Textbook Reading

Lesson 1: Living Organisms

What is Science?

What do you think of when you hear the words science or scientist? When some people hear the word science, they imagine someone working with dangerous chemicals in a laboratory. Although some scientists do work with dangerous chemicals, and many do work in labs, there is much more to science than this.

There is much more to science than working with chemicals in a lab.

Science is a way of understanding the world based on repeated tests and evidence. If scientists are doing their job right, they should base their conclusions on evidence, not just on what most people think is true. **Evidence** is an observation of a thing, group of things, or a process that takes time.

Sometimes, the evidence will go against "common sense" or popular opinions. For example, many people use plastic cutting boards because they think they have fewer germs than wooden ones.

But just "thinking" something is not science. To test which kind of cutting board is really best, scientists exposed wooden and plastic cutting boards to germs, cleaned them, and then checked how many germs were still left.

They were surprised to find that although the plastic cutting board looked prettier, the evidence showed that the wooden board actually had fewer bacteria. What was shown by the evidence was not the same as what had believed by many people. When this happens, science says we should trust the evidence.

The plastic cutting board had more bacteria than the wood.

Sometimes, scientists will discover evidence that goes against what has been believed for many years. When this happens, scientists must change their way of thinking. For example, scientists thought for many years that dinosaurs were slow animals.

Recently, scientists began looking at preserved dinosaur footprints. They were most interested in the space between the footprints.

As you may know, when you move faster, there is more space between your footprints. (Try running around your room if you want to check this.) Judging by the space between dinosaur footprints, scientists discovered they were much faster than they had thought, and that some dinosaurs were possibly even faster than people.

Dinosaur footprints were helpful in determining their speed.

Even more recently, scientists attempted to create computer models of dinosaur skeletons to calculate how fast they could have run. Based on this, scientist Bill Sellers concluded that a small dinosaur called compsognathus might have been the fasted animal on two legs to ever have lived.

Every time new, more reliable evidence is discovered, scientists must look back at what they had believed, and be willing to change their minds if necessary.

The Scientific Method

Imagine you are a scientist interested in studying something that you think will help people, like the health risks of living in a smoggy city.

If you were going to share your discoveries with your fellow scientists, it would be helpful to have a procedure to follow that all scientists knew about.

For this reason, scientists sometimes use the **scientific method.** The scientific method is a series of steps that can be used to answer questions and solve problems.

Scientists don't use the scientific method all the time. It is possible to do good scientific research without it. However, this method is sometimes helpful because it allows other scientists to easily see the steps taken and reproduce the experiment themselves if they want to. The steps of the scientific method are

1. Make observations
2. Ask a question
3. Research what is already known about your question
4. Suggest an answer to the question, called a hypothesis
5. Test the hypothesis
6. Analyze the results to see if the hypothesis was correct
7. Communicate the results

Making Observations

The first step in the scientific method is to make an observation. An **observation** is anything noticed using the five senses. In the example above about the health risks of smog, you may look at the sky in a city like Los Angeles and see a great amount of smog. You might even walk around hear people coughing as they go about their business on the smoggy day. This may lead you to think that the coughing has something to do with the smog, but this is just an idea you have. We are nowhere near having actual scientific evidence, but we are on the way.

Observing the smog in Los Angeles could be the start of a scientific investigation.

Ask a Question

You have seen the smog in Los Angeles. You have heard people coughing. Now it's time to take those observations and use them to help you create a question to be answered. Coughing is associated with some medical problems, including asthma, so perhaps you would ask, "Does living in a city with a high level of smog increase the risk of developing asthma?"

Research the Topic

No matter what you are studying, it is likely someone has studied it before. In the case both of smog and asthma, many people have studied it. By doing some research, you can learn information about your topic. The Internet can be a great place to do research if you are careful. The web has some great information, and it has some terrible information. The trick is knowing the difference. As the researcher, you need to look at who the author of the website is and determine if you trust them.

Hypothesis

Now that you've asked a question and conducted some research on it, the next step is to suggest an answer to the question. A suggested answer to a scientific question is called a **hypothesis**.

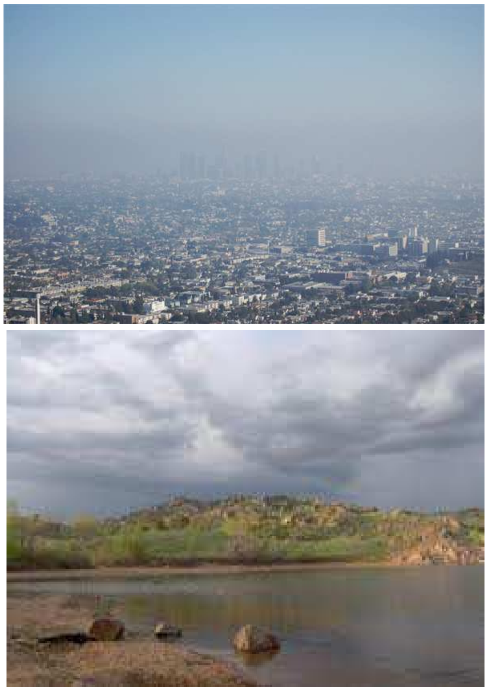
Sometimes you will hear people refer to hypotheses (that's the plural of hypothesis) as educated guesses. A hypothesis is a guess, because you have not yet done any experiments to see if it is correct or incorrect, but it is educated because it is based on the research you did in the last step.

Good hypotheses do not have to be right. In fact, some of the most important scientific research is made when a hypothesis is found to be wrong. However a good hypothesis must be testable. If scientists cannot run a test to see whether or not the hypothesis is correct, it is not a useful hypothesis.

For example, many years ago, before we knew about the importance of washing your hands, people wondered why certain patients would get sick more often than others. A popular "hypothesis" at the time was that there was something "bad" about the person that made them more likely to get sick. This is not a scientific hypothesis, however, because there is no way to test if a person is good or bad.

In our smog example, a testable hypothesis could be, "people living in cities with high levels of smog will have more cases of asthma than those living in cities with low levels of smog." This is an okay hypothesis, but it could be better. Instead of saying, "cities with high (or low) levels of smog" we could do a little more research, and pick some actual cities to study.

The website www.stateoftheair.org, ranks cities in the U.S. according to their levels of air pollution. (Take a moment to go to the website. Who created it? Based on that, do you think it's trustworthy?) According to the website, the city in the U.S. with the most air pollution is Bakersfield, California, and the city with the least is Cheyenne, Wyoming.



Bakersfield (top) and Cheyenne (bottom) are America's most and least air-polluted cities.

With this new information, we can get more specific in our hypothesis and say, "The rate of asthma infections will be higher in Bakersfield than in Cheyenne." This is testable, and will lead to a yes or no answer based on our experiment.

Testing the Hypothesis

Now is (finally) the time to conduct an experiment. It is important to carefully document all the steps of your procedure, so that other scientists can evaluate and review your work. Documenting your work will also allow other scientists to reproduce your experiment if they would like to. Information you collect during your experiment is called **data**.

Data from our smog experiment, collected from the website http://www.statemaster.com/graph/hea_pre_of_ast-health-prevalence-of-asthma would tell us that both California and Wyoming have asthma rates of 7.6%.

You don't have to surf the web to find data: you might set up an experiment that gives you data as well. (We'll learn more about how to do this later in the unit.)

Analyzing Data and Making Conclusions

Now is the time to look at our data, look back at our hypothesis, and see if we were right or wrong. We hypothesized that Bakersfield would have more cases of asthma than Cheyenne.

Although we didn't find city data, the states in which the cities are in have the same rates. (Do a little research and see if you can find city rates, if you'd like.) It appears that our hypothesis was wrong. At this point, we might want to say all kinds of things about our results.

We might want to say that it must be genetics that causes asthma, or that smog doesn't make you have asthma, but could make it worse if you already have it.

These are all interesting ideas, and could lead to a new experiment, but it's important to realize that we have not *proven* any of these things.

All we have proven is that the rates of people with asthma are not higher in smoggier states.

Communicating Results

The last step of the scientific method is to communicate your results. Whether your hypothesis was right or wrong, it is important to let other scientists know what you have discovered.

This will allow them to conduct their own experiments based on yours. This is how science moves forward. To communicate results, scientists sometimes create web sites, give lectures, or write articles for scientific magazines.

Wow! That was a lot of work just to answer a question. It's true that the scientific method is a lot of work, and that's one reason why it's not used in all cases. Even so, understanding this process is important because so many important discoveries have been made in this way.

Controlled Experiments

In an experiment, it is important to make sure that you are really testing the thing you mean to test. For example, imagine a scientist developed a new medication that she thought could treat bronchitis.

If she tested the medication by giving it to 100 people with bronchitis, and 90 of them got getter in three days, does that mean the medication works?

Maybe. Or maybe the people would have gotten better even without the medication. The problem is that we have no way of knowing. For that reason, this experiment is not good. But it can be improved.

What if the scientist took 200 people, gave 100 of them the medication, and gave the other 100 nothing. If 90 of the people who got the medication were better after three days, but only 50 of the 100 people who didn't get the medication got better, would that be proof that the medication works.

Well, we're getting closer, but there is still a problem. Sometimes, people who are getting medication think they are going to get better, so they start to feel better, *even if the medication is doing nothing!* If you don't believe this, watch little kids playing on a playground and wait for one of them to fall down. (Don't push them.)

In many cases, the child will ask for a Band-Aid, even if they have no cut! If their parents give them one, they often start to magically "feel better" and go on playing. Now, if you were watching this, you would know the Band-Aid is not helping. But the young child has convinced himself that he will be getting better, so he feels better.

This idea of feeling better because you expect to feel better is known as the **placebo effect**, and can be a big problem for scientists testing new medications. The people in the experiments might tell scientists they are feeling better, and they aren't really lying. It's just that what is making them feel better has nothing to do with what the scientist is trying to test.

So let's go back to our scientist with the bronchitis medication. We know she needs to give both groups of people *something*, but we also know she can't give everyone the medication.

So what's the solution? The scientist must give one group the real medication and the other group something that looks like the medication, but isn't actual medication. This fake medication is called a **placebo**. In this type of experiment, the group of people receiving the actual medication is called the **experimental group** and the group getting the placebo is called the **control group**.

At the conclusion of the experiment, one of three things will happen:

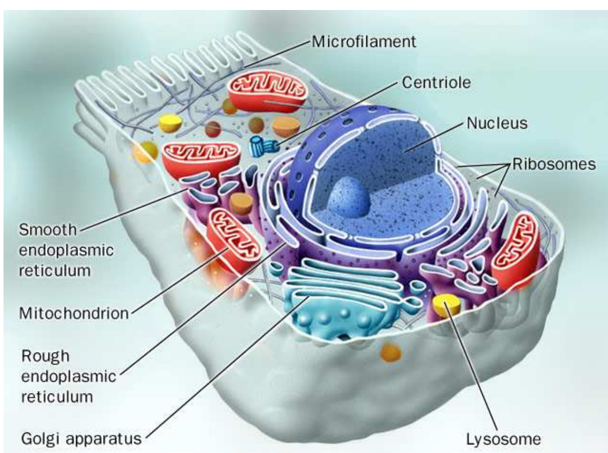
1. Neither the experimental group nor the control group will get better. This means the medication does not work.
2. The experimental and control group will get better at the same rate. This means that it is the placebo effect, not the medication, that is making people better. There is no proof that the medication works.
3. The experimental group gets better at a higher rate than the control group. This would be evidence that the medication works.

Control groups and experimental groups are not just for experiments about medications. Scientists looking to study animal behavior, what makes plants grow, or how bacteria multiply will likely have these types of groups in their experiments.

Using Models in Science

One of the most important tools scientists have are models. **Models** are representations of other things. Even the best model will never be as good as the real thing, so scientists only use models when the real thing cannot be easily studied, usually because it is too big or too small.

For example, highly powerful microscopes have allowed scientists to see pretty good images of cells, the tiny structures that make up all living things, but even with these tools, understanding cells is made easier when scientists create larger models of them.



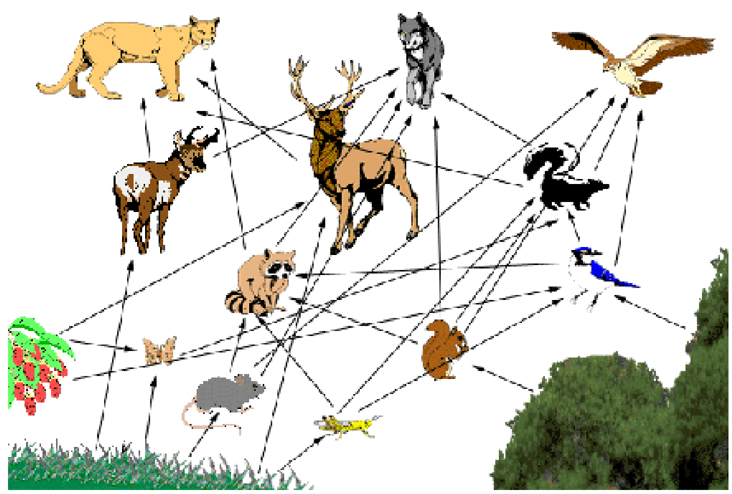
A model of a cell allows scientists to show the parts of these tiny objects.

On the other extreme, a scientist studying the solar system might want to create a smaller model.

Not every model represents physical objects. Some represent ideas.

For example, a scientist studying the life science field of **ecology**, the study the interaction of living things with other living things and non-living things, might wish to discuss what animals eat what in a certain area.

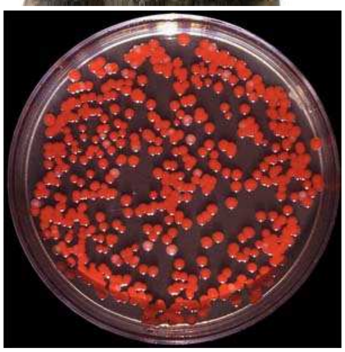
A model called a **food web** can be created to show this idea. These models allow scientists to show what eats what in a visual way, rather than relying on words alone.



Food webs graphically show what eats what.

What Makes Something Alive?

Life science is the study of living things, which are also called **organisms**. But how do we know if something is alive? We can't tell just by looking at it. A dog and a dish of bacteria are both alive, but they look very different.



A dog and a dish of bacteria do not look similar, but both are alive.

Luckily, there are some things that tell us something is alive.

All Living Things Keep a Stable Internal Environment

The first thing all living things have in common is that they keep things inside their bodies stable, or just about the same.

For example, think about our body temperature. You probably know that if everything is going well, your body temperature stays at about 98.6 degrees F (37 degrees C.) This is true whether it's hot or cold outside. Our bodies do certain things to keep this temperature.

Some things, like sitting under a shady tree on a hot day, are conscious.

But in humans, and in many living things, most are unconscious. When it's cold, you start to shiver and the amount of blood going to your body parts goes down. When it's hot, you begin to sweat. Doing this allows our body to make sure that no matter what it's like outside, our body is about the same temperature inside. This is not only true about body temperature.

There are many things about our bodies that stay the same no matter what. Keeping a stable internal environment is something all things do, and it is called **homeostasis**.

All Living Things Reproduce

Reproduction is the process of creating new organisms, and is another thing all living things do.

During reproduction, one or more living things (the parents) pass on information, called traits, about themselves to a new organism (the offspring.) Traits control many of the things about us, including our eye color, body size, whether we have a beak or a mouth, and whether we have feathers, fur, gills, or something else. This process of passing on traits is called **heredity**.

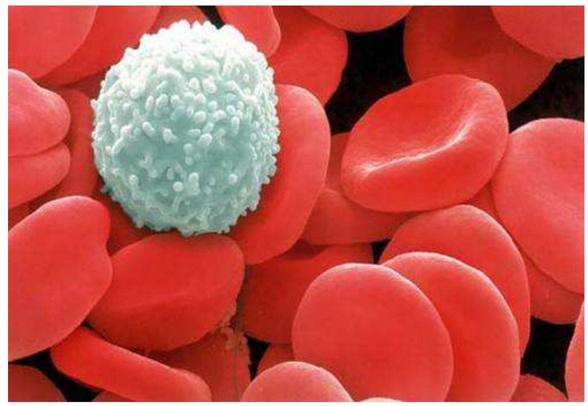
The baby birds will have many of the same traits as their mother.

Some living things require a male and female to reproduce. Others only need one parent passes on information to the offspring, like bacteria. Some lizards also do this: lizards (which are all female) just lay an egg, and a baby is born that has all the same traits as the parent.

Living Things are Made of Cells

As different as living things look from each other, it may be hard to believe that we are all made of the same thing, but living things are all made of **cells.** Cells are the smallest parts of organisms that are still considered to be alive.

Human beings have trillions of cells, and many of them have special jobs, like the ones shown below. For this reason, cells are sometimes called the building blocks of life.



A human has about 40 billion blood cells, like the ones shown here.

Living Things Need Energy

All living things need energy. Some living things are able to produce their own energy. These organisms are called **autotrophs**.

For example, plants use energy from the sun to produce the energy they need to grow and reproduce. Other living things, like humans, can't make their own food from the sun. These organisms get energy by eating plants, or by eating animals that eat plants. Organisms like this are called **heterotrophs**.

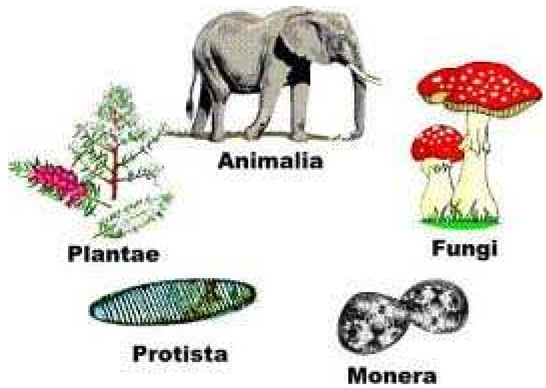
Classifying Living Things

If you like music, you might have some CDs, or songs loaded onto an mp3 player, and they may not be in any particular order. This fine if you don't have that many CDs or songs, but if you get a lot of them, you'll probably need to start organizing them, by doing things like putting all the CDs by the same artist in the same spot, or organizing the songs alphabetically.

Organizing things into groups is called **classification.** If classification is needed for a collection of songs, imagine how badly it is needed with organisms.

There so many kinds of living things – many more than there are songs on even the biggest music-lover's mp3 player. So how can they be organized? Scientists have been working on this problem for several hundred years. This has led to a detailed system to classify organisms.

First, living things are classified into kingdoms. Kingdoms are things like animals, plants, or funguses. All in all, there are five named kingdoms, although current science indicates that there may need to add more kingdoms as are more organisms are discovered and described. Kingdoms include many organisms, but all the organisms in the same kingdom have things in common. For example, all plants are autotrophs.



The five kingdoms of life

Animals in a kingdom are broken down into groups based on similarities. Each of these groups is called a phylum. From here, things get more and more specific, as you can see below:

kingdom → phylum → class → order → family → genus → species

Each organism has a scientific name, which is created by putting together the name of the genus and species.

In a scientific name, the genus is capitalized and the species is written in lower case.

Scientific names are always underlined or written in italics. These names can be very useful when communicating around the world about a particular organism.

For example, a dog is called perro in Spanish and chien in French.

But whether you are in the U.S, Spain, or France, the scientific name for dog is *Canis familiaris*.

Since scientists often work with scientists from other countries, having a common language when describing organisms is important.

Conclusion

Life science is a type of science studying organisms and how they interact with their environment. Science is a way of thinking and answering questions, sometimes in a process called the scientific method. Living things all have certain things in common, and can be classified and names based on their characteristics.

