Lesson 5: Jöns Jakob Berzelius (1779 – 1848)


This is a portrait of Jöns Jakob Berzelius.

Jöns (yuhns) **Jakob** (yah' kawp) **Berzelius** (bur say' lee oos) was born in Sweden. His parents died while he was young, however, so he was raised by relatives. He received a good education and ended up studying to be a medical doctor. During that time, he read about a simple battery produced by Alessandro Volta, and he was fascinated. He did experiments to see if the electricity from such a battery could heal certain diseases. He found that it didn't, but he discovered that he loved doing experiments, so rather than treating patients, he became a professor at an important medical university in Sweden. One of the subjects he taught was chemistry, which is the study of matter and how it changes. He wanted to discover all that he could about this interesting subject, so he did many experiments.

If you studied the science that went on shortly before the time period covered in this course, you might have learned about Joseph Louis (loo wee') Proust (proost). He was the son of an apothecary and went on to study the composition of some of the chemicals his father used to make medicines. Along the way, he is credited with the Law of Definite Proportions, which says that in a given chemical, the proportions of elements are always the same. In other words, if two elements combine to form a chemical, they always mix with the same recipe. In water, for example, there are always 8 grams of oxygen for every 1 gram of hydrogen. Berzelius did many experiments that confirmed this law, and because he did so many experiments, he ended up developing a method for representing chemicals that is still used to this day.

To understand a bit more about why Berzelius's method for representing chemicals is important, perform the following experiment.

Rusting Iron Quickly

What you will need:

- Steel wool (You need only two small clumps of it.)
- White vinegar
- Hydrogen peroxide (It is sold in drug stores to clean wounds.)
- Water
- A ¼-cup measuring cup
- Two small glasses, like juice glasses
- A wooden or plastic spoon

Please note: Don't let anything from this experiment come into contact with a stainless steel sink!

What you should do:

1. Tear off two small clumps of steel wool that are about the same size.
2. Put one clump of steel wool in one glass and the other clump in the other glass.
3. Add ¼ cup of white vinegar to each glass.
4. Add ¼ cup of water to one glass.
5. Add ¼ cup of hydrogen peroxide to the other glass.

6. Swirl each glass to mix the contents.
7. Use the wooden spoon to push the steel wool down so it is mostly covered by liquid. Do this first in the glass that contains vinegar and water. Then do it in the glass that contains vinegar and hydrogen peroxide.
8. Let the two glasses sit for at least 15 minutes. Thirty minutes would be better.
9. After at least 15 minutes, compare the contents of the two glasses. What differences do you see?
10. Use the wooden spoon to pull the steel wool out of the glasses and throw the steel wool away.
11. Pour the contents of the glasses down the drain and rinse out both the glasses and the sink thoroughly. Clean up the rest of your mess.

You should have noticed a huge difference between the glasses when you looked at them in step 9. The glass that contained vinegar and water should have looked pretty much the same as it did in step 7. However, the glass that contained vinegar and hydrogen peroxide should have been red or orange. What caused the mixture in that glass to be a different color? Some of the steel wool rusted, and the rust mixed with the liquid in the glass, giving it a red color.

These nails are in various stages of rusting.

Most likely, you already know that steel can rust. The picture on the left, for example, shows a few nails that are in various stages of rusting. The gray color comes from the steel that makes up the nails, and the reddish-orange color comes from the rust that is forming on the nails. You have probably seen other examples of metals that have rusted or are in the process of rusting. Even though you are familiar with the fact that many metals can rust, you probably don't know what the process really is.

Let's concentrate on the rusting that occurs in steel. Steel is made mostly of iron, which is an **element**. Over time, it interacts with oxygen, which is another element. Those two elements combine to make a completely new substance: rust. When two or more elements combine to make a new substance, we call that substance a **compound**. A compound has properties that are completely different from the elements that make it up. While vinegar and hydrogen peroxide cause iron to rust quickly, vinegar and water do not.

Now here's the amazing thing. Water is made up of two elements: hydrogen and oxygen. Hydrogen peroxide is made up of *exactly the same elements*! Even though these two compounds (water and hydrogen peroxide) are made up of exactly the same elements, they have completely different effects on iron. When mixed with vinegar, water doesn't seem to affect the iron in steel much, at least not quickly. However, when mixed with vinegar, hydrogen peroxide rusts the iron in steel quickly! What's the difference between hydrogen peroxide and water? There is twice as much oxygen in hydrogen peroxide as there is in water. Because it has more oxygen, hydrogen peroxide can give some of that oxygen to the iron, causing the iron to rust. Water doesn't have any "extra" oxygen to give away, so by itself, it cannot cause iron to rust. It can cause the rusting process to occur more quickly if there is oxygen present (in the air, for example), but it cannot supply that oxygen itself.

Because the amount of each element in a compound is very important, Berzelius decided to develop a system that would help chemists symbolize elements and compounds in a way that was easy to understand and print. Rather than writing the name of an element, he suggested that we should use a letter to represent each element except oxygen. Hydrogen, for example, could be represented with an "H." Since oxygen seemed to be very common, he thought that it should just be represented with a dot. For compounds, you would use numbers to represent how many of each element (except oxygen) was in the compound. For oxygen, you would put dots over the other element's symbol, indicating how many oxygens were in the compound.

For example, water has two hydrogens for every oxygen. Because of this, Berzelius used $\dot{H}^2$ to symbolize water. The "2" after the "H" indicates that there are two hydrogens, and dot above the "H" indicates there is one oxygen. On the other hand, he would have used $\ddot{H}^2$ to symbolize hydrogen peroxide, indicating there are two hydrogens (because of the "2" after the "H") and two oxygens (because of the two dots above the "H"). The chemical difference between water and hydrogen peroxide, then, is very easy to see. Hydrogen peroxide has the same number of hydrogens as water, but it has twice as many oxygens (twice as many dots) as water.

Nowadays, chemists use a similar notation. Some element symbols are composed of one letter. The element carbon, for example, is represented with a "C." Because there are so many elements, however, we often must use two letters. Iron, for example, is not represented by an "I," because another element (iodine) is represented with that letter. Instead, it is represented with "Fe." Those are the first two letters of its Latin name, *ferrum*. Notice that only the first letter is capitalized. This is always the case. If an element's symbol has two letters in it, only the first one is capitalized.

Modern chemists do two things differently from Berzelius. First, the number is no longer a superscript (after and above the letter). Instead, it is a subscript (after and below the letter). Also, oxygen is abbreviated with an "O" instead of dots. Rust, for example, is symbolized by Fe_2O_3, which tells us there are two irons and three oxygens. This is called a **chemical formula**, and it tells you the elements that make up a compound as well as how many of each element is present. If there is no number after and below an element, there is only one of that element present. For example, you used ammonia in the experiment you did for Lesson 3. Its chemical formula is NH_3. Since the element nitrogen is represented by "N," the chemical formula tells you that ammonia has one nitrogen and three hydrogens.

LESSON REVIEW

Youngest students: Answer these questions:

1. In order for iron to rust, what other element must be made available to the iron?

2. Which has more oxygen in it: water or hydrogen peroxide?

Older students: Describe your experiment and its results. Using the chemical formula for water and the chemical formula for hydrogen peroxide, explain the results of your experiment. Use the chemical formula of rust in your explanation.

Oldest students: Do what the older students are doing. In addition, carbon dioxide is a gas that we both inhale and exhale. Its chemical formula is CO_2. Carbon monoxide (whose chemical formula is CO) is a dangerous gas we shouldn't inhale. Explain what the two chemical formulas tell us about these compounds, and indicate which one is heavier.

NOTE: The experiment for the next lesson should be started the night before you do the lesson.

Lesson 10: William Charles Wells (1757 – 1817)

William Charles Wells (for whom there is no known portrait) was born in Charleston, South Carolina, but he didn't spend much of his life in the United States. When he was 11, he was sent to school in Scotland, but he returned to Charleston a few years later and was apprenticed to a physician. However, he left in 1775 to avoid the American Revolution. He and his family were loyal to the British crown, and their refusal to side with the revolutionaries in the American colonies was causing quite a bit of tension.

He studied medicine at Edinburgh University and graduated in 1780. That same year he went back to America, but his loyalty to the crown still caused him trouble. In fact, he was imprisoned for a short while. After only four years in America, he went to London to be a physician. He did not have a lot of patients, probably because he was not a very personable fellow. One of his close friends remarked that he had "dry and, in general society, ungracious manners." (Christopher Upham Murray Smith and Robert Arnott, *The Genius of Erasmus Darwin*, Ashgate 2005, p. 86)

The fact that he didn't have a lot of patients meant that he had a lot of money problems. He borrowed money from several friends, and it took him most of his life to pay off those debts. However, the lack of demands on his time allowed him to do a lot of experiments. For most of his life, those experiments didn't produce any noteworthy results. However, just a few years before his death, a paper that he had written was read before the Royal Society, the most important group of natural philosophers at that time. It ended up being so important that Wells was awarded the Rumford Medal, a recognition that is still given by the Royal Society today.

Dew forms as droplets of water on plants.

The subject of this important paper was the formation of **dew**. You have probably walked outside on a clear morning and noticed water droplets on the grass and flowers, despite the fact that there wasn't any rain the night before. That water is called dew, and its formation was a real mystery at the time Wells started his experiments. Some natural philosophers agreed with Aristotle (who lived in the fourth century BC) that dew was actually water vapor that rose from the ground and then condensed on plants. Others thought that dew was the result of a fine mist that fell from the sky but was very hard to see. Wells did careful experiments that showed these explanations were wrong. Perform your own experiment to better understand how dew and frost form.

How Do You Dew?

What you will need:

- Salt
- Water
- Ice
- A marker or crayon
- A tablespoon

- Three metal cans, like the kind soup comes in
- A large plastic freezer bag, like a gallon-sized Ziploc bag
- A dishcloth
- A bowl that is big enough to hold one of the cans but small enough to fit in the plastic freezer bag (see the photo below)
- A freezer that has room for all three cans

What you should do:

1. Add three tablespoons of salt to one of the cans. Mark the outside of the can with a marker or crayon so you know which can has salt in it.
2. Fill each can halfway with water.
3. Stir the contents of the can that has salt and water in it.
4. Add ice to each of the cans so that they are each nearly full.
5. Put all three cans in the freezer and wait for an hour.
6. After the hour is over, wet the dishcloth with warm water and put it in the bowl. Fold the dishcloth so the surface is fairly flat, because you will be setting one of the cans on it (see the photo below).
7. Take all three cans out of the freezer.
8. Put the can that has salt in it on a counter that can get wet, and put one of the other two cans near it on the same counter.
9. Put the other can on the wet dishcloth that is in the bowl.
10. Cover the bowl and can with the freezer bag so that the bag covers them. That part of your experiment should now look like the picture on the right.
11. Let the three cans sit for 15 minutes.
12. Uncover the can and bowl that has been covered in the freezer bag.
13. Compare the three cans to one another. What are their similarities and differences?
14. Clean up your mess.

What differences did you see among the three cans? The most striking difference should have been that one of the cans (the one with salt in it) had ice clinging to the outside of the can, while the other two cans had water clinging to their outsides. The other noticeable difference should have been that the can sitting in the bowl covered by the freezer bag had more water clinging to its outside than the other can that had water clinging to it.

How do we explain the results of the experiment? Well, the fact that water was clinging to the outside of the two cans is pretty easy to understand. The cans got very cold sitting in the freezer. Once they were taken out of the freezer, they stayed cold because of the ice and water inside them. The outside surfaces of the cans, then, stayed cold for the entire time that the two cans were sitting out on the counter.

As those cans sat on the counter, they were exposed to the air around them. Well, the air has a certain amount of water vapor it in. What happens when you cool water vapor? It condenses into a liquid, doesn't it? So when the water vapor in the air was cooled by the surface of the cans, it condensed, forming water droplets on the outside of the can. But why was there more water on the can that had been in the bowl and covered with the freezer bag? Because some of the water in the wet washcloth evaporated and was trapped by the bag. As a result, the air around the can in the bowl had more water vapor in it, so more water condensed onto the side of that can.

This tells us how dew forms. When the grass and flowers are cool enough, water vapor in the surrounding air condenses, forming water droplets on the grass and flowers. Of course, the more water vapor that is in the air, the more dew can form. This is, in fact, a very important factor in the formation of dew. Dew forms when the temperature reaches a certain value, which is called the **dew point**. However, the dew point depends on the amount of water vapor in the air. The more water vapor in the air, the higher the dew point. In other words, if there isn't much water vapor in the air, the temperature must get very low in order for dew to form. When there is a lot of water vapor in the air, the temperature doesn't have to get as low in order for dew to form. This is one big reason you don't see dew every cold morning. The temperature might be low, but if the amount of water vapor in the air is also low, the temperature may not be at or below the dew point, so dew will not form.


The frost on these leaves tells you that the leaves are very cold.

But what about the can with ice on it. How did that happen? Because of something you will learn about when you take high school chemistry, saltwater freezes at a lower temperature than freshwater. This means the can that had salt in it was actually at a lower temperature than the other two cans. In fact, it was at a low enough temperature to freeze the water vapor that is in the air. That's what **frost** is. It is the result of water vapor in the air freezing on a very cold surface.

William Charles Wells was the first to explain this correctly, and he became well known among natural philosophers as a result. Unfortunately, he died just a few years later. However, there is another thing for which he is recognized today. He wrote an essay about a white woman who had patches of very dark skin, and in that essay, he suggested that the differences in skin color between white people and black people was the result of them adapting to different places. He suggested that black skin was probably associated with something that helped people live better in Africa, while white skin was associated with something that helped people live better in Europe. This turned out to be correct, and the *Helps & Hints* book that comes with this course tells you why.

LESSON REVIEW

Youngest students: Answer these questions:

1. Where does dew come from?

2. Fill in the blank: Frost can form on grass when its temperature is low enough to _______ water.

Older students: Explain how dew forms, and then explain how frost forms. Also, describe the term "dew point" in your own words.

Oldest students: Do what the older students are doing. In addition, suppose it is very cold outside. You wake up in the morning, expecting to see dew or frost on the grass, but there is none. The next morning is warmer, but there is dew on the ground. On which morning was there more water vapor in the air?

Lesson 13: Hans Christian Ørsted (1777 – 1851)

This is a portrait of Hans Christian Ørsted.

Hans Christian Ørsted (ur' sted) was born in an island town in Denmark. He was homeschooled and spent a lot of time helping his father, who owned a pharmacy. This work helped him develop an interest in natural philosophy, so he went to the University of Copenhagen. He won prizes for some of his papers, and a couple years after earning his doctorate, he was awarded a scholarship to travel through Europe to meet other natural philosophers and exchange ideas with them. This is an important part of scientific advancement, because when scientists get together and discuss things, new ideas are often generated. Today, universities encourage their professors to travel to other universities and talk to the professors there. Scientists also get together in large groups, sharing what they have been doing in their research and hearing what others have to say.

Not surprisingly, Ørsted's trip across Europe introduced him to a lot of new ideas in natural philosophy. Most importantly, he met with a natural philosopher named Johann Wilhelm Ritter, who believed that there was a connection between electricity and magnetism. At that time in history, most natural philosophers believed that electricity and magnetism were two different things. After all, as you may already know, electricity was produced either by rubbing certain things together (like glass and wool) or with a Voltaic pile (which is the basis of today's batteries). Magnetism, on the other hand, was something that naturally existed in certain substances, such as an iron-based mineral called magnetite. Electrically-charged things were not attracted to or repelled by magnets, so most natural philosophers didn't think electricity and magnetism were related in any way. Nevertheless, Ritter believed that they must be connected, and Ørsted agreed with him.

A couple of years after he traveled across Europe, he became a professor at the University of Copenhagen. He developed a completely new chemistry and physics program there, setting up new laboratories that would allow him and his students to do lots of experiments. He spent a lot of time trying to connect electricity and magnetism, but he met with little success. Then something unexpected happened. He was setting up for a lecture in which he did a few experiments to demonstrate scientific facts. One of those experiments involved connecting a thin wire to a Voltaic pile. As electricity from the Voltaic pile ran through the wire, it would get hot, eventually glowing. This showed that there was some relationship between electricity, heat, and light.

He was going to do another experiment that involved a compass, and while he was setting everything up, he noticed something amazing. Perform the following experiment to learn what he saw.

Electricity and Magnetism

What you will need:

- A battery (either a D or C cell)
- Some Play-Doh or modelling clay
- Aluminum foil
- Cellophane tape
- A pencil
- A compass

What you should do:

1. Get a piece of aluminum foil that is about 2.5 cm (1 in) wide and about 30 cm (12 in) long.
2. Roll the foil into a "snake" so you have what looks like a thick wire made from aluminum.
3. Use the tape to attach one end of the aluminum foil "wire" to the negative side of the battery (the side that is flat). Make sure the foil presses firmly against the metal on the battery.
4. Put a lump of Play-Doh that is a bit larger than the battery on the table or counter where you are working.
5. Press the battery into the Play-Doh so the Play-Doh holds the battery in place.
6. Use the tape to attach the other end of the aluminum foil "wire" to the pencil.

7. Bring the pencil that has the foil taped to it near (but not touching) the positive end of the battery (the one with the knob on it).
8. Now your foil "wire" should form a "U" shape, starting at one end of the battery and ending near the other end. (See the picture on the left.)
9. Put the compass next to the foil "wire" anywhere along the "U" shape.
10. Looking at the compass needle as much as possible, hold the pencil and use it to bring the foil into contact with the metal on the positive end of the battery. Don't touch the foil to the battery where there is tape on the foil. You need to touch the bare aluminum foil to the metal part of the battery. Notice what happens to the compass needle.
11. Pull the aluminum foil away from the battery while you are watching the compass needle. What happens?
12. Move the compass so it is next to another part of the aluminum "wire" and repeat steps 10 and 11.
13. Repeat step 12 a few more times.
14. Clean up your mess.

What did you see in the experiment? You should have seen the compass needle move when you touched the foil to the battery. When you removed the foil from the battery, the compass needle should have gone back to pointing the way it did before you touched the foil to the battery. As you moved the compass around, you might have found a place where the compass needle didn't move when you touched the foil to the battery. However, for most of the places you checked, the compass needle should have moved.

How can we explain these results? You might already know that the earth has a magnetic field. The needle on a compass is also magnetic, and its attraction to the earth's magnetic field causes the marked end of the needle to point north. However, if you bring a magnet close to a compass, the magnet will attract the needle as well. That's because the strength of the force between two magnets is stronger the closer the magnets are to one another. That means the magnet you bring close to the compass attracts the needle with a greater force than the earth's magnetic field, so the needle moves in response to the magnet instead of the earth's magnetic field.

Since the compass moved when you touched the foil to the battery, that tells you the foil became magnetic. How? Well, when you touched the foil to the battery, electricity ran through the foil. That must have produced a magnetic force, which attracted the compass needle. In other words, your experiment showed that when electricity flows, it produces a magnetic field!

This is what Ørsted noticed when he was setting up for his lecture. The compass just happened to be close to the wire that he connected to the Voltaic pile. He noticed, just like you, that when electricity ran through the wire, it deflected the compass needle. This told him that Johann Wilhelm Ritter was right. There is a connection between electricity and magnetism! Ørsted did a lot of experiments with magnets and electricity running through wires, and he found that when electricity runs through wires, the magnetic force it produces is actually circular! What does that mean? Well, suppose you put a bunch of magnets in a circle on a table. Their needles would all point north. If you ran a wire vertically through the center of the circle and ran electricity through it, the compass needles would move so that they formed a circle! Nowadays, we can make strong magnets with electricity. They are called **electromagnets**, and Ørsted is often credited with discovering electromagnetism.

Hans Christian Ørsted's discovery was a very important contribution to our understanding of electricity and magnetism, but it was also very important for a practical reason. It inspired the work of the next natural philosopher you are going to study, and the result of that work made it possible for us to produce electricity in a very efficient way. If it weren't for that work, you probably wouldn't have electricity in your home!

While Ørsted's discovery was important, I think his views on science and Christianity were more important. He saw a deep connection between his scientific studies and his Christian faith. Indeed, near the end of his life, he wrote a book entitled *The Soul in Nature*. In it, he wrote, "Thus do the truths of Natural Science continually approach nearer those of religion, so that at last both must be united in the most intimate connection." (Hans Christian Ørsted, *The Soul in Nature: With Supplementary Contributions*, Leonora and Joanna B. Horner, trans., Henry G. Bohn 1852, p. 109)

LESSON REVIEW

Youngest students: Answer these questions:

1. Fill in the blank: The earth's ________ field causes a compass needle to point north.

2. What caused the aluminum foil in your experiment to become magnetic?

Older students: Explain what you did in your experiment and what it demonstrated. Then explain what an electromagnet is.

Oldest students: Do what the older students are doing. In addition, explain the shape of the magnetic force made by electricity flowing through a wire.

Lesson 56: Charles Robert Darwin (1809 – 1882)

If you studied the science that was done in the 18th century, you learned about Erasmus Darwin. He was a famous physician, but he was also a great scientist who helped us understand photosynthesis, weather, underground water, and many other aspects of nature. One of his sons, Robert, followed in his father's footsteps, becoming a well-known physician. Robert's fifth child, born in England, was named **Charles Robert Darwin**, who grew up to become one of the most famous (and controversial) scientists who ever lived.

This portrait of Charles Darwin was made shortly after the HMS *Beagle* returned from its journey.

Initially, Charles's father wanted him to follow the family tradition and become a physician. In fact, when Charles was 16, he spent the summer as his father's apprentice. That fall, he enrolled in medical school, but he didn't find his studies very interesting. He eventually transferred to Christ's College in Cambridge to study theology, but he wasn't interested in that, either. Instead, he loved collecting beetles and studying nature. Shortly after he graduated from Christ's College, one of his professors and lifelong friends (a botanist named John Henslow) recommended him for an unpaid position as a naturalist on the HMS *Beagle*, a ship that was planning a trip around the world. Darwin took the position, and it ended up radically changing how he viewed the natural world.

Before Darwin worked on the HMS *Beagle*, he believed what most scientists of the day believed – that the animals they were studying had been individually made by God and had not changed in any significant way since they were created. However, as he travelled around the world, he made many observations that challenged that idea. For example, while studying the wildlife on a series of islands called the **Galápagos** (guh lah' puh gohs), he noticed that the tortoises (turtles that live on land) of the islands had shells of slightly different shapes, and those differences in shapes indicated the island on which they lived.

Each of these tortoises comes from a different island in the Galápagos. Notice how different the shapes of their shells are.

Most scientists of Darwin's day would say those tortoises had each been created separately with that particular kind of shell, but that didn't make sense to Darwin. Instead, he suggested that a long time ago, all of those tortoises were the same. However, since each group lived on a different island, they eventually changed to the point where each group was noticeably different from the rest. In other words, he thought that these different groups of tortoises were originally nearly identical, but over time, they evolved to have several differences, such as differently-shaped shells.

But this idea raised an important question: How could animals do that? How could they change so dramatically? After all, scientists had spent a lot of time studying how animals reproduce, and while each newborn animal was unique, it would not look very different from its parents. When turtles reproduced, for example, the baby turtles would have shells that looked very, very similar to their parents' shells. A turtle like the one in the top picture on the previous page would never have a baby that developed a shell like the one in the bottom picture! Darwin came up with an ingenious answer to this question. Do the following activity so you can better understand his idea.

Natural Selection

What you will need:

- Soft treats like gumdrops, marshmallows, gummy bears, etc. (You need at least a dozen.)
- A plastic spoon that can be ruined
- A plastic fork
- A large, clean serving tray or cookie sheet
- A bowl
- Scissors
- An adult helper with a watch or timer that can read seconds

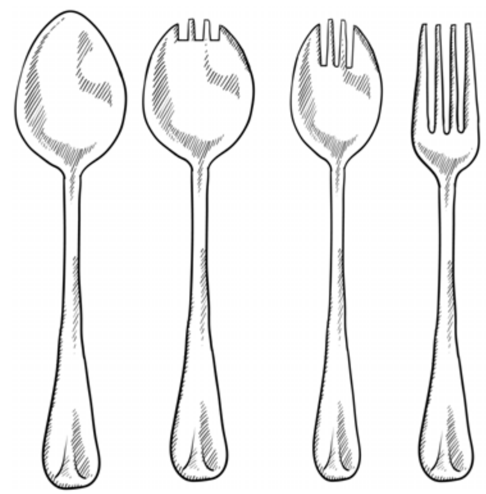
What you should do:

1. Spread the treats out on the serving tray. They should be spread over the entire surface of the tray, and there should be a lot of space between each treat.
2. In a moment, you are going to use the spoon to try to pick up treats one at a time. When you have picked one up, transfer it to the bowl. However, *you can only use the spoon*. You cannot use your other hand or any other part of your body. Once you have gotten the treat on the spoon and pulled it off the tray, you can grab it with your other hand, pull it off the spoon, and put it in the bowl.
3. Have your helper start the timer and tell you to go. He or she needs to stop you in 30 seconds.
4. Pick up as many treats as you can and put them in the bowl over the next 30 seconds.
5. Once your helper has stopped you, count the treats you have in the bowl.
6. Take the treats out of the bowl and put them back on the tray, making it look as much as possible like it did in step 1.
7. Repeat steps 3-5, but this time, use the fork.
8. Compare the number of treats you picked up with the fork to the number you picked up with the spoon. You should have been able to pick up more with the fork, because you could spear them with the fork's tines.
9. Repeat step 6.
10. Have the adult help you use the scissors to cut a triangle out of the end of the spoon. It doesn't have to be neat. You just want to make a couple of jagged points on the end of the spoon.
11. Repeat steps 3-5, but this time use the spoon that you just cut with the scissors.
12. Compare the number of treats you picked up this time to the number of treats you picked up the other two times.
13. Clean up your mess, and eat some of the treats if your parents give you permission.

As I mentioned in your experiment, you should have picked up the most treats with the fork and the least treats with the spoon. However, once you cut a notch out of the end of the spoon, you should have been able to pick up more than you were able to pick up with the spoon at the beginning of your experiment.

Think about the treats as an animal's food, and think about the spoon and fork as the way the animal collects the food. Which would end up resulting in a well-fed animal? The fork, of course! It was able to collect the most food. The spoon with the notch cut out of it would produce an animal that was better fed than the one with the original spoon, but not as well fed as the one with the fork, right?

Now suppose that initially, only animals with a spoon existed on an island. They could pick up some food, but not a lot. Suppose one day that a baby animal was born with a "broken spoon," like the one you had once you cut your spoon with scissors. That baby animal would be better fed than the other animals. It would be stronger and healthier, and if food supplies ever ran short, it would be less likely to starve to death. In short, it would be the most likely version of the animal to survive. When it had babies, it would have babies with the same kind of "broken spoon." Since it is more likely to survive, it is more likely to have babies, so over time, more and more animals with "broken spoons" would exist. Eventually, they would be eating almost all of the available food, which would cause the animals with the "unbroken spoons" to die off. After a long time, only the animals with the "broken spoons" would be left.



This illustration shows how a fork could come from a spoon.

Of course, this process could continue. If another baby animal were born with more breaks in its spoon, that baby would probably be able to get even more food, making it more likely to survive. Over time, those breaks could deepen to the point where the animals had something like a fork with which to pick up their food. That would allow them to get even more food. Over a long period of time, then, the animals that had spoons would be completely gone, and the only animals left would be the ones with the forks.

This is the idea that Darwin came up with. He said that we know there are slight differences which come up between parents and their offspring. Suppose one of those slight differences in a newborn animal made it more likely to survive. Maybe the animal was just slightly faster than the others in the area. It would be able to get to the food more quickly and get away from danger more quickly, so it would be more likely to survive and pass on this new quickness trait to its offspring. From generation to generation, small differences like that might add up to make animals that look very different from the original animal.

Darwin called this process **natural selection**, because he thought nature was "selecting" creatures based on how well they survived. He wrote a book about it, and the short title is *On the Origin of Species*. Many scientists in Darwin's day disagreed with the book's conclusions, because they believed that all the animals they studied were made by God and hadn't changed significantly over time. Darwin's book indicated that many (if not most) of the animals scientists studied had descended from other types of animals, and they were probably quite different from anything that was originally created by God. Indeed, there were even some scientists who said that Darwin's theory indicated that we could explain the life that we see on earth today without ever referring to God. Obviously, then, the book was not only famous, but it was also controversial.

Nevertheless, there were those who really liked the conclusions of the book. Wallace, for example, was very enthusiastic about Darwin's idea. In fact, he and Darwin exchanged ideas frequently, and he had sent Darwin a paper that made an argument very similar to natural selection. When Darwin published his book, Wallace immediately supported it. In addition, some of the scientists who initially didn't agree with Darwin were eventually persuaded by the evidence that Darwin put forth.

One of the more powerful arguments Darwin used to support his idea of evolution by natural selection came from his discussions with people who bred animals for a living. For example, pigeon breeding was popular in his day, and he talked to people who had bred pigeons for most of their lives. They told him that they would choose certain pigeons that had really desirable traits (interestingly-colored feathers, for example) and have them mate and lay eggs. They would then pick the most desirable of the pigeons produced by those eggs and have them mate and lay eggs. They would do this generation after generation and after many generations, the pigeons they eventually got looked nothing like the original parents.

A rock pigeon (top), and one of its descendants, a fantail pigeon (bottom).

Consider, for example, the two pigeons pictured on the left. The one on the top is a wild rock pigeon. The one on the bottom is called a fantail pigeon. Do you know how the fantail pigeon came into existence? Pigeon breeders started with wild rock pigeons and, over time, began selecting baby pigeons that had fancier-looking tails. They would then breed those selected pigeons together. Over many, many generations, the fantail pigeon was produced.

Darwin called this process "artificial selection." The pigeons weren't being selected naturally based on which survived to reproduce. They were being selected artificially based on how they looked. Nevertheless, they ended up evolving. Most people would never guess that the pigeon in the bottom picture is a descendant of the pigeon in the top picture, but it is! Darwin argued that if artificial selection could produce such different pigeons, natural selection should be able to produce incredibly different animals.

Today, pretty much every scientist in the world agrees that Darwin was right about natural selection. In the next lesson, however, you will learn how many scientists take this scientifically-correct idea way too far.

LESSON REVIEW

Youngest students: Answer these questions:

1. What did Darwin call his idea that nature chooses animals based on how well they survive so they can reproduce?

2. (True or False?) Darwin presented strong evidence for his ideas in his book.

Older students: Explain natural selection in your own words. Indicate how Darwin used the experiences of breeders like pigeon breeders as evidence for natural selection. What did he call the process that breeders used?

Oldest students: Do what the older students are doing. In addition, explain why Darwin's view is often called "survival of the fittest." Check your explanation and correct it if it is wrong.

Lesson 57: The Proper Use of Darwin's Theory

This cane toad is part of the population that has been "invading" Australia for more than 80 years now.

Since Darwin published his book more than 150 years ago, scientists have been observing nature to see if natural selection really works, and they have found that it does. For example, back in the 1930s, Australian farmers were trying to grow sugar cane, but it was being eaten by some insects. A government agency decided to help the farmers by bringing **cane toads**, which are from Central and South America, to Australia. These toads are large and eat lots of insects, so the agency thought they would eat the insects that were making it hard for the farmers to grow sugar cane. Unfortunately, the situation didn't go as planned.

Some animals in Australia, like snakes, tried to eat the cane toads, but the toads were poisonous to them. As a result, there was nothing to keep the number of cane toads down, and the population has been increasing at an incredible rate. The toads were brought to the northeast coast of Australia, but because their numbers are growing so rapidly, they are spreading out. Their population has travelled more than 1,500 miles from where cane toads were originally brought!

As scientists have studied this "cane toad invasion" of Australia, they have noticed two very interesting things. First, the cane toads that have moved the farthest west are bigger, faster, and have longer legs than the cane toads that were originally brought to Australia. Second, some snakes in the area where the cane toads are living now have significantly smaller heads than they did prior to the cane toads living there.

Why have the snakes and the toads changed? Think about it. As the toads started to move away from where they were originally brought, the faster ones (which were the bigger ones with the longer legs) travelled farther than the slower ones. When it came time to reproduce, they had to mate with the ones that were in the same area, so the bigger, faster toads mated with other bigger, faster toads. This produced new toads that were even bigger and faster. This happened generation after generation, so the toads that have moved the farthest are the ones that are biggest, fastest, and have the longest legs. That's natural selection in action.

But what about the snakes? Remember, cane toads are poisonous to the snakes that try to eat them. Well, cane toads are fairly big (even the smaller ones), so only snakes with big heads can eat them. Those snakes end up dying when they eat the cane toads, however. The snakes that can't eat the cane toads end up being more likely to survive, so in the end, small-headed snakes are more likely to reproduce, passing on their small heads to their offspring. Over time, small-headed snakes are the only ones left. Once again, that's natural selection in action.

Scientists have studied lots of examples of natural selection in action, so we know that it is a real process happening in nature. As a result, we know that animals change from generation to generation, and often the new version of the animal is noticeably different from the original version. While natural selection is clearly something that God has designed into His creation, most scientists take the idea way too far. To become more familiar with natural selection, do the following activity.

Clay Evolution

What you will need:
- Play-Doh or other modeling clay
- A camera or a pencil and paper for drawing

What you should do:
1. Use the Play-Doh to make a model of an animal. It can be any animal you want (real or imaginary), and it needs to be about the size of your hand.
2. Once you have made your animal, take a picture of it or make a drawing of it.
3. Your task is to make your animal "evolve." You can do so by taking a small amount of clay off of your model, adding a small amount of clay to your model, or reshaping a small part of the animal itself. However, whatever you do has to make your animal more likely to survive. For example, if you added a little bit of clay to each leg, it would be faster, making it more likely to get to the food and get away from danger. If you added a bit of clay to its ears, it might be able to hear better. If you dug out a little clay from where its eyes are to them bigger, it would be able to see better and be more likely to survive. So you need to make a small change that will make the animal better at surviving.
4. Repeat step 3 at least nine more times. You can do it more times if you are having fun.
5. Compare the animal to the picture or drawing you made in step 2. How different is the animal?
6. Take a picture or make a drawing of your "evolved" animal.
7. Clean up your mess.


These are pictures of a lion (top), tiger (middle), and liger (bottom).

How different was your "evolved" animal from your original animal? Depending on the choices you made and how many times you repeated step 3, your "evolved" animal might be very different from your original animal, or it might be very similar but with longer legs, thicker legs, bigger ears, etc. The key to the activity was in doing something that would make the animal more likely to survive. Natural selection will only select those kinds of changes.

Look, for example, at the pictures on the left. The top one is of a female lion. Notice how well she blends in with the golden grass in which she is standing. This allows her to sneak up on her prey. The middle picture is of a tiger. It lives in the forests, and its stripes help it to blend in with the shadows being cast by the forest's trees. Once again, this helps it sneak up on its prey. The bottom picture is of a liger, which is the offspring of a male lion and a female tiger.

These three types of cat illustrate what evolution by natural selection can do. God probably didn't create lions or tigers; instead, He created a single kind of cat. As time went on, those cats began to reproduce, and small changes appeared between the parents and the offspring. When those changes made the offspring more likely to survive, those changes got preserved. This eventually produced cats that could hunt well in the golden grasses of Africa (lions) and others that could hunt well in the forests of Asia (tigers). Lions and tigers, then, probably evolved from the single kind of cat that God created. This is probably true about all the cats we see today.

From the lions of Africa to the pet cats that sleep on our laps, all of them probably came from the original kind of cat that God created.

The liger that is pictured at the bottom of the previous page gives us evidence that this idea is correct, at least when it comes to lions and tigers. That animal has a lion as its father and a tiger as its mother. If lions and tigers can have offspring together, they must be very similar, regardless of how different they look. It makes sense, then, that they are both descendants of one specific created kind.

Here's the important thing to remember: While lions, tigers, and our pet cats are very different, *they are all still cats*. They look different, but they have a lot of similarities. They have similar diets, similar behaviors, and similar chemicals in their blood. This is where some people take Darwin's idea of evolution by natural selection too far. They think that since cats can evolve into different types of cats like lions and tigers, they might eventually be able to evolve into a completely different kind of animal, like a horse. They think that a huge amount of change can occur within a basic kind of animal. As a result, they think that all the living things we see today can be the descendants of a single life form. While the scientific evidence clearly supports evolution by natural selection, it definitely does not support the idea that all the living things we see come from a single life form. Evolution by natural selection simply doesn't produce such huge changes.

Even though Charles Darwin was (and still is) attacked for his theory, he not only helped us understand God's creation better – he helped us understand the Bible better! Have you ever wondered how Noah was able to fit all the animals on the ark? If you look at all the different types of animals we see today, there is simply no way he could have taken two of each (and seven pairs of some) onto the ark. There wouldn't have been enough room. However, he didn't have to take lions, tigers, and other types of cats on the ark. He only needed to take two cats on the ark. Once the cats got off the ark and started to spread out over the world, natural selection would start selecting the traits that made them more likely to survive in the places they ended up living, and that eventually produced lions, tigers, and the other types of cats we see today. The same is true for many animals we see today. Noah only had to take representatives of each basic kind of animal, and all the animals we see today are the result of those kinds of animals evolving by natural selection. Charles Darwin helped us understand that. Unfortunately, many people take this very good scientific idea too far and try to use it to explain all of nature without referring to a creator God. Not only is that unfortunate, it is not supported by the scientific evidence.

LESSON REVIEW

Youngest students: Answer these questions:

1. If an animal is born with a new trait, what must that trait do in order for natural selection to keep it?

2. (True or False?) A pair of lions and a pair of tigers were on the Ark.

Older students: Put your pictures or drawings into your notebook and explain how you went from your original model to your final model. How is this like evolution by natural selection?

Oldest students: Do what the older students are doing. In addition, explain how Darwin's theory helps us understand the Biblical account of the Ark.

NOTE: The experiment for the next lesson requires some setup by the parent/teacher. Read the *Helps & Hints* book before you do the lesson.