structure within a cell that performs a specific task. Prokaryotic cells do not contain these internal structures. Nevertheless, they still can perform all of the necessary functions of life. You might wonder how that is possible. Well, you'll find out in the next module. For right now, just familiarize yourself with the distinction between prokaryotic and eukaryotic cells with Figure 1.5.

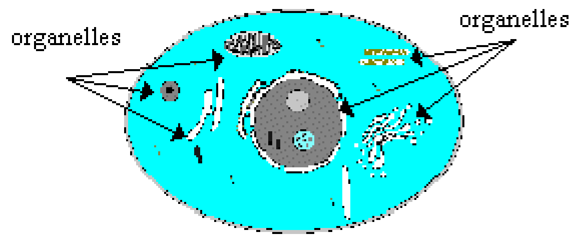
FIGURE 1.5
The Difference Between Prokaryotic and Eukaryotic Cells

Sketch of a Prokaryotic Cell



A prokaryotic cell contains no distinct structures. The main feature of a prokaryotic cell is the DNA strands visible throughout the cell.

Sketch of a Eukaryotic Cell



A eukaryotic cell has distinct structures called "organelles." These organelles have their own tasks to perform in order to maintain the life of the cell.

Now that we know the distinction between these two basic cell types, we can finally discuss how to split organisms up into the five different kingdoms. Kingdom Monera contains all organisms that are composed of either one prokaryotic cell or a simple association of prokaryotic cells. What do we mean when we say "a simple association" of cells? Well, if cells work together in order to complete the tasks necessary for life, they can do so in one of two ways. They can either be highly specialized, each taking on a specific set of tasks needed for the organism to survive, or they can simply work together as a group, each performing essentially the same tasks, but doing so as a group. The cells in a human being, for example, work together in the first way. The cells that make up your eyes specialize in the detection of light and the transmission of light-induced information to your brain, while red blood cells specialize in transporting oxygen to other cells. These cells perform different functions, each of which is necessary for the support of life. Blue-green algae (also known as cyanobacteria), however, simply group themselves together in chains. The cells in the chain are usually bound together by mucus, but they each do essentially the same task. They simply find strength and survivability in numbers. This is an example of a "simple association" of cells. Blue-green algae and bacteria are both members of kingdom Monera.

The next kingdom is called Protista. It contains those organisms that are composed of only one eukaryotic cell or a simple association of eukaryotic cells. Amoebae and paramecia are members of kingdom Protista. Kingdoms Monera and Protista together contain most of the microorganisms that exist on earth.

Moving out of the microscopic world (for the most part) and into the macroscopic world (the world we can see with the naked eye), we come to the kingdom Fungi. This kingdom is comprised of decomposers. If you remember from the earlier parts of the chapter, decomposers are those organisms that feed off of dead organisms, decomposing them into their constituent chemicals so that they can be used again by the producers. Most members of the kingdom Fungi have eukaryotic cells. In addition, most Fungi are multicellular, but there are a few single-celled Fungi. Mushrooms and bread molds are examples of the organisms in kingdom Fungi.

The next kingdom, Plantae, is composed of autotrophs (organisms that produce their own food). Almost all members of kingdom Plantae are multicelled organisms with eukaryotic cells. Even though we say that members of kingdom Plantae are autotrophs, there are a few exceptions. Some parasitic organisms are considered members of kingdom Plantae. As you have probably already guessed, members of kingdom Plantae are often called "plants." Thus, trees, grass, flowers, etc., are all members of kingdom Plantae.

The last kingdom, Animalia, contains multicellular organisms with eukaryotic cells. Members of kingdom Animalia are separated from kingdom Plantae by the fact that they are heterotrophs (dependent on other organisms for food) but are not decomposers (decomposers are in kingdom Fungi). Of course, members of kingdom Animalia are called "animals." Grasshoppers, birds, cats, and humans are all members of kingdom Animalia.

ON YOUR OWN

1.8 An organism is made up of one eukaryotic cell. To what kingdom does it belong? 1.9 An organism is multicellular and an autotroph. To what kingdom does it belong? 1.10 An organism is multicellular with eukaryotic cells. It is also a decomposer. To what kingdom does it belong?

The Definition of Species

After reading the last section, you should have noticed a few things about classifying organisms. It's not very easy or clear-cut. To separate organisms into five separate groups, we already ran into exceptions. Kingdom Plantae, for example, is supposed to contain autotrophs. There are, however, some parasites that belong to that kingdom as well. In addition, I use the word "mostly" quite a lot, because although the majority of the members in a kingdom might have a certain characteristic, there will be some members that do not. Thus, classification of organisms into kingdoms gets a little complicated.

As you might expect, classifying organisms in phyla, classes, orders, families, genera, and species becomes even more difficult. After all, as you move down the hierarchy in our classification scheme, your are getting more and more specific. While kingdoms have many, many members, those members are split into phyla. Thus, each phylum has fewer members than does the kingdom of which they are a part. In the same way, classes have fewer members than the phylum that they are in, orders have even fewer members, families have even fewer, and genera have still fewer. By the time you get to species, you have a very small group of organisms.

Since classification gets more and more difficult as you go down the hierarchy, splitting organisms into species becomes incredibly hard. If you thought that our definitions for what organisms go into each of the five kingdoms was bad, it is so hard to classify at the species level that biologists can't even agree on a definition for what the classification "species" really means! There is a lot of work going on right now in the field of biology trying to figure out a good way to define this difficult classification. For our purposes, however, we must have a definition, so we will go with the most commonly accepted one:

Species - A unit of one or more populations of individuals that can reproduce under normal conditions, produce fertile offspring, and are reproductively isolated from other such units

Although this definition is not perfect , it is the one that we will use for now. What does it mean? Basically, if organisms can reproduce and their offspring can also reproduce (that's what "fertile" means), these organisms belong to the same species. Any other organism with which this species cannot reproduce is said to be "reproductively isolated" from this species and therefore must belong to a different species.

Notice that in the previous section, we gave you the characteristics by which you can separate all organisms on earth into the five kingdoms of our classification system. Then, in this section, we skipped over all of the other classification groups except for species. For that classification group we gave a definition. Why did we leave out the other classification groups? Mostly because we did not want to overwhelm you with information. There are (depending on whose classification system you use) at least 51 different phyla. Members of each phyla have their own characteristics, and we would have to go through each phylum individually to give you a good feel for how to classify organisms into these groups. Of course, since each phylum is split into several classes, there are even more of those. Thus, to go through and give you a view of each kingdom, phylum, class, order, family, and genus would be an incredibly long discussion! When we get to species, however, the classification is so specific that we can actually come up with a weak definition for it. That's why we skipped from kingdoms all of the way to species.

Biological Keys

Well, if a discussion of all groups in our classification system is prohibitively long, how will we ever be able to classify organisms? In order to classify organisms, biologists often refer to **biological keys**. These keys help you to classify organisms without having to memorize the characteristics of all groups within the classification scheme. A simple such biological key is given below. It also is given in the appendix at the back of the book. Please remove those pages of the appendix so that while we discuss the key, you can easily refer to it.

FIGURE 1.6
A Simple Biological Key

1.	Microscopic	**2**
	Macroscopic (visible with the naked eye)	**3**
2.	Eukaryotic cell	*kingdom Protista*
	Prokaryotic cell	*kingdom Monera*
3.	Autotrophic ... *kingdom Plantae*	**4**
	Heterotrophic	**5**
4.	Leaves with parallel veins ... *phylum Anthophyta*	*class Monocotyledoneae*
	Leaves with netted veins ... *phylum Anthophyta*	*class Dicotyledoneae*
5.	Decomposer	*kingdom Fungi*
	Consumer ... *kingdom Animalia*	**6**
6.	No Backbone	**7**
	Backbone ... *phylum Chordata*	**22**
7.	Organism can be externally divided into equal halves (like a pie but it has no distinguishable right and left sides	**8**
	Organism either can be divided into right and left sides that are mirror images or cannot be divided into two equal halves	**9**
8.	Soft, transparent body with tentacles	*phylum Cnidaria*
	Firm body with internal support; covered with scales or spiny plates; tiny, hollow tube feet used for movement	*phylum Echinodermata*
9.	External plates that support and protect ... *phylum Arthropoda.*	**14**
	External shell or soft, shell-less body	**10**
10.	External Shell ... *phylum Mollusca*	**11**
	No external shell	**12**
11.	Coiled shell	*class Gastropoda*
	Shell made of two similar parts	*class Pelecypoda*
12.	Worm-like body without tentacled receptors on head	*phylum Annelida*
	Non-worm-like body or tentacled receptors on head ... *phylum Mollusca*	**13**
13.	Worm-like body with tentacled receptors on head	*class Gastropoda*
	Non-worm-like body but 8 or more tentacles used for grasping	*class Cephalopoda*
14.	More than 3 pairs of legs	**15**
	3 pairs of walking legs ... *class Insecta*	**16**
15.	4 pairs of walking legs, body in two divisions	*class Arachnida*
	More than 4 pairs of walking legs	*class Malacostraca*
16	Wings	**17**
	No wings	**21**
17.	All wings transparent	**18**
	Non-transparent wings	**19**
18.	Capable of stinging from back of body	*order Hymenoptera*
	Cannot sting (may be able to bite)	*order Diptera*
19.	Large, sometimes colorful wings	*order Lepidoptera*
	Thick, hard, leathery wings	**20**
20.	Pair of hard wings covering a pair of folded, transparent wings	*order Coleoptera*
	Pair of leathery wings covering a pair of transparent wings	*order Orthoptera*
21.	Piercing, sucking mouthparts for obtaining blood	*order Siphonaptera*
	Mouthparts for chewing	*order Hymenoptera*
22.	Jaws or beak	**23**
	No jaw or beak	*class Agnatha*
23.	Skin covered with scales	**24**
	No scales on skin	**26**
24.	Fins and gills	**25**
	No fins, breathes with lungs	*class Reptilia*
25.	Mouth on lower part of body	*class Chondrichthyes*
	Mouth on front part of body	*class Osteichthyes*
26.	No scales, no hair, no feathers; skin is slimy ... *class Amphibia.*	**27**
	Feathers or hair	**28**
27.	Tail	*order Caudata*
	No tail	*order Anura*
28.	Feathers on body	*class Aves*
	Hair on body ... *class Mammalia*	**29**
29.	Hooves	**30**
	No hooves	**31**
30.	Odd number of toes	*order Perissodactyla*
	Even number of toes	*order Artiodactyla*
31.	Carnivore	**32**

Now don't get overwhelmed by this key. It is actually quite simple to use once you are led through it. You see, this key allows you to look at the organism, seek its key features, and go through the key until you end up with a classification. For example, consider an elephant:

To classify this elephant, I would just start at the top of the key. When you find the proper characteristic, you proceed to the number that follows that characteristic. You continue to do this until you reach a classification that is not followed by a number.

So, we start at the top of the key. Key 1 asks about size. Since we don't need to magnify an elephant in order to see it with the naked eye, the elephant is macroscopic. This means that we move to key #3, because a "3" follows the term macroscopic. In key 3, we are asked whether or not the elephant is autotrophic (uses photosynthesis to make food) or heterotrophic (eats other organisms). Clearly, the elephant is heterotrophic. This means we move to key 5, where we need to determine whether it is a decomposer or a consumer. Since the elephant eats plants, it is a consumer. That tells us that our first classification is kingdom Animalia.

Now of course, this should be no surprise. An elephant is an animal. The key also tells us to move on to key 6 for a more detailed classification. Here, we determine whether or not it has a backbone. Now from the picture, you might not be able to tell, but all you have to do is think. Have you seen pictures or movies of people riding on elephants' backs or elephants carrying heavy loads on their backs. They must have a backbone to do that, so we learn that the elephant is in phylum Chordata and we move on to key 22.

Key 22 asks if the animal has a jaw or beak. Since the elephant's mouth opens and closes up and down, it has a jaw. Thus, we move to key 23, which asks if there are scales on the skin. There are not, so we move to key 26. This key asks about hair or feathers. The picture shows a line of hair along the back, especially on the neck. Thus, we move to key 28, which distinguishes between hair and feathers. Based on that distinction, we learn that the elephant is in class Mammalia and we move to key 29.

In key 29, we must decide whether the elephant has hooves or not. The feet have skin all the way to the bottom, so there are no hooves. This means we go to key 31, which asks whether the elephant is a herbivore or carnivore. Although not readily apparent from the picture, you should probably already know that elephants eat plants, making them herbivores. That means we move to key 33, which asks about teeth. There are certainly no enlarged teeth apparent, so we move to key 35. In this key, we are asked whether there is an enlarged trunk. Yes, there is. Thus, we know that the elephant is in order Proboscidea. This is as detailed a classification as we can make with this key. As far as this key is concerned, then, the elephant classification is:

Kingdom: Animalia Phylum: Chordata Class: Mammalia Order: Proboscidea

Note that in the case of the elephant, we went all the way to the end of the key. This will rarely be the case. You continue on in the key until you run out of numbers. At that point, you have as detailed a classification as is possible with that key. Take your own shot at classification by performing Experiment 1.1.

EXPERIMENT 1.1 Using A Biological Key

Supplies:

- Photographs provided
- Biological Key in Figure 1.6

Object: The object of this exercise is to identify sixteen living things by using the biological key in the text. Keys vary in their style and content. This key is applicable to all five kingdoms, made especially for use in this course. A good library exercise would be to check other keys and how they are used.

The chart below gives you an example of how to identify the elephant that has been described for you in the text. Reread the section on how to identify the elephant and note how the chart has been completed for "example". Once you understand how the chart is filled in, identify each of the sixteen pictures by working through the key. As you work through the key, make a chart in your laboratory notebook and fill it in. Your chart should have all of the columns listed in the example chart below, and it should have 16 rows (one for each picture). Note how Kingdom (K.), Phylum (P.), Class (C.), and Order (O.) are written in the third column. Write them out that way in your chart as well.

Number	Specimen	Specimen Classification	Numbers From The Key
Example	Elephant	K. Animalia C. Mammalia P. Chordata O. Proboscidea	1, 3, 5, 6, 22, 23, 26, 28, 29, 31, 33, 35
1.	Moth	K. C. P. O.	

(continue chart for all 16 specimens in your laboratory notebook)

Once you have completed the chart in your laboratory notebook, check your work against the answers that are provided at the back of this module.

Specimens For The Lab:

1. Moth

2. Chipmunk

3. Grapes

4. Swan

5. Spider

6. Lion

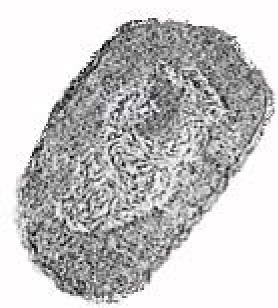
7. North American Flag

8. Fish

9. Paramecium
(Magnified 1,000x)

10. Mushroom

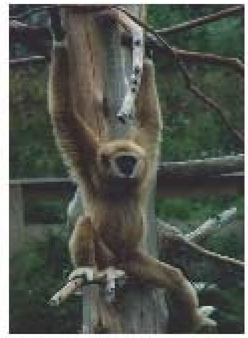
11. Toad



12. Bacterium
(Magnified 10,000x)

13. Deer

14. Grasshopper



15. Gibbon

16. Zebra

Naming Organisms Based on Classification

Of course, with a more complicated key, you could continue your classification of an organism right down to species. Why bother? Well, as I said before, classification is a way of ordering the diverse data in biology into some reasonably understandable system. This is such an important practice that an entire field of biology is devoted to it. We call this field **taxonomy**.

Taxonomy - The science of classifying organisms

Taxonomy is a very important part of biology because, in order to give a scientific name to an organism, we must know both its species and its genus. In biology, we name things with **binomial** (bye no' mee ul) **nomenclature** (no' mun klay chur).

Binomial Nomenclature - Naming an organism with its genus and species name

Humans, for example, are called Homo sapiens. Homo is the genus to which humans belong, and sapiens is the species.

So, in order to properly name an organism, I need to know its genus and species. For example, if you were classifying oak trees, you would find that all oak trees are in the genus Quercus. A red oak is given the species name rubra while a white oak is given the species name alba. Notice that while we have capitalized all classification names up to this point, we do not capitalize the species name. This is a convention that makes binomial nomenclature a bit clearer. Thus, the scientific name of the red oak is

Quercus rubra whereas the scientific name of the white oak is Quercus alba. As a point of notation, once we have introduced a genus name, we are allowed to abbreviate it in discussions that follow. Thus, we could say that the read oak is Q. rubra and the white oak is Q. alba.

Now why bother to do this? Why not just call a white oak a white oak and a red oak a red oak? Wouldn't that be easier? Well, yes and no. You see, English is constantly changing. What we mean by "oak" today may not mean the same thing in 100 years. That's because a spoken language continues to change. Latin, however, is a dead language. It will never change. Thus, Q. rubra will mean the same thing 100 years from now that it means today. Also, by using the genus name in the name of the organism, we have a start at being able to figure out other organisms that are similar to it. Any other organism that belongs to genus Quercus will be very similar to the red or white oaks. In addition, if we find out what family the genus Quercus comes from, we can find other organisms that are also similar to the white and red oaks. That's why we use this complicated naming system.

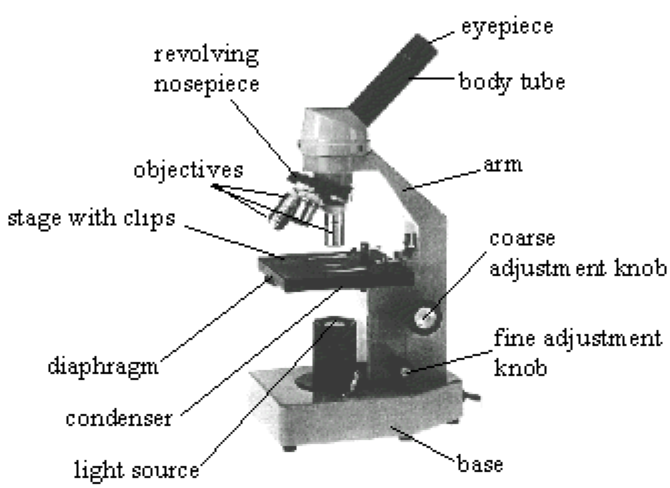
The Microscope

We'll be revisiting classification in nearly every module, so don't worry. It won't go away. However, this brief introduction allows us to get started exploring Creation. In the next two modules, we will be taking an in-depth look at kingdoms Monera and Protista. Since these kingdoms are composed of microorganisms, the labs we do in those two modules are heavily microscope oriented. If you don't have a microscope, however, don't be concerned. We will have drawings or pictures of everything that you need to know, so a microscope isn't essential for taking this course. It does, however, help to make things clearer and more interesting. So for those who do have one, you need to perform Experiment 1.2. If you don't have a microscope, just skip this experiment.

EXPERIMENT 1.2 Introduction to the Microscope

Supplies:

- Microscope
- Lens Paper
- Slides
- Slide Covers
- Swabs
- Dropper
- Water
- Small Pieces of Bright Thread
- Methylene Blue Stain



Object: To learn the various parts of the microscope and to learn to use the microscope properly
Procedure: A. Place the microscope on your table with the arm of the microscope nearest you. With the aid of the illustration, locate all the parts of the microscope and become familiar with them.

Body tube: This tube runs half the length of the microscope. The eyepiece that you look into begins the tube. The specimen is placed at the other end of the tube.

Revolving nosepiece: the disc at the bottom of the body tub that holds the lenses (which are called objectives). Coarse adjustment knob: the large knob on each side of the microscope. On the National 131 these are found just below the stage of the microscope. They are used for quick focus.

Fine adjustment knobs: These knobs are usually smaller and lower than the coarse adjustment knobs. They are used to help produce sharper focus.

Arm: the heavy structure that supports the body and stage. It is attached to the base.

Base: the horseshoe shaped structure at the bottom of the microscope. The base supports and makes the microscope steady.

Stage with clips: a platform just below the objectives and above the light source. The clips are used to hold the slide in place.

Eyepiece (called the ocular): located at the top of the body tube. It usually contains a 10X lens.

Objectives: found on the revolving nosepiece. They are metal tubes that contain lenses of varying powers.

Diaphragm: regulates the amount of light that passes through the specimen. It is located between the stage and the light source. There are iris and disc diaphragms. The 131 has a disc diaphragm.

Condenser: also located between the light source and stage. It is a lens system that affects resolution by bending and concentrating the light coming through the specimen.

Light source: found at the base. It is used to provide necessary light for the examination of specimens.

The magnifications are an important feature of any microscope. In your laboratory notebook, write down the three magnifications of your microscope. You calculate the magnification by taking the power of the ocular (usually 10x) and multiplying it by the power of each objective. Thus, if your ocular is 10x and your objectives are 4x, 10x, and 40x, your three magnifications are 40x, 100x, and 400x. Label your three magnifications as Low, Medium, and High.

B. Now that you are familiar with the parts of the microscope, you are ready to use it.

Rotate the low-power objective so that it is in line with the eyepiece. Listen for a click to make sure it is in place. Turn your light on. If you have a mirror instead of a light, look through the eyepiece and adjust the mirror until you see bright light. Using the coarse adjustment, raise the stage (or lower the body tube) until it can move no more. (Never force the microscope gears.) Place a drop of water on a clean slide and add several short pieces of brightly colored thread.

Add a cover slip (a thin piece of plastic that will cover the water and press it against the slide). This works best if you hold the cover slip close to the drops of water then drop it gently. If air bubbles form, tap the cover slip gently with the lead of your pencil. Place the slide on the stage and clip it down making sure the cover slip is over the hole in the stage.

Looking in the eyepiece, gently move the stage down (or body tube up) with the coarse adjustment. If you do not see anything after a couple of revolutions, move your slide a little to make sure the threads are in thecenter of the hole in the stage. This indicates that the threads are in the field of view.

When you have focused as best you can with the coarse adjustment, then "fine tune" your resolution by using the fine adjustment.

Note: Microscopes vary, carefully read the next steps.

Once you have the threads focused in as well as possible, then you are ready for the medium power. Place the specimen in the verycenter of the field of view by moving the slide.

Turn the nosepiece so that the medium power objective is in place. Until you are very familiar with any microscope, do not turn the nosepiece without checking to make sure it will not hit the slide. Always move the nosepiece slowly, making sure that it does not touch the slide in any way. A lens can easily be damaged if it hits or breaks a slide.

Once the medium power objective is in place, you should only have to move your fine adjustment slightly to be back in focus. Again, place the specimen in thecenter of the field. Again, watching to make sure you don't hit the slide, turn the nosepiece so that the high magnification objective is in place. To re-focus, you should only need to use the fine adjustment.

Using the procedure laid out in steps 7-12, you can now view the thread under the highest magnification of the scope. Had you tried to bring the threads into focus under high magnification without first looking at them under low and then medium magnification, you almost certainly would have never found the threads. This is the procedure that we will always use to look at things under high magnification. We will start with the lowest magnification and then work our way up.

C. Now that you have had some experience working with your scope, it is time to get your first look at cells!

Collect some epithelial cells by rubbing a cotton swab back and forth on the walls of your cheek inside your mouth. Use only one side of the swab.

Remove the swab carefully without getting a lot of saliva on the swab. Rub the side of the swab with the cells on the slide. If we were to look at the cells under the microscope right now, it would be hard to find them, because they are almost transparent. To help make them easier to see, we will add a dye to them. This dye is called a "stain," and it will help contrast the cells against the light, making them much easier to see. Place a drop of methylene blue stain on the area where you placed the cells. (This stain will not come out of most things, so use with care.)

Add the cover slip carefully.

Now place the slide on the microscope and begin the procedure outlined in steps 7-12 of section B, looking at the cells under low, then medium, and then high magnifications. In your laboratory notebook, draw what you see at each magnification level. You should see a dark blob (the nucleus) and a ring outlining the cell (the plasma membrane). Note the irregular shape of the cells.

Believe it or not, we are at the end of your first module in biology. Now you need to take a look at the study guide. On a separate sheet of paper, write out all of the definitions listed in the study guide, and answer any questions. Then, check your work with the solutions. When you are confident that you understand any mistakes you might have made, you are ready to take the test.

ANSWERS TO THE ON YOUR OWN QUESTIONS

1.1 a. Carnivores - Tigers eat only meat; thus, they are carnivores. b. Herbivores - Horses eat hay, alfalfa, and other grasses. This makes them herbivores. c. Omnivores - Humans eat plants and meat. This makes us omnivores. d. Herbivores - Sheep graze on grasses. This makes them herbivores.

1.2 a. Producers - Flowers have green stems and leaves to produce food via photosynthesis. b. Decomposers - All fungi are decomposers. c. Consumers - Lions depend on other organisms for food. d. Consumers - Humans depend on other organisms for food.

1.3 These organisms reproduce asexually. If they reproduced sexually, then the offspring's traits would be a blend of both parents' traits. Since these offspring are identical to the parent, this must be asexual reproduction.

1.4 Science cannot prove anything. The best science can say is that all known data support a given statement. However, since data contradicting the statement might be uncovered, there is no way that science can prove anything.

1.5 This is a hypothesis. The explanation will have to be tested with a significant amount of data before it can even be considered a theory.

1.6 In a hierarchical classification scheme like ours, the further you go down the classification groups, the more similar the organisms within the groups become. This is because each group is made by splitting the previous group into smaller groups. Thus, since kingdoms are split into several phyla, we expect the organisms within the phyla to be more similar than those in the entire kingdom. Since family is several steps down from kingdom, the organisms in the same family should be much more similar.

1.7 Since going down the hierarchical scheme tells us that the organisms are getting more similar, going up the hierarchical should enhance the differences. Since class is one step higher than order, the organisms from different classes should have more differences.

1.8 Protista - This kingdom has the single-celled eukaryotes.

1.9 Plantae - Almost all autotrophs belong in this kingdom.

1.10 Fungi - Decomposers are in this kingdom.

STUDY GUIDE FOR MODULE #1

1. On a separate sheet of paper, write down the definitions for the following terms. You will be expected to have them memorized for the test!

a. metabolism
b. photosynthesis
c. herbivore
d. carnivore
e. omnivore

f. producer
g. consumer
h. decomposer
i. autotroph
j. heterotroph
k. receptors
l. asexual reproduction
m. sexual reproduction
n. inheritance
o. mutation
p. hypothesis
q. theory
r. scientific law
s. microorganism
t. abiogenesis
u. prokaryotic cell
v. eukaryotic cell
w. species
x. binomial nomenclature
y. Taxonomy

2. What are the four criteria for life?

3. An organism is classified as an carnivore. Is it a heterotroph or an autotroph? Is it a producer, consumer, or decomposer?

4. An organism has receptors on tentacles that come out of its head. If those tentacles were cut off in an accident, what life function would be most hampered?

5. A parent and two offspring are studied. Although there are many similarities between the parent and the offspring, there are also some differences. Do these organisms reproduce sexually or asexually?

6. What is wrong with the following statement?

"Science has proven that energy must always be conserved."

7. Briefly explain the scientific method.

8. Why does the story of spontaneous generation illustrate the limitations of science?

9. Where does the wise person place his or her faith: science or the Bible?

10. Why is the theory of abiogenesis just another example of the idea of spontaneous generation?

11. Name the classification groups in our hierarchical classification scheme in order.

12. An organism is a multicellular consumer made of eukaryotic cells. To what kingdom does it belong?

13. An organism is a single-celled consumer made of prokaryotic cells. To what kingdom does it

belong?

14. Use the biological key in the appendix to classify the group of organisms living inside the log.

STUDY GUIDE SOLUTIONS

1. a. Metabolism - The process by which a living organism takes energy from its surroundings and uses it to sustain itself, develop, and grow

b. Photosynthesis - The process by which a plant uses the energy of sunlight and certain chemicals to produce its own food. Oxygen is often a byproduct of photosynthesis.

c. Herbivore - An organism that eats plants exclusively

d. Carnivore - An organism that eats only organisms other than plants

e. Omnivore - An organism that eats both plants and other organisms

f. Producer - An organism that produces food directly from sunlight

g. Consumer - An organism that eats living producers and/or other consumers for food

h. Decomposer - An organism that breaks down the dead remains of other organisms

i. Autotroph - An organism that is able to make its own food

j. Heterotroph - An organism that depends on other organisms for food

k. Receptors - Special structures or chemicals that allow living organisms to sense the conditions of their surroundings

l. Asexual Reproduction - Reproduction accomplished by a single organism

m. Sexual Reproduction - Reproduction that requires two organisms, a male and a female

n. Inheritance - The process by which physical and biological characteristics are transmitted from the parent (or parents) to the offspring

o. Mutation - An abrupt and marked difference between offspring and ancestor

p. Hypothesis - An educated guess that attempts to explain an observation or answer a question

q. Theory - A hypothesis that has been tested with a significant amount of data

r. Scientific Law - A theory that has been tested by and is consistent with generations of data

s. Microorganism - A living creature that is too small to see with the naked eye

t. Abiogenesis - The theory that, long ago, very simple life forms spontaneously appeared through random chemical reactions

u. Prokaryotic Cell - A cell that has no distinct, membrane-bound organelles

v. Eukaryotic Cell - A cell with distinct, membrane-bound organelles

w. Species - A unit of one or more populations of individuals that can reproduce under normal conditions, produce fertile offspring, and are reproductively isolated from other such units

x. Binomial Nomenclature - Naming an organism with its genus and species name

y. Taxonomy - The science of classifying organisms

2. All life forms contain deoxyribonucleic acid (DNA). All life forms have a method by which they extract energy from the surroundings and convert it into energy that sustains them. All life forms can sense changes in their surroundings and respond to those changes. All life forms reproduce.

3. Carnivores eat non-plants. This means they depend on other organisms for food, making them heterotrophs, which are also known as consumers.

4. If the tentacles are cut off, then the organism has no receptors, which sense the conditions of the environment. Thus, sensing change in the surroundings and responding to those changes will be impossible for this wounded creature.

5. These organisms reproduce sexually. In sexual reproduction, the offspring's traits are a blend of the parents, their parents, and so on. This would account for the differences between parent and offspring.

6. Science cannot prove anything.

7. In the scientific method, a person starts by making observations. The person then develops a hypothesis to explain those observations or to answer a question. The person (often with the help of others) then designs experiments to test the hypothesis. After the hypothesis has been tested by a significant amount of data and is consistent with all of it, then it becomes theory. After more testing with generations of data, the theory could become a scientific law.

8. The story of spontaneous generation shows how almost 2,000 years of executing the scientific method resulted in a law that was clearly wrong. Thus, you can't put too much faith in scientific laws. They are fallible.

9. The wise person trusts the Bible, because it is infallible.

10. Abiogenesis is a theory that states that life sprang from non-living chemicals eons ago. This is an example of spontaneous generation, a law that said life could arise from non-life.

11. Kingdom, Phylum, Class, Order, Family, Genus, Species

12. Animalia - Since it is multicelled, it is not Monera or Protista. In addition, it is not Plantae because it is not an autotroph (consumers are heterotrophs) and it is not Fungi because it is not a decomposer.

13. Monera - Prokaryotic cells belong to this kingdom.

14. 1. macroscopic, proceed to key 3 3. heterotrophic, proceed to key 5 5. decomposer, kingdom Fungi

Kingdom: Fungi (This is as far as we can go using this key.)

TEST FOR MODULE #1

1. Give definitions for the following terms:
a. heterotroph
b. mutation
c. theory
d. photosynthesis
e. prokaryotic cell

2. An organism is classified as a decomposer. Is it an autotroph or a heterotroph?

3. A tiger develops lockjaw and can no longer open its mouth. Which of the four life functions will it not be able to perform?

4. In laboratory studies, organisms from group A produce offspring with subtle differences as compared to the parents. Organisms from group B produce offspring that are identical to the parents, and organisms from group C produce offspring with marked differences as compared to the parents. Which group reproduces asexually? Which reproduces sexually? Which group is experiencing mutations?

5. A biologist studies two organisms from the same family. She then studies two organisms from the same genus. In which case do you expect the most similarity between organisms?

6. A biologist wishes to study how two remarkably different organisms react to the same changes in their surroundings. Should he choose organisms from different phyla or different orders?

7. Why did the law of spontaneous generation survive for so many years?

8. An organism is a multicellular decomposer with eukaryotic cells. To what kingdom does it belong?

9. An organism is a multicellular autotroph with eukaryotic cells. To what kingdom does it belong?

10. An organism has a single, prokaryotic cell. To what kingdom does it belong?

11. Classify the following organisms with the biological key in the appendix:

a. 

b. 

ANSWERS TO THE TEST FOR MODULE #1

1. a. Heterotroph - An organism that depends on other organisms for food

b. Mutation - An abrupt and marked difference between offspring and ancestor

c. Theory - A hypothesis that has been tested with a significant amount of data

d. Photosynthesis - The process by which a plant uses the energy of sunlight and certain chemicals to produce its own food. Oxygen is often a byproduct of photosynthesis.

e. Prokaryotic Cell - A cell that has no distinct, membrane-bound organelles

2. heterotroph

3. It will not be able to extract energy from the surroundings and convert it into energy that sustains life.

4. A. Reproduce Sexually B. Reproduce Asexually C. Experiences Mutations

5. The two organisms from the same genus will probably have the most similarity.

6. Different phyla

7. It survived because the experiments that confirmed it were flawed.

8. Fungi

9. Plantae

10. Monera

11. a. Kingdom: Plantae b. Kingdom: Animalia
Phylum: Anthophyta Phylum: Chordata
Class: Dicotyledoneae Class: Aves

ANSWERS TO EXPERIMENT 1.1

Number	Specimen	Specimen Classification	Numbers From The Key
1.	Moth	K. Animalia C. Insecta P. Arthropoda O. Lepidoptera	1, 3, 5, 6, 7, 9, 14, 16, 17, 19
2.	Chipmunk	K. Animalia C. Mammalia P. Chordata O. Rodentia	1, 3, 5, 6, 22, 23, 26, 28, 29, 31, 33, 34
3.	Grapes	K. Plantae C. Dicotyledonae P. Anthophyta O.	1, 3, 4
4.	Swan	K. Animalia C. Aves P. Chordata O.	1, 3, 5, 6, 22, 23, 26, 28
5.	Spider	K. Animalia C. Arachnida P. Arthropoda O.	1, 3, 5, 6, 7, 9, 14, 15
6.	Lion	K. Animalia C. Mammalia P. Chordata O. Carnivora	1, 3, 5, 6, 22, 23, 26, 28, 29, 31, 32
7.	Frond	K. Plantae C. Monocotyledonae P. Anthophyta O.	1, 3, 4
8.	Fish	K. Animalia C. Osteichthyes P. Chordata O.	1, 3, 5, 6, 22, 23, 24, 25
9.	Paramecium	K. Protista C. P. O.	1, 2
10.	Mushroom	K. Fungi C. P. O.	1, 3, 5
11.	Toad	K. Animalia C. Amphibia P. Chordata O. Anura	1, 3, 5, 6, 22, 23, 26, 27
12.	Bacteria	K. Monera C. P. O.	1, 2
13.	Deer	K. Animalia C. Mammalia P. Chordata O. Artiodactyla	1, 3, 5, 6, 22, 23, 26, 28, 29, 30
14.	Grasshopper	K. Animalia C. Insecta P. Arthropoda O. Orthoptera	1, 3, 5, 6, 7, 9, 14, 16, 17, 19, 20
15.	Gibbon	K. Animalia C. Mammalia P. Chordata O. Primates	1, 3, 5, 6, 22, 23, 26, 28, 29, 31, 33, 35
16.	Zebra	K. Animalia C. Mammalia P. Chordata O. Perissodactyla	1, 3, 5, 6, 22, 23, 26, 28, 29, 30