Earth Science Student Coursebook

All in One Curriculum

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Objective: The student will research a modern area of astronomical study.

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Objective: The student will examine concerns about overpopulation and urban growth as well as possible solutions to these concerns.

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Lesson 1
The Scientific Method

"No amount of experimentation can ever prove me right; a single experiment can prove me wrong." – Albert Einstein

The scientific method is the name given to the steps we take to investigate a scientific question. In short, we first make an observation about the world. Then we make a guess about it, and perform an experiment to test that guess. Now, let's look at those steps in detail.

Steps of the Scientific Method

1. **Make an observation.**
   Science is all about observing facts and asking questions about them. We want to know how things work and why things happen. The first step in the scientific method is to simply observe something and become curious for an explanation.

2. **Form a hypothesis.**
   A hypothesis is just an educated guess. When we form a hypothesis, we come up with a possible explanation for our observations. It could be right; it could be wrong.

3. **Test the hypothesis with an experiment.**
   The experiment should be designed to disprove the hypothesis. That might seem backwards, but a scientist must figure out the truth by process of elimination.

4. **Record the results.**
   Whether or not the results of the experiment went the way the scientist thought they would, the results are still helpful. Even if the hypothesis is disproved, that causes the scientist to go back and form a new hypothesis which might be more accurate. If the results support the hypothesis, the scientist might then go about testing the hypothesis in another way—in science, skepticism is the rule. It's normal for scientists to repeat steps 2-4 many times before getting a satisfying answer to the original question.

All of that can be a little abstract, so let's try the scientific method on a down-to-earth example. Let's say there's a girl named Jennifer and scientists wonder whether or not she likes the taste of coconuts.

1. The whole time we were in Jamaica together, Jennifer didn't eat any coconuts. (Observation)
2. I'm guessing that Jennifer does not like the taste of coconuts. (Hypothesis)
3. I offered Jennifer a coconut cake. (Experiment)
4. Jennifer refused to eat the coconut cake. (Results)

In this case, the result (the fact that Jennifer refused my coconut cake) supports my hypothesis that she does not like the taste of coconuts. However, it does not prove it. If I firmly conclude that Jennifer does not like the taste of coconuts just because she refused to eat a coconut cake, I'm committing an error because there are too many other variables which could account for the result. This error is called **affirming the consequent**. That will be explained a little later.

Dependent and Independent Variables
One of the more confusing aspects of the scientific method is knowing the difference between independent and dependent variables. Every experiment has a dependent and an independent variable. The independent variable is the thing that is manipulated by the person doing the experiment. The dependent variable changes according to the independent variable. That's why it's called dependent: it depends on the other variable. These usually come together in if/then statements:

If [independent variable] then [dependent variable].

Now, to replace those placeholders with real things:

If I eat too much bacon, I will have a heart attack.

In this case, eating too much bacon is the independent variable, and having a heart attack is the dependent variable. That's because having a heart attack depends on whether or not I eat too much bacon. Notice that the reverse is not true: eating too much bacon does not depend on whether I have a heart attack. The independent variable alters the dependent variable, but not the other way around.

Affirming the Consequent: **Don't do it!**
Affirming the consequent is a **fallacy**, meaning it's an error in logic; it is not a valid way to figure things out. Basically, affirming the consequent means assuming the hypothesis is true just because

The results of an experiment don't contradict the hypothesis. In formal logic, this fallacy expressed like this:

If P, then Q.
Q. Therefore P.

That probably looks vague and confusing, but P and Q are just placeholders for other things; in science, they're the independent and dependent variables. So, let's replace P and Q with real phrases.

Let's say P is "Bob drinks bleach" and Q is "Bob is sick." The statement would then be:

If Bob drinks bleach, then Bob is sick.
Bob is sick.
Therefore, Bob drinks bleach.

Do you see why this is wrong? Even if the first two statements are true (drinking bleach would make Bob sick, and Bob happens to be sick right now) that does not mean that Bob drank bleach. We can't jump to that conclusion because there are many causes of sickness.

Now, let's apply this to the previous example: our hypothesis about Jennifer not liking the taste of coconuts.

In this case, P is my hypothesis, "Jennifer does not like the taste of coconuts" and Q is the predicted result, "Jennifer will refuse to eat my coconut cake." If we plug in those phrases, the statement above becomes:

If Jennifer does not like the taste of coconuts, then Jennifer will refuse to eat my coconut cake.

Jennifer refused to eat my coconut cake.

Therefore, Jennifer does not like the taste of coconuts.

Like the previous example about Bob drinking bleach, this conclusion isn't necessarily correct. Little did the researcher know, Jennifer is actually allergic to coconuts, and that's why she refused to eat the coconut cake.

So remember: don't affirm the consequent (and don't drink bleach).

Lesson Wrap-Up: What does it mean to *affirm the consequent*, and why shouldn't you do it?

Lesson 1
The Scientific Method

Name:______________________________________**Date:**__________________________

Directions: Complete the scientific method worksheet.

The scientific method isn't just for the laboratory; it's used in everyday life.

Part 1: The Broken Car

Observation: My car won't start.

Hypothesis 1 (a guess about why it's not starting):

Experiment to test hypothesis:

Hypothesis 2:

Experiment to test hypothesis:

Part 2: The Mysterious Acquaintance

Next, make an observation about someone you know and fill out the steps of the scientific method. For an example of this, look back at the experiment involving Jennifer and coconuts.

Observation:

Hypothesis 1 (a guess about why it's not starting):

Experiment to test hypothesis:

Hypothesis 2:

Experiment to test hypothesis:

What does it mean to *affirm the consequent*, and why shouldn't you do it?

Lesson 2
The Limits of Science

"I think science has enjoyed an extraordinary success because it has such a limited and narrow realm in which to focus its efforts. Namely, the physical universe." ~Ken Jenkins

Science has certainly answered countless questions about the world, and there are more questions not yet answered which will hopefully someday be answered by science. However, there are some questions which can never be answered by science. This is because science works by taking objective measurements of things. Nonscientific questions, then, are questions that cannot be answered by any empirical measurement.

There are three basic categories of questions which cannot be answered by science.

First, science cannot answer questions of subjective value. An example of this kind of question would be "which dog is the cutest?" Since there is no objective and measurable standard for what is cute, this is not a scientific question.

Second, science cannot answer moral or ethical questions. Ethics and morality are not based on scientific measurements, but on philosophy, religion, and intuition. No matter how much we study the physical world, science can never by itself answer a question about whether or not something is morally wrong. An example of this is the abortion debate. Scientists can point out when the heartbeat or brainwaves begin in a fetus—but scientific facts are not, in and of themselves, moral judgments.

Third, science cannot answer questions about the supernatural. *Supernatural* literally means "above the natural," and since science is by definition the study of the natural world, *supernatural* claims are likewise above science (or if you prefer, outside science). The existence of spirits, for example, cannot be verified by science because we have no means of scientifically studying what is not part of the physical world.

So, science has its limits. However, there are many things which science cannot prove or disprove, science can still help people arrive at nonscientific judgments. For example, the discovery that there is no significant, testable difference in overall intelligence between males and females has helped combat sexism in academia and the workplace.

After reading the above explanation, complete the Limits of Science Worksheet. When you are finished, discuss your answers with your teacher.

Lesson Wrap-Up: Name the three types of questions science cannot answer.

Lesson 2
The Limits of Science

Name: ____

Date: ____

Circle "scientific" or "nonscientific" for each of the questions below to indicate whether or not the given question can be answered by science. Then, briefly give your reasoning for why the question can or cannot be answered by science.

1. Do canaries have teeth? ☐ Scientific ☐ Non scientific

2. Is murder morally wrong? ☐ Scientific ☐ Non scientific

3. Is it better to be a Republican or a Democrat? ☐ Scientific ☐ Non scientific

4. How much acid does a lemon contain? ☐ Scientific ☐ Non scientific

5. What is the best flavor of ice-cream? ☐ Scientific ☐ Non scientific

Lesson 3
Why Study Science?

Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house. ~Henri Poincaré, Science and Hypothesis, 1905

If you wonder why you should care about science, you're in good company. This is an excerpt is from the Great Russian novelist Leo Tolstoy.

> A plain, reasonable working man ...expects science to tell him how he ought to live: how to treat his family, his neighbors and the men of other tribes, how to restrain his passions, what to believe in and what not to believe in, and much else. And what does our science say to him on these matters?
>
> It triumphantly tells him: how many million miles it is from the earth to the sun; at what rate light travels through space; how many million vibrations of ether per second are caused by light, and how many vibrations of air by sound; it tells of the chemical components of the Milky Way, of a new element—helium—of micro-organisms and their excrement, of the points on the hand at which electricity collects, of X rays, and similar things.
>
> "But I don't want any of those things," says a plain and reasonable man—"I want to know how to live. – Leo Tolstoy. In 'Modern Science', Essays and Letters (1903), 221-222.

Many people don't see the need to know much about science because they consider it to be just a bunch of practically useless facts.

However, science is not just a collection of facts and theories. It's also a way of thinking. There are three main reasons to study science: to satisfy curiosity, to help solve the world's problems, and to improve the way we think about the world.

Satisfying Curiosity

Nearly every time a young child learns something new, he or she asks, "why?" If the child receives an answer, sometimes this only leads to more questions—a potentially endless string of why's. One reason people study science, perhaps the very first reason, is curiosity. Though most people don't plan on becoming research scientists as a career path, curiosity is a part of human nature. We, as humans, endlessly search for knowledge.

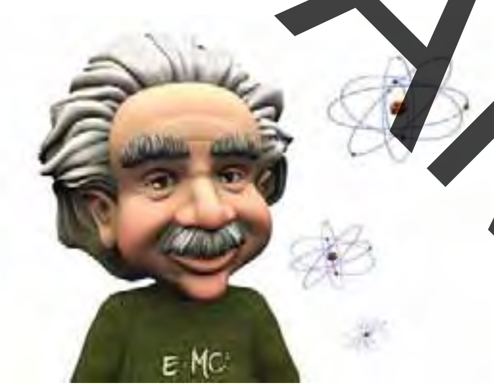
One thing that's especially alluring about science is that, unlike more theoretical subjects like philosophy and psychology, science can offer definite answers. The scientific method measures results in a concrete way, and offers answers that can be verified by others.

Improving Life

Science has enabled us to cure many diseases, purify drinking water, grow food more efficiently, heat and cool our homes--it's made getting everything we need to survive much easier. Not only that; science has also resulted in the invention of countless conveniences like indoor plumbing, quick transportation, computers and the internet, even recorded music and entertainment. The constant advances in standard of living across the globe are due in large part to the continuing advances of science.

Refining Thinking

But what about for those who are not especially curious about how things work and don't plan on being researchers or inventors? Well, Einstein said "The whole of science is nothing more than a refinement of everyday thinking." The skills developed by science are also useful for everyday life.



In other words, the more you learn to think scientifically, the better you'll be able to approach more real-life problems.

Cultivating a scientific mindset will help distinguish fact from fiction. Often, the media reports wild claims based on insufficient evidence, faulty logic, or shoddy research. Such claims can be published for reasons ranging from personal glory to political agendas to selling a product. The more you know about science, the more you'll be able to resist the unsupported nonsense that competes for your attention, support, and wallet.

On the most practical level, you'll need science not only to pass this class, but also in other classes and in higher education.

Lesson 3
Why Study Science?

Name: ____

Date: ____

1. Albert Einstein said that science is just a refinement of what?

2. Summarize Tolstoy's comment about science. What is his apparent opinion of science?

3. What is wrong with Tolstoy's assessment of science? *Hint: look at the Henri Poincaré quote at the beginning of this Lesson.*

4. According to this Lesson, what are the three main benefits of scientific study?

5. Give an example (other than a car that will not start) of how the scientific method could be used to solve an everyday problem. Give an example of how knowledge of science would help keep you from wasting

Lesson 4
Levels of Certainty

"Reasoning must never find itself contradicting definite facts; but reasoning must allow us to distinguish, among facts that have been reported, those that we can fully believe, those that are questionable, and those that are false."
— René-Antoine Ferchault de Reaumur
Memoires pour Servir a l'Histoire des Insectes (1736), Vol. 2, xxxiv. Quoted in Jacques Roger, *The Life Sciences in Eighteenth-Century French Thought,* ed. Keith R. Benson and trans. Robert Ellrich (1997), 16

There are differences between observations, hypotheses, theories, laws, and facts. Each is different, and it's important to know which is which.

After Lesson 2, you should be familiar with the relationship between observations and hypotheses: after one observes something, one comes up with a possible explanation (hypothesis).

A hypothesis becomes a theory if enough evidence is found for it. A hypothesis is purely a guess; one might come up with many hypotheses that explain the same observation. A theory is a more established explanation with support from evidence, fleshed out with related concepts to form a more full explanation of something.

Evolution is one example of a theory. It is more than a hypothesis because it is not just an arbitrary guess; it explains many separate observations and attempts to offer a comprehensive explanation for how life came about on earth.

A law is a general rule that describes a whole body of observations about something. In order for something to be a law, what the law describes has to be observed over and over again without any observation contradicting the law. There must be no known circumstance in which it is not true. In other words, a law basically says "given such-and-such conditions, thus-and-so always happens, and as far as we know there are no exceptions." A good example of this is gravity. If you hold your pencil in the air and then let go, it will accelerate downward unless some other force interferes with it. This will be the case no matter how many times you do it. Our explanation of the force of gravity upon an object is completely predictable because no one has ever observed an exception. So, we call gravity a law.

An important thing about laws is that they do not answer "why" questions. Sir Isaac Newton was never able to explain why gravity occurs. Even today, scientists haven't totally figured it out. Laws simply describe what consistently happens.

Lastly, a fact is a specific and provable truth. It's not any kind of guess, principle, or explanation. It's a specific, undisputed statement about a specific thing, like "dogs have ears" or "George Washington was the first US president." In science, facts and observations are basically the same thing.

Now, complete the Levels of Certainty Worksheet.

Lesson Wrap-Up: Give an example of each: observation, hypothesis, theory, law. The examples should not be from this text.

Lesson 4
Levels of Certainty

Name: ____

Date: ____

For each statement below, write whether the statement is an observation, hypothesis, theory or law.

1. She winked at me. ____________________
2. She thinks I'm cute. ____________________
3. Life came about through evolution. ____________________
4. Force equals mass times acceleration. ____________________
5. The earth is billions of years old. ____________________
6. Water always boils at 212 degrees Fahrenheit. ____________________
7. The universe is expanding. ____________________
8. My laundry came out with white spots. ____________________
9. This old onion will grow if I plant it in dirt. ____________________
10. Perhaps that fish made me sick. ____________________

Lesson 5
Chapter 1 Quiz and Discussion

Name: ______________________________________

Date: ____

1. Name and explain the four steps of the scientific method.

   a)

   b)

   c)

   d)

2. What is a fallacy?

3. What is the following fallacy called?

   If Bob drinks bleach, then Bob is sick.
   Bob is sick.
   Therefore, Bob drinks bleach.

4. In the above example, why is it bad logic to assume Bob drinks bleach?

5. What three types of questions cannot be answered by science?

6. Give an example of a question that cannot be answered by science.

7. Albert Einstein said that science is a refinement of what?

8. According to Lesson 3, what are the three main benefits of scientific study?

   a) ______________________________

   b) ______________________________

   c) ______________________________

9. Give an example of how you could use the scientific method to solve an everyday problem.

10. Is the following statement a hypothesis, theory or law?

    An object at rest will stay at rest unless acted upon by an outside force.

11. Is the following statement a hypothesis, theory or law?

    The earth is billions of years old.

12. Is the following statement a hypothesis, theory or law?

    Based on the sound on the roof, it must be raining outside.

Lesson 6
Earth: A Closed System

An Interdisciplinary Science
Earth science is one of the broadest physical sciences; it's a little bit of everything. Earth science can be broken down into many more specific sciences: geology is the study of the solid, inorganic parts of the earth, including everything from sand and rocks to mountains to the earth's innermost core. This is probably the first topic most people think about when they hear the phrase "earth science." However, earth science includes many other subjects.

Environmental science studies how to best care for the environment. This includes figuring out how to best manage resources, how to limit and clean up pollution and trash, and how to make sure we don't unintentionally damage our planet. Recent discussions about pollution and climate change have made environmental science one of the most active branches of earth science, and perhaps the branch that the general public is most concerned with.

Oceanography and hydrology explore the waters on earth and everything in them, including the vast array of life in the ocean.

Atmospheric sciences study the atmosphere: what it's made of and how it behaves. One atmospheric science we can appreciate on an everyday basis is meteorology, the science that allows us to measure atmospheric conditions to predict the weather.

These are only a few examples, and each of these sciences could be broken down further into more specific disciplines, some of which will be touched on in later Chapters.

System Classifications

Scientists refer to the earth as a closed system. What does that mean? Well, there are three types of systems: open, closed, and isolated. An open system is **permeable** to both matter and energy, meaning matter and energy can move in and out. A closed system is permeable to energy but not matter, and an isolated system is permeable to neither.

Open Systems

In an open system, both matter and energy can go in and out. Most things in our everyday experience are open systems. Your own body is an example of an open system. Both matter and energy move in and out. You gain matter when you eat or drink and lose it when you use the bathroom. You also gain and lose energy from food as well as heat. A house, a car, or any plant or animal--all these are open systems.

Closed Systems

In a closed system, matter cannot go in or out. Only energy is transferred. An example of this could be a sealed glass jar. Matter cannot go in and out, but as the temperature of the jar changes, thermal energy goes in and out.

The earth is considered a closed system. It is not an isolated system because the earth absorbs energy from the sun. But it is not an open system because matter does not enter or leave earth. Earth absorbs radiation from the sun and emits radiation back into space.

Of course, strictly speaking, matter does pass in and out of the earth's atmosphere. Meteorites make it to earth every day, and the our exploration of space removes matter from earth. For example, the launch of space shuttles leaves debris in space. The Mars Rover, though it may not weigh very much, its mass is from earth and is now on Mars. So, matter does go in and out of earth, but it's not very much matter. Most meteorites that hit earth are tiny. Even large masses like space stations are not at all significant when compared to the overall mass of earth. So, while earth is not technically a closed system, it's close enough that's it's helpful to think of it that way.

Isolated Systems

In an isolated system, neither matter nor energy move in or out. It is totally separated from everything around it. A true isolated system is only theoretical, because nothing in our experience is totally isolated from all other matter and energy. There are, however, things that are practically isolated systems. One example would be our solar system. The solar system is not technically an isolated system because, for example, sun is subject to the gravitational pull of other stars in the galaxy. However, when we are examining the solar system itself, it does not appear to be affected by outside forces in any significant way.

We sometimes call the universe an isolated system, but that's only because the universe is the word we use for "all matter and energy we can observe." It's isolated because, by definition, there is no matter or energy outside of it.

It's also important to remember that these terms are in the context of the study of physics. In other contexts, like computer science or business, open and closed systems have other meanings.

When you have finished the above reading, complete the Open and Closed Systems Worksheet. When you are finished, confirm your answers with your teacher.

Lesson Wrap-Up: Name some of the subjects included in earth science. Explain why the earth is considered a closed system.

Lesson 6
Earth: A Closed System

Name:_______________________________________**Date:**_______________

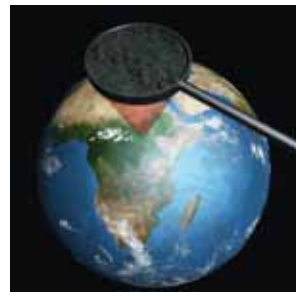
Name some of the subjects included in earth science. Explain why the earth is considered a closed system. Write whether each of the items below is an open or closed system.

1. A glass jar with an airtight seal. ____________________
2. An apple tree. ____________________________
3. A car. ____________________________
4. A college dormitory. ______________________________
5. A battery. ___________________________________
6. A light bulb _________________________________
7. The ocean. _________________________________
8. A spacesuit. _________________________________
9. A gas station. _________________
10. A dog. ________________

Lesson 7
The Four Spheres

As you learned in the previous Lesson, earth science is an interdisciplinary science that covers many aspects of our planet. Though there are many sciences, the study of earth is the study of four main systems, which are called spheres. These systems are: the geosphere, the atmosphere, the hydrosphere, and the biosphere.

Geosphere
The geosphere includes all of the solid parts of the earth's crust and interior, including soil, rocks, minerals, and the earth's mantle and core.



How the geosphere interacts with other systems:
The geosphere is shaped by all the other spheres. Rocks are broken down by a combination of wind, water, plants and even bacteria. The broken down materials then form soils and sediments. In this way, earth's other systems contribute to the rock cycle. This is one reason why Earth Science is so broad. As soon as you start to study geology, you realize how many other aspects or science are involved to explain how rocks form and change.

Atmosphere
The atmosphere is the layer of gasses surrounding the earth.

How it affects other systems:
While earth is not the only planet with an atmosphere, earth's atmosphere is unique in its ability to support life. The air is full of both oxygen and carbon dioxide to support plant and animal life. It lets in plenty of sunlight while filtering out most of the sun's harmful radiation. The atmosphere also carries water from one place to another, spreading the hydrosphere across the land through precipitation to nourish the biosphere.

Hydrosphere
The hydrosphere is composed of all the water on earth. Water is what sets earth apart from other planets in the solar system. Oceans and seas alone cover more than 2/3 of the earth's surface. There are also rivers and streams connecting them and water underground. Depending on the region, water also saturates the soil and the air. If the earth were somehow flattened--all the mountains knocked down and holes filled in so that the earth was one flat ball--the earth would be entirely covered by water 8,200 ft deep (that's over 1.5 miles deep, or six and a half empire state buildings stacked on top of one another!).

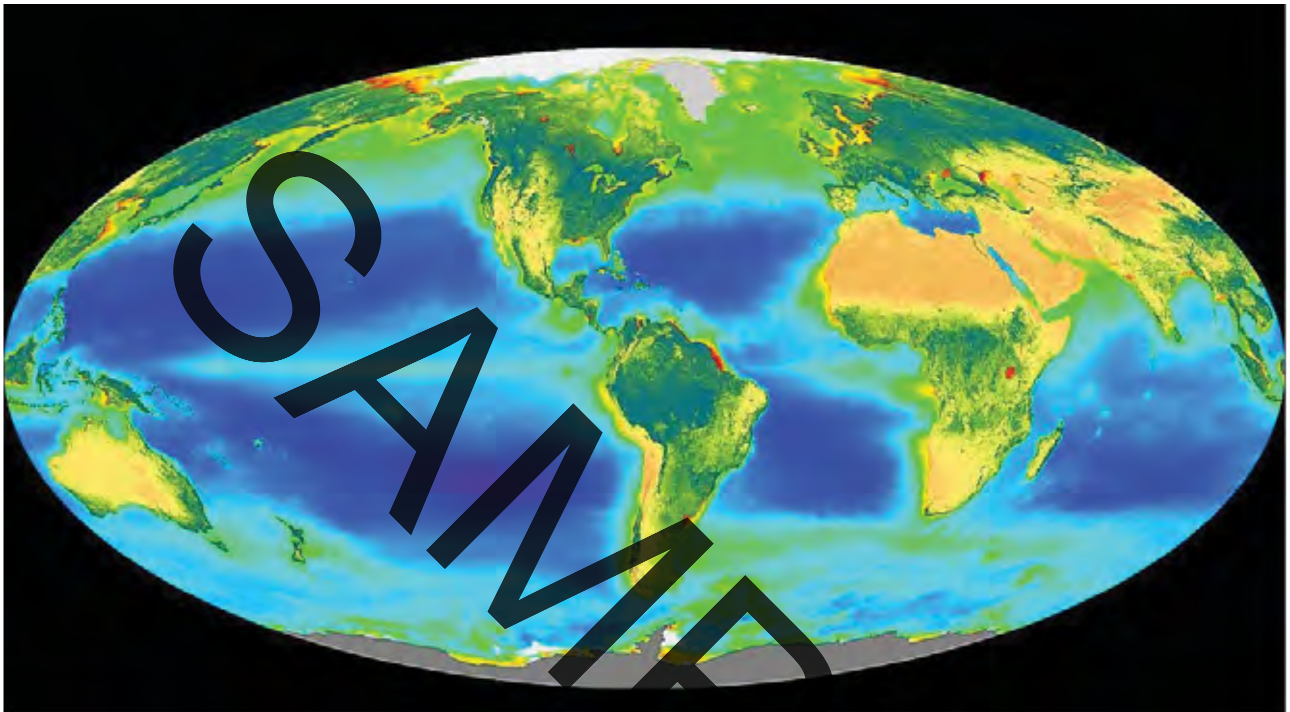
How it affects other systems:
The presence of water almost everywhere on earth gives a clear example of just how connected the four spheres are. There is groundwater in the geosphere, not only in the topsoil but deep beneath the earth's surface as well.

Our atmosphere is full of water. Sometimes we can see it as clouds, fog, and precipitation. Sometimes we can feel it: humidity, which is just another word for the amount of water in the air around us, is responsible for that hot and sticky feeling on summer days.

The human body is mostly water (somewhere between 50 and 80% depending on the person) and we humans need to consume about two liters of it on a daily basis just to avoid dehydration, and even under the most ideal conditions, anyone will die within one week without water.

The oceans also regulate the earth's climate, which you will learn about more in a later Chapter.

Biosphere
The biosphere is the collection of all life on earth. Since we have not yet found signs of life anywhere beyond earth, the biosphere includes all life that we currently know of: microorganisms, plants, animals, and human beings.



How the biosphere affects other systems:
Plants take carbon dioxide, a compound useless to animals and humans, and release oxygen into the air. Without the way plants interact with the atmosphere, we'd all asphyxiate.

Some bacteria create gas when they break down living matter; this is responsible for the bad smell given off by rotting things. Plants also shape geosphere by breaking down rocks. Sometimes this is a problem for humans when vines and roots damage the structure of buildings. Of course, we humans are part of the biosphere, and our behaviors affect all the systems of earth in many ways; some of these will be covered in Lesson 9.

Complete the Spheres of Earth and Sphere Interaction Worksheets.

Lesson Wrap-Up: Ask the teacher any questions you may have about how the four spheres relate to each other.

Lesson 7
The Four Spheres

Name: ____

Date: ____

Spheres of Earth Worksheet

In the blank provided, write which sphere each item belongs to: geosphere, atmosphere, hydrosphere or biosphere.

1. A rock. ____________
2. Dirt. _______________
3. A rosebush. _____________
4. Oxygen in the air. ________________
5. The Nile River. __________________
6. A pizza. ________________________
7. A volcano. _____________________
8. A rain puddle. __________________
9. A garden. ________________
10. Clouds. ____________________
11. The Indian Ocean. _______________
12. The ozone layer. ____________________

Sphere Interaction Worksheet

Using examples from the reading above or from your own thoughts, answer the questions below.

1. Give an example of how the geosphere and atmosphere interact.

2. Give an example of how the geosphere and hydrosphere interact.

3. Give an example of how the geosphere and biosphere interact.

4. Give an example of how the atmosphere and hydrosphere interact.

5. Give an example of how the atmosphere and biosphere interact.

6. Give an example of how the hydrosphere and biosphere interact.

Lesson 8
Ecology

Ecology is the study of the environment as it relates to living organisms. Though it relates to earth science, it is technically a subdivision of biology. However, ecology is broader than most aspects of biology; while biology tends to study the specific characteristics and processes of individual living things, ecology studies how organisms are adapted to their environment and how they are distributed across that environment.

If there's one word that describes life on earth, it's *variety*. There are 1.4 million known species on earth, of which humans are only one. If you took only five seconds to look at each one, it would take 67 years just to see them all! About 250,000 species are plants. Half of the species on earth (750,000) are insects, and 300,000 of those are beetles. Without insects, most plants and animals on earth would be extinct within one year. It is said that J.B.S. Haldane, a well-known British biologist and geneticist was once asked what one might be able to tell about the creator of the world from what Haldane had studied of creatures on earth. His reply was that the creator exhibits "an inordinate fondness for beetles."

Life on earth has been found at temperatures as cold as -41 degrees Fahrenheit and as hot as 235 degrees. At these temperatures, humans and most animals we know of would be frozen solid or cooked alive. Yet, life on earth is diverse enough that some life forms thrive even under such conditions.

Populations of various forms of life are held in a delicate balance, and a change in the population of one thing affects other things that share the same space. For example, individual grasshoppers are relatively harmless, but there are many instances of grasshoppers (locusts) destroying entire crops, causing the people who relied on those crops to face hunger and even starvation. The problem comes when there are too many in a given area.

One important term in ecology is biodiversity: the level of diversity, or variety, in biological life in a certain area. Biodiversity helps protect against ecological disasters. One famous example is the potato famine in Ireland (also called the Great Famine) between 1845 and 1852. During that time, the people of Ireland relied heavily on potatoes as their main food source. When a blight swept over the crops--a particular fungus that rotted potatoes--a large portion of Ireland's food source was ruined. As a result many Irish people starved to death or died of disease due to malnutrition.

This illustrates the importance of biodiversity. Disasters like this are far less likely when multiple crops are cultivated; they won't all have the same vulnerability.

Extinction is a growing threat to biodiversity. Though scientists are not yet agreed on the exact numbers, extinction of plants and animals seems to be occurring at a much higher rate than usual, perhaps higher than at any other time in history. Though extinction is not exclusively the fault of human activity, destruction of habitats by human activity is a major contributor to the extinction of many species.

There are a few cases in which humans have intentionally caused extinction. The Smallpox virus, responsible for so many deaths all across the globe, is now extinct due to the widespread distribution of the vaccine. The last naturally occurring case was in 1977. Since then, the virus only exists in a few labs for research purposes.

When you have finished reading the above material, complete the Ecology Comprehension Check.

Lesson Wrap-Up: Explain what ecology is without reading from the text.

Lesson 8
Ecology

Explain what ecology is without reading from the text.

1. How many known species are on the planet earth?

2. A prominent biologist noted that there was an unusually high number of species in what order (category)?

3. What are the most extreme temperatures at which life been found on earth?

4. The study of the environment as it relates to living things is called what?

____

5. Humans have caused the intentional extinction of what organism? ____________________

6. What disaster in Ireland was partially caused by lack of biodiversity? __________________

7. What seems to be happening at a higher rate than usual as a result of human activity?

Lesson 9
Humans and the Biosphere

Gaia Hypothesis

The biosphere is one complex, interacting system in which forms of life rely on other forms of life for survival. Because of this, the earth can be thought of almost as a single organism with different parts that work together. This idea is called the *Gaia Hypothesis*.

Of course, the Gaia hypothesis doesn't suggest that the earth or "mother nature" is actually a single life form--but that it is so interconnected that it acts like one. Consider the way the various systems in our own bodies work together. If any number of vital systems failed, the whole body would die. It is only by working together that each part is able to function. Similarly, the entirety of life on earth acts together as one balanced system.

One of the clearest examples of this is the way plants increase the level of oxygen in the air. Instead of competing for oxygen with animals and humans, plants instead absorb carbon dioxide, which is useless to humans, and release oxygen into the air.

Without plants, we would run out of air. Why? Oxygen is one of the most reactive elements in the atmosphere, second only to fluorine. This means that oxygen combines with other gases and minerals easily. Once oxygen has combined with another substance, we can no longer breathe it. Water contains an oxygen atom (that's the O in H2O), but you can't breathe water. Even fish only filter loose oxygen out of the water; they don't break down the H2O molecule. If plants did not release oxygen into the air, the level of oxygen in the atmosphere would decrease.

Through the chemical process we call respiration, animals absorb oxygen and produce carbon dioxide. If there were only animals, all the oxygen would get used up. Plants absorb carbon dioxide and produce oxygen. Life on earth is so perfectly balanced that animals and humans have all the oxygen we need and plants have all the carbon dioxide they need. Because of the presence of both forms of life, the total amount of oxygen and carbon dioxide in the atmosphere never changes.

Fruit bearing plants create seeds inside of food we eat. The sugars, proteins and other nutrients in fruit sustain animals, and taking the fruit helps spread the seeds, either through animal waste, or even by a person simply picking an apple off a tree and tossing the core somewhere else. Other plants spread their offspring with a type of seed called a bur that sticks to clothes and fur as people and animals pass by.

The Lonely Humans

Are humans the dominant form of life or earth? It depends how we decide to measure dominance. Humans are by far the smartest creature on earth. Human intelligence has given us the ability to create tools and engineer solutions that afford us dominion over plants and animals.

Still, when studying the biosphere, it's important to keep in perspective how small humans are. Humans are certainly not the largest creatures, nor the most physically capable. Many animals have us beat in that department. Most humans would not want to pick a fight with a lion, a shark, or an elephant. Even a big dog will put up a good fight against a bare-knuckled human.

Humans are not the most abundant life form on the planet either. Compared to other forms of life on earth, humans are a relatively rare creature. In terms of sheer numbers, the most abundant life on the planet is bacteria. Scientists estimate that the earth contains approximately 5 x 10^30 cells of bacteria. That's 5,000,000,000,000,000,000,000,000,000,000 or five trillion-billion-billion. There are more bacteria in your own body than there are human cells.

You might think there wasn't much life at the ocean floor, where it's cold, dark, and the pressure is very high. But bacteria thrive there, too. The seafloor can contain as many as 10 billion bacteria per milliliter. Bacteria have even been found almost 3,000 feet below the seafloor, where no oxygen can penetrate. The bacteria there are anaerobic, meaning they do not require oxygen to survive.

One reason humans can still be considered the dominant species of earth is that no other creature comes close to us in intelligence. Even apes, who share most of our genetic code, only reach the approximate intelligence of toddlers. As far as we know, no species other than humans are capable of artistic expression or abstract reasoning. And while humans come in many shapes and colors, we're all the same species, and no other creature comes even close.

Lesson 9
Humans and the Biosphere

Name: ____

Date: ____

Comprehension Check

Complete the comprehension questions.

1. The idea that the whole biosphere behaves like one organism is called what?

2. In your own body, human cells are outnumbered by what?

3. In your own words, why would we run out of oxygen without plants?

4. Judging by pure quantity, what is the most abundant form of life on earth?

5. How many species of humans are there? ________________________________

6. Describe two ways plants use animals to spread seeds.

7. Are there any forms of biological life on earth that don't require oxygen?

Lesson 10
Landform Vocabulary

The surface of earth is more varied and interesting than that of any other planet. If you've ever seen pictures of the surface of mars, you know it looks like one vast, boring desert. The other planets, as far as we know, seem to be dead masses of gas and rock. The earth, on the other hand, is full of variety. Because of the variety of landforms on earth, we have names for many of the different shapes and types of land on earth.

Lesson 10
Landform Vocabulary

Perform an internet image search for each of these landforms below. From the pictures, write a short description of what you think the word means. After you have finished guessing the definitions for each word based on pictures, your teacher will read the actual definition of each word. Record the definition and compare it to yours.

Basin:

Canyon:

Cape:

Cay (or key):

Cliff:

Delta:

Dell:

Desert:

Divide:

Forest:

Glade:

Hill:

Isthmus:

Jungle:

Mountain:

Peninsula:

Plain:

Plateau:

Prairie:

Rainforest:

Savannah:

Tundra:

Valley:

Volcano:

Landforms Worksheet

Answer the following questions

1. What's the difference between a plain and a plateau?
2. Which is larger, a gulf or a bay?
3. What's the definition of a desert?
4. Are all deserts hot?
5. How is a jungle related to a rainforest?
6. What's the difference between an isthmus and a peninsula?
7. How is a savannah different from a prairie?

8. What's the difference between a canyon and a cliff?

Lesson 11
Land and Water Vocabulary

Name: ____

Date: ____

Two thirds of the earth's surface is covered in water. Just as there are many names for types of land, there are also many names for bodies of water or land shaped by water. In this Lesson, you will learn the names of many types of water forms and water-related landforms.

Perform an internet image search for each of these landforms below. From the pictures, write a short description of what you think the word means. After you have finished guessing the definitions for each word based on pictures, your teacher will read the actual definition of each word. Write down this definition and compare it to yours.

Archipelago:

Atoll:

Bay:

Bayou:

Brook:

Canal:

Channel:

Coast:

Cove:

Glacier:

Gulf:

Island:

Lagoon:

Lake:

Marsh:

Oasis:

Ocean:

Reef:

River:

Sea:

Shoal:

Spring:

Swamp:

Tributary:

Waterfall:

Lesson 11
Land and Water Vocabulary

Name:____**Date:**_______________

Land and Water Worksheet

1. Which of the following is man made by definition? Lake, brook, canal.
2. Rank from wet to dry: lagoon, marsh, jungle, prairie, and desert.
3. An atoll is a type of what landform?
4. What's the difference between a marsh and a swamp?
5. What's the difference between a lake and a sea?
6. A small cave in the side of a cliff or mountain is called what?

7. What's the difference between a sea and a lagoon?

8. An archipelago is a collection of what?

Lesson 12
Chapter 2 Quiz and Discussion

Name: ________________________

Date: _________________________

1. Is a sealed glass jar an open, closed or isolated system?

   ____

2. Is the human body an open, closed or isolated system?

   ____

3. Is a battery an open, closed or isolated system?

   ____

4. How many known species are on the planet earth?

   ____

5. A prominent biologist noted that there was an unusually high number of species in what order (category)?

6. What are the most extreme temperatures at which life been found on earth?

   ____

7. The study of the environment as it relates to living things is called what?

____

8. Humans have caused the intentional extinction of what organism?

____

9. What disaster in Ireland was partially caused by lack of biodiversity?

____

10. What seems to be happening at a higher rate than usual as a result of human activity?

11. The idea that the whole biosphere behaves like one organism is called what?

12. In your own body, human cells are outnumbered by what?

____

13. In your own words, why would we run out of oxygen without plants?

14. Judging by pure quantity, what is the most abundant form of life on earth?

15. Describe one way plants use animals to spread seeds.

16. Which is larger, a gulf or a bay?

17. What's the definition of a desert?

18. Are all deserts hot?

19. How is a jungle related to a rainforest?

20. What's the difference between an isthmus and a peninsula?

21. What's the difference between a canyon and a cliff?

22. Which of the following is man made by definition? Lake, brook, canal.

23. Rank from wet to dry: lagoon, marsh, jungle, prairie, desert.

24. An atoll is a type of what landform? ________________________

25. What's the difference between a marsh and a swamp?

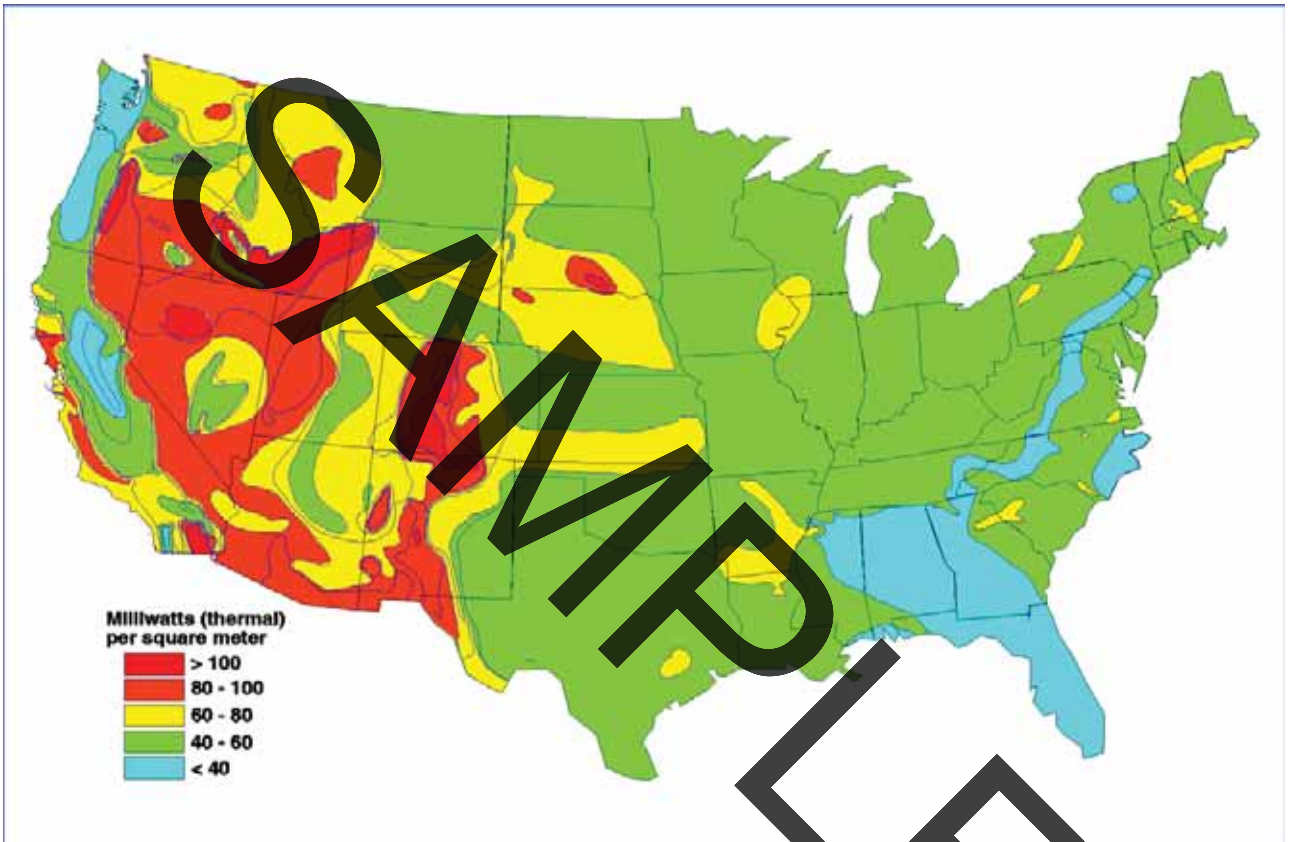
26. What's the difference between a sea and a lagoon?

27. In your own words, what makes humans a unique species? In what ways are we "dominant"?

28. Explain why earth science includes so many different sciences

Lesson 13
Types of Energy

The earth and objects on it have three main sources of energy: gravity, the sun, and geothermal energy from radioactive decay.



W kimedia Commons - Geothermal Energy Map

Geothermal Energy and Radioactive Decay
Geo means earth, thermal means heat, so geothermal means "earth heat." Geothermal energy is the warmth emitted by the earth's mass, especially from deep inside the earth. The very center of the earth is thought to be warmer than the surface of the sun, or somewhere between 7000 and 13000 degrees Fahrenheit, though we don't have a way to actually measure that deep.

Radioactive Decay is the main source of geothermal energy. As complex elements decay into more stable ones, they shed energy in the form of heat. The center of the earth is full of very dense elements which give off plenty of heat as they decay.

Solar Energy
Ultimately, most of earth's energy comes from the sun. We receive radiation from the sun. About 30% is reflected back into space. Some is absorbed by clouds, which warms the atmosphere. About 50% makes it to the earth's surface (the land and ocean). Some is used for solar power. Some is used by plants, which in turn is used by animals, including ourselves.

Lesson 13
Types of Energy

Name: ___________________________________

Date: ____________________________________

1. Ultimately, most of the earth's energy comes from what source?

2. After being filtered through the atmosphere, how much of the sun's energy reaches the earth's surface? __________

3. What is the estimated temperature range for the center of the earth? ________________

4. Why don't we know the exact temperature of the center of the earth?

5. What does "geothermal" literally mean? _________________

6. What is the main source of geothermal energy?

7. Briefly explain the process of radioactive decay in your own words.

Lesson 14
Gravity

Another source of energy on earth is gravity. Simply put, the higher something is off the ground, the more energy it has due to gravity. This is called gravitational potential energy. If you put a book on a desk, it has gravitational potential energy. If you slide it off, that energy is released as gravity pulls it to the earth. As things fall, they accelerate at a rate of about 9.8 m/s^2, meaning its speed increases every second by a rate of 9.8 meters a second.

That might be confusing, so let's use an example. Imagine dropping a watermelon from the top of the Empire State Building, which is about 381 meters tall. To make the example easy to understand, we'll ignore air resistance, which slows down falling objects on earth.

The starting velocity is of course zero, because you are holding the watermelon and it isn't moving. After you let go, one second later the watermelon would be traveling downward at a speed of 9.8 m/s, and this speed will increase by another 9.8 m/s every second that passes. So, after ten seconds, the watermelon would be traveling at a rate of 98 meters per second. That's 219 miles per hour!

Now the formula to figure out how far an object will fall in a certain number of seconds or how long it would take to hit the ground from a certain height is a bit more complicated, and better suited for a physics class. For now, simply think about this in terms of energy on earth: gravitational potential energy (GPE) is transferred into motion, which we call kinetic energy. The more GPE it gives up (in height above the earth), the more kinetic energy it gains (in speed it's traveling). This continues until the watermelon smashes on the ground, transferring its kinetic energy into the ground.

When it's halfway to the ground, part of its energy is GPE and part is kinetic. That's because what it has lost in GPE by falling it has gained in kinetic energy (motion). Just before it hits the ground, virtually all its energy will be kinetic and its GPE will be spent.

Of course, there are more useful applications of gravitational potential energy than smashing produce on the ground. Gravitational energy is used to keep satellites in orbit (including the moon), to help food move from your mouth to your stomach, and to keep you from floating to the certain doom of outer space every time you jump. Gravity holds the earth's atmosphere in place, giving us air and rain. As forces go, gravity is not very strong, but without it, life on earth would be impossible.

Homework Required: Finish the Worksheet for homework if you need more time after the Lesson.

Lesson Wrap-Up: Explain the relationship between kinetic energy and gravitational potential energy.

Lesson 14
Gravity

Name: ____

Date: ____

Complete the following:

1. Name three ways you might die if there was suddenly no gravity on earth.

2. What's another term for energy of motion?

3. Does an object higher off the ground have more or less GPE than a lower object?

4. The type of energy an object has due to its position above the earth is called ____, abbreviated ________.

5. A still object suspended high in the air has plenty of ________________________ energy and no _______________________________ energy.

6. An apple falls off a tall tree. Just before it hits Isaac Newton's head, most of its energy is ____________________________ energy and almost none is ___________________________ energy.
7. Aside from gravity, the other two primary sources of energy on earth are what?

Lesson 15
Energy Renewal

We use energy on earth from a variety of sources for many things, like electricity, heat, and transportation. Energy sources can be divided into two groups: renewable and nonrenewable. Renewable energy sources are sources which are naturally replenished over time. Nonrenewable resources do not naturally replenish fast enough to match how quickly we use them, which means we will eventually run out.

Note that whether an energy source is renewable or not does not automatically mean it is good or bad for the environment. With nonrenewable resources, the main concern is running out of them. As of 2008, about 19% of the energy used worldwide is renewable. The rest is nonrenewable. In this Lesson, we'll briefly go over examples of both categories.

Non-Renewable Sources

The biggest sources of non-renewable energy are fossil fuels. Fossil fuels include petroleum (which is processed into oil and gasoline, among other things), natural gas, and coal. These are all naturally occurring substances which release plenty of energy when burned. These all come from ancient plants and animals which died, were buried and processed inside the earth.

You might think fossil fuels should be considered renewable because new plants and animals die every day. However, it would take millions of years for something that died today to become fossil fuel. The earth cannot possibly replace fossil fuels nearly at the rate we currently use them, so they are considered non-renewable. In this way, whether something is renewable depends not only on the properties of the energy source, but on how much we use it.

Nuclear energy is also non-renewable. It relies on harnessing Uranium, a naturally-occurring element in the earth, which will eventually run out.

Wind Power

Wind can also be harnessed for energy. Wind power is by no means new; boats have long used sails to catch wind to push them along, and windmills use the wind's motion to spin the turbine and grind grain. Recently, wind has become a more viable source of commercial electricity. Like windmills, turbines are used to create mechanical energy from wind, but this can be used to produce electricity instead of grinding grain.

Hydropower

Hydropower works on a similar principle to wind power; flowing water is used to turn a turbine which powers a generator. Since water is about 800 times denser than air, plenty of energy can be obtained from a body of water even if it isn't flowing very fast. Hydropower accounts for the largest amount electricity we currently get from renewable sources. Hydropower is most often harnessed by dams, which block the water and use its pressure to turn a turbine.

Solar Energy

The sun sends about 3,850,000 exajoules of energy to earth every year. This is more than the total amount of energy that could be obtained from all the non-renewable resources currently on earth. This makes it one of the most promising sources of energy for the future. Solar panels capture photons (light particles) which knock electrons into a higher state of energy, causing electricity. This is called the *photovoltaic effect*. Research is still being done on how to best harness solar energy, and though its future is promising, it's not yet a major source of commercial electricity, even compared to other forms of renewable energy.

At Nellis Air Force Base in Nevada, 70,000 solar panels are linked together in an array that can generate 15 megawatts of electricity for the base. Photo credit: U.S. Air Force.

Biomass and Bio-fuel

Biomass and bio-fuel refer to the use of plant and animal matter for power. Unlike fossil fuels, bio-fuel is made from recently dead organisms. It is a renewable source because we don't have to wait millions of years before the mass is used for energy. One of the most well-known uses of biomass for energy is burning wood and dead plants for heat and light. Rotting garbage also produces methane gas which can be gathered and used as fuel. Some crops like corn and sugarcane are fermented to produce alcohol which can then be used as a flammable fuel. Bio-diesel is fuel made from oils and fats from plants and animals.

Geothermal Energy

Geothermal energy is derived from hot water or steam pumped from the earth's hot core. Since heat engines are not very efficient, much of the heat goes to waste.

However, since the earth provides a practically endless supply of thermal energy, efficiency is less of a concern than it would be for a machine that consumes fuel. Once a geothermal power plant is built, it is relatively easy to maintain.

However, they are expensive to build and have been historically limited to areas where the earth's inner heat comes closer to the surface.

Homework Required: Investigate whether the energy for your house is renewable or nonrenewable. You may have to call your power company or visit its website. Write down your findings and bring them to the next Lesson.

Lesson Wrap-Up: Without referring to the reading, explain the difference between renewable and nonrenewable energy.

Lesson 15
Energy Renewal

Name: ______________________________

Date: _______________________________

1. Complete the following questions

2. Define renewable energy source.

3. Define nonrenewable energy source.

Write renewable or nonrenewable next to each energy source.

4. Solar power ____________________
5. wind power ____________________
6. hydro power ____________________
7. biomass ____________________
8. coal ____________________
9. petroleum ________________

10. natural gas ______________

11. nuclear power ______________________

12. What's the biggest source of non-renewable energy we use?

13. What's the biggest source of renewable energy we use?

14. Coal, petroleum and natural gas are all referred to as what category of energy source?

Lesson 16
Heat Transfer

Heat is the movement of thermal energy from one thing to another, changing an object's temperature as the energy moves. Heat is transferred through three processes: conduction, convection, and radiation. Let's take a look at them one at a time.

Conduction

Conduction is the physical transfer of heat from matter in contact with other matter. Vibrating atoms and molecules bump into other atoms and molecules, transferring kinetic energy. Conduction happens with all forms of matter, but its conductivity varies.

Thermal conductivity refers to the speed at which a certain material changes temperature. The higher a substance's thermal conductivity, the faster it will heat up or cool off. Thermal conductivity varies greatly from one material to another. Something with very low conductivity which slows the transfer of heat is called an insulator.

Solids are better at conducting heat than liquids and gasses because they are more dense. Likewise, denser solid objects are often more conductive than less dense objects. Notice that solid objects that conduct heat quickly tend to be heavier (like an iron skillet, for example), while insulators such as blankets or coats tend to be light.

Metals are generally the best conductors of heat. On a molecular level, metallic bonds have many free-moving electrons which are able to transfer heat faster.

Convection

Convection is the transfer of heat along with the transfer of particles in liquids and gasses. If you boiled water in a tea kettle and poured it into a cool bath, the water of different temperatures would mix together, and the water in the bath would be an in-between temperature, warmer than the original bath, but not as warm as the boiling water. This is convection. It is simply a mixture of conduction (the vibrating particles brush against each other) and the motion of fluids as particles of different temperatures mix together.

Radiation

Heat can also be given off as radiation. All matter with any thermal energy at all emits thermal radiation. The movement of charged particles in matter creates radiation. Unlike conduction and convection, radiation transfers heat without requiring any matter to touch it. For example, the sun warms your skin without passing through matter directly--there are millions of miles of relatively empty space between you and the sun. Sitting in the sun is warmer than sitting in the shade, even though your distance from the sun is not changing. In the same way, a bright bonfire radiates heat even if the surrounding air is cold.

The way matter affects radiated heat is, in a way, opposite from how it works in conduction. Conduction requires matter, especially dense matter. Radiation, like light, can be blocked by matter. Some of the best blockers of radiation are dense metals like lead.

Homework Required: Finish the Worksheet for homework if you need more time after the Lesson.

Lesson Wrap-Up: Think of everyday examples of conduction, convection and radiation.

Lesson 16
Heat Transfer

Name: ________________________________
Date: __________________________________

1. What is conduction?

2. What is radiation?

3. What is convection?

For each example below, write which type of heat transfer takes place: conduction, convection or radiation. Note: Every case of convection involves conduction. For these cases, write convection, not conduction.

4. You're near a bright bonfire. It feels hot even though the air is cold.

   ____

5. When you open your air-conditioned car on a summer day, the car becomes warmer almost instantly. _______________

6. Lost in the woods, two friends sleep back to back to keep warm for the night.

   ____

7. You use your microwave to heat yesterday's leftovers. ____________
8. When you hold your hand an inch away from an incandescent light bulb, it feels hot. ______________
9. On a cool summer evening, you turn on a fan which blows out the window, cooling your room. ____________
10. You pour cold cream into hot coffee, which cools the coffee slightly. ____________
11. You turn on a burner on your kitchen stove and make pancakes on a hot griddle. _________________
12. On a sunny day, the sand is so hot that it burns your feet.

Lesson 17
Chapter 3 Quiz and Discussion

Name:____**Date:**_______________

1. What is kinetic energy?

2. Ultimately, most of the earth's energy comes from what source?

3. After being filtered through the atmosphere, how much of the sun's energy reaches the earth's surface?

4. Why don't we know the exact temperature of the center of the earth?

5. What does "geothermal" literally mean?

6. What is the main source of geothermal energy?

7. Briefly explain the process of radioactive decay in your own words.

8. Name three ways you might die if there was suddenly no gravity on earth.

9. What's another term for energy of motion?

10. Does an object higher off the ground have more or less GPE than a lower object?

11. The type of energy an object has due to its position above the earth is called ____, abbreviated ________.

12. A still object suspended high in the air has plenty of ___________________________ energy and no ______________________________ energy.

13. An apple falls off a tall tree. Just before it hits Isaac Newton's head, most of its energy is ____________________________ energy and almost none is ___________________________ energy.

14. Aside from gravity, the other two primary sources of energy on earth are what?

15. Define renewable energy source.

16. Define nonrenewable energy source.

Write whether each energy source below is renewable or nonrenewable.

17. Solar power ______________________

18. wind power ______________________

19. hydro power ______________________

20. biomass ______________________

21. coal ______________________

22. petroleum ______________________

23. natural gas ______________________

24. nuclear power ______________________

25. What's the biggest source of non-renewable energy we use?

26. What's the biggest source of renewable energy we use?

27. Coal, petroleum and natural gas are all referred to as what category of energy source?

28. What is conduction?

29. What is radiation?

30. What is convection?

For each example below, write which type of heat transfer takes place: conduction, convection or radiation. Note: Every case of convection involves conduction. For these cases, write convection, not conduction.

31. You're near a bright bonfire. It feels hot even though the air is cold.

____

32. When you open your air-conditioned car on a summer day, the car becomes warmer almost instantly. ____________________________

33. Lost in the woods, two friends sleep back to back to keep warm for the night.

____

34. You use your microwave to heat yesterday's leftovers.

____

35. When you hold your hand an inch away from an incandescent light bulb, it feels hot.

____

36. On a cool summer evening, you turn on a fan which blows out the window, cooling your room.

____

37. You pour cold cream into hot coffee, which cools the coffee slightly.

____

38. You turn on a burner on your kitchen stove and make pancakes on a hot griddle.

____

39. On a sunny day, the sand is so hot that it burns your feet.

____

Lesson 18
Cycle of Elements

Biogeochemical cycle is a big term, but if you break it down, it means exactly what it sounds like. Bio means related to life (remember that biology means the study of life). Geo means related to earth. It may help you remember the word's meaning if you look at its parts and see that it literally means something like "life earth chemical cycle." It's the cycle of chemicals between living things and the non-living earth.

A biogeochemical cycle is the process by which a chemical moves back and forth between living organisms and the physical environment. Chemicals that have biogeochemical cycles move through multiple spheres, often all of them: the biosphere, geosphere, hydrosphere or atmosphere.

The law of conservation of mass tells us that the total amount of matter in any closed system is constant. Since the earth is considered a closed system, the total amount of mass stays the same. It doesn't get created or destroyed—just moved around a lot.

Remember that an atom is a single element, like oxygen, which is defined by its number of protons; oxygen always has 8 protons. A molecule refers to two or more combined atoms to form a new substance, called a compound, such as water: two hydrogen atoms and one oxygen atom connected together.

Although atoms can change from one element to another through fusion and radioactive decay, the primary elements that sustain life here on the earth's surface are relatively constant in their amounts on earth, although they may form into different compounds. Oxygen, for example, is in the air as the O2 molecule, but it's also part of the water molecule: it's the O in H2O.

The biogeochemical cycles are a little different for each element, but they are all cyclical; an atom that starts in one place as one compound will go through other stages before ending up in the same state again, over and over. Different cycles also move at different speeds. The Phosphorus cycle, for example, is slower than the oxygen cycle.

A *reservoir* is where a chemical is stored for a long period of time. The study of biogeochemical cycles is the study of how these chemical move around from one reservoir to another and change states or compounds.

The First Example: Phosphorus

Oxygen, nitrogen and carbon all enter the atmosphere and are essential for organic life. Phosphorus, also important for life, doesn't enter the atmosphere. Phosphates are used to form molecules called nucleotides, which store chemical energy inside cells. Nucleotides are also necessary for forming DNA and RNA, which serve as blueprints for life. Phosphates are eroded from rocks, partly with the help of acid rain. It's then absorbed into plants, eaten by animals, which are eaten by other animals including humans.

Oxygen, nitrogen and carbon all have cycles which include the atmosphere as well as plants and animals. They will be explained over the next few Lessons.

Homework Required: Finish the Worksheet for homework if you need more time after the Lesson.

Lesson Wrap-Up: After the Lesson, verbally re-answer the Engaging Question based on what you have just learned.

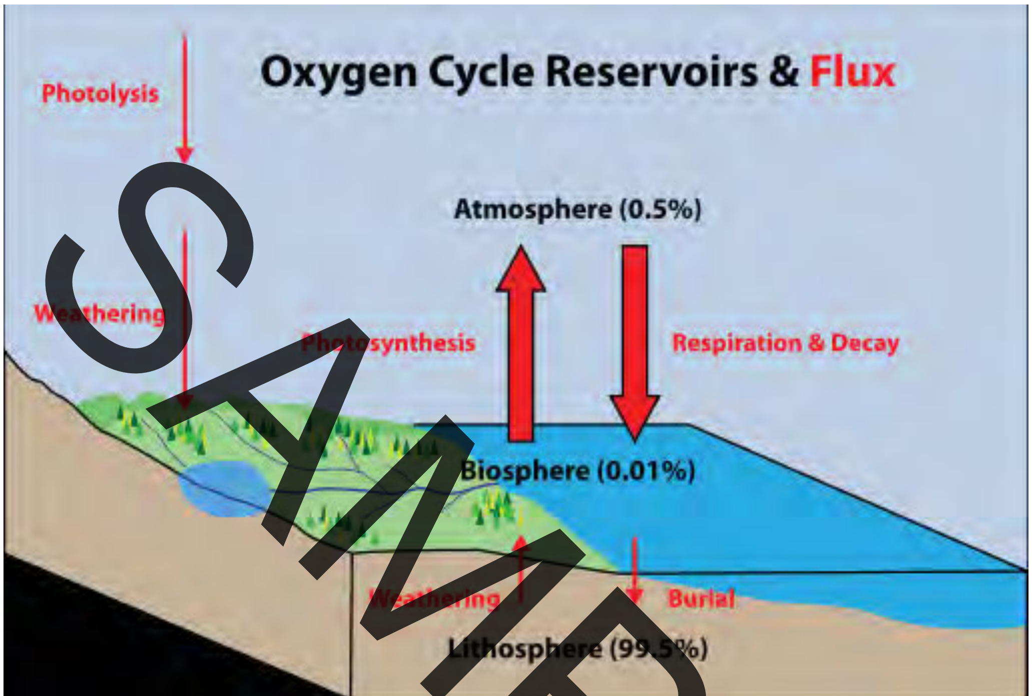
Lesson 18
Cycle of Elements

Name: ______________________________

Date: ________________________________

1. The total amount of matter in a closed system like earth stays the same. This is called the law of what? __________________________
2. Among oxygen, nitrogen, carbon, and phosphorus, which of these is not in the atmosphere? ______________________
3. Breaking down each part of the word, what does *biogeochemical* mean?
4. A place where a chemical is stored in nature before it moves somewhere else is called what? _______________________________
5. What is a biogeochemical cycle?
   ____
6. What's the difference between an atom and a molecule.
7. Compared to other cycles like the oxygen cycle, is the phosphorus cycle fast or slow? ________________

Lesson 19
Oxygen Cycle



Oxygen cycle; Source: Wikimedia Commons- from en.wikipedia.org; Author: Cbusch01; Cbusch01 **at the** English language Wikipedia**, the copyright holder of this work, hereby publishes it under the following license:**Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 o

There are three main reservoirs of oxygen: the atmosphere, the biosphere, and the lithosphere (the earth's crust, the outer part of the geosphere).

Without oxygen, you'd die in a matter of minutes. Along with all animals, we humans nourish our cells by extracting oxygen from the air and delivering it all over our bodies through our blood. The process of extracting oxygen is called respiration. While you may think of respiration as simply breathing, it's more complicated than that. The equation is this:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy

In plain English, we eat carbohydrates and breathe in oxygen, then give off carbon dioxide and water while using the energy released. As you can see from the equation, there is no oxygen left after respiration – it's all used up.

We have plants to thank for the fact that we don't use up all the oxygen by breathing it. Thankfully, what plants do to survive is called photosynthesis, and it's the reverse of respiration:

$6CO_2 + 6H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6O_2$

Plants absorb water and carbon dioxide to produce carbohydrates and oxygen. Plants also break down carbohydrates using a little of the oxygen they produce. But plants produce approximately ten times as much oxygen as they use, freeing up the rest for us to breathe.

This part of the oxygen cycle is a perfect circle: plants give off exactly what animals need, animals give off exactly what plants need.

There's also another complexity to the cycle. Oxygen gets dissolved in water with rapids; when water flows quickly and spreads over rocks, oxygen from the air gets mixed in. Once the rivers and streams pour into more still bodies of water like ponds, microorganisms use the oxygen in the respiration process and giving off carbon dioxide. This is another form of the oxygen cycle.

The ocean plays a big role in the oxygen cycle. Most of the earth's carbon dioxide and most of the earth's oxygen come from ocean creatures. Animals like fish don't have lungs, but they still use respiration to absorb oxygen from water. The speed at which living things consume the oxygen in water is called the oxygen uptake rate. The amount of oxygen in the water usually remains fairly constant.

Homework Required: Finish the Worksheet for homework if you need more time after the Lesson.

Lesson Wrap-Up: Based on what you have just learned, write a new answer the Engaging Question in his journal below his previous answer.

Lesson 19
Oxygen Cycle

Name:______________________________________**Date:**__________________________

1. What is this process called?
   $6CO_2 + 6H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6O_2$

2. Name each of the compounds in the above equation.

3. Is this process carried out by plants or by animals? __________________________

4. The following equation represents what process?
   $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$
   ____

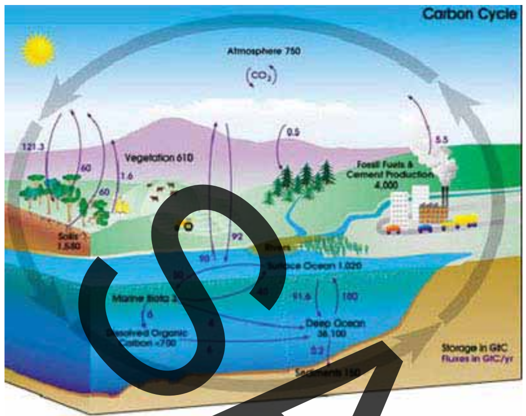
5. Is this process carried out by plants or by animals?

   ____

6. Do plants need oxygen? __________________

7. Most of the earth's oxygen and carbon dioxide comes from where? ______________

Lesson 20
Carbon Cycle



Carbon is the fourth most abundant element in the known universe. Not counting water, the human body is about half carbon.

The Carbon cycle is bound to the oxygen cycle, as both are governed by respiration and photosynthesis. In carbon dioxide, the two elements are literally bonded together. The two are also bonded together in equal parts in the carbohydrate glucose, $C_6H_{12}O_6$. However, there are some differences between the two cycles.

For one thing, there is much less pure carbon in the atmosphere, compared to the abundance of oxygen gas. Most carbon is found within plants, and about 86% of the earth's above-ground carbon is contained in forests.

Though we need carbon to survive, we can't get it from the air the way we get oxygen. Animals aren't capable of breaking apart carbon dioxide to use the carbon and oxygen needed for respiration. We need both elements, but when they're bonded together as carbon dioxide, we can't directly use either.

That's why we need plants to give off oxygen with photosynthesis. How then do we get the Carbon we need? Let's look at the respiration equation again.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

See the carbon? That's the C at the beginning of the equation. It's part of the $C_6H_{12}O_6$ molecule, also known as the carbohydrate glucose. Glucose is a type of sugar, and we need sugars for energy. Plants build glucose out of water and carbon dioxide during photosynthesis. Animals get glucose by eating plants, and animals higher on the food chain get it by eating animals. Note that this is part of respiration; it includes not just breathing but also eating.

Carbon goes into the ground when plants and animals die. After they are buried for millions of years, these carbons can become fossil fuels. Coal, for instance, is almost pure carbon. Old carbon also forms graphite (pencil “lead”) and diamonds, depending on the configuration of atoms.

When fossil fuels are burned, carbon dioxide is given off as a byproduct which goes back into the air. That connects the cycle – CO_2 was taken from the air to become a part of plants and animals. Millions of years later, that CO_2 is formed again and put back into the air.

Some carbon is in the atmosphere and can be dissolved by oceans. Some of this is used to make shells for sea creatures. Then these creatures die, their shells become sediment which either becomes limestone or, eventually, fossil fuels.

As you can see, the Carbon cycle is not one simple circle but a series of interconnections. Carbon travels between the atmosphere, biosphere, geosphere and ocean.

There’s one more complexity to the carbon and oxygen cycles. Photosynthesis stops at night because there is no sunlight, but respiration continues regardless of time of day. That means the concentration of CO_2 in the atmosphere changes depending on the time of year, when daylight hours are longer or shorter.

Homework Required: Finish the Worksheet for homework if you need more time after the Lesson.

Lesson Wrap-Up: Based on what you have just learned, write a new answer the Engaging Question in your journal below your previous answer.

Lesson 20
Carbon Cycle

Name: ____

Date: ____

1. How does Carbon get into the atmosphere? Name two ways.

2. How does carbon get into the ground?

   ____

3. Do animals need to absorb carbon dioxide to produce energy?

   ____

4. What gas is given off by respiration? ______________________________

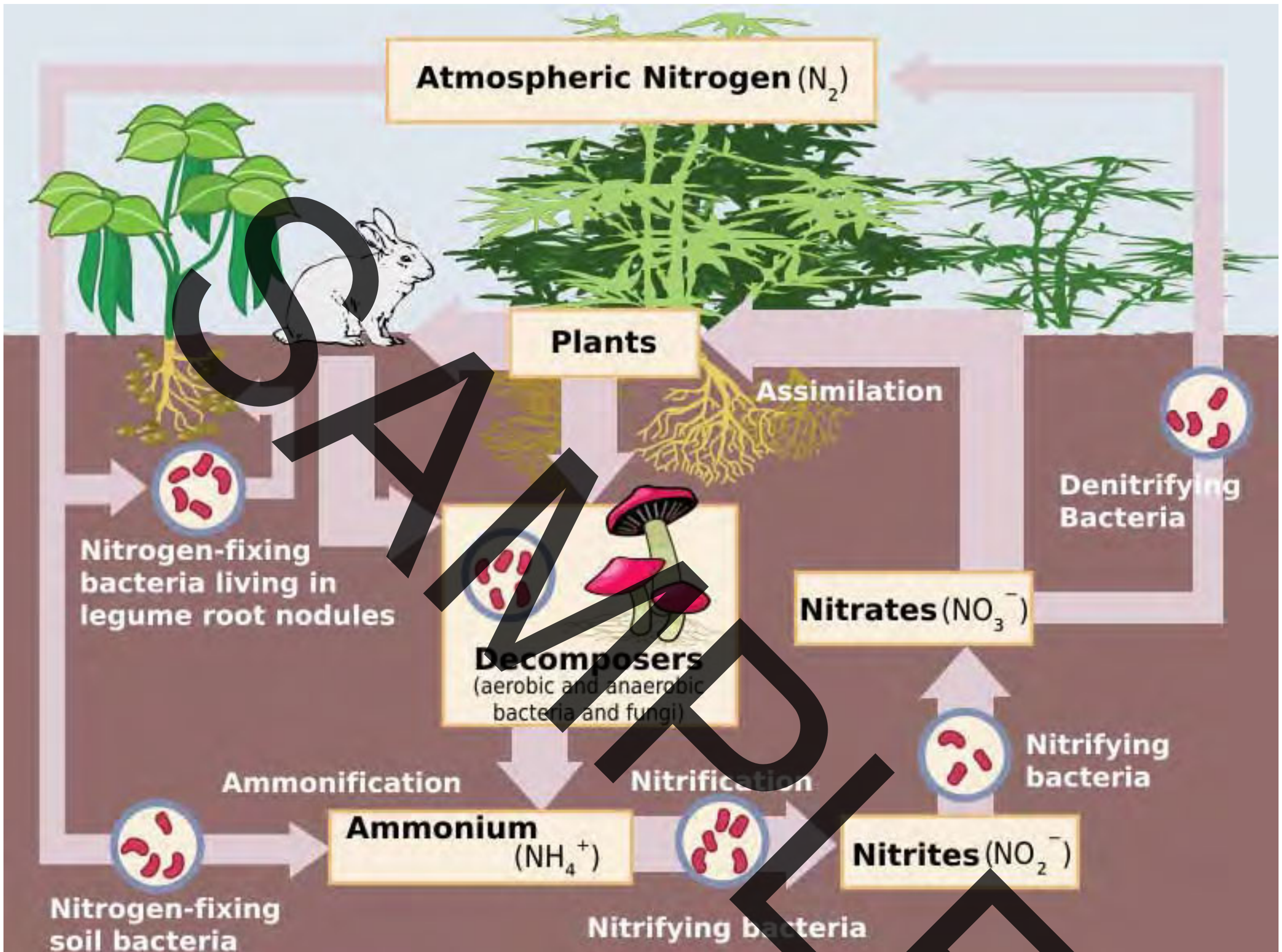
5. How do animals and humans get carbon we need for our bodies?

   ____

6. How does carbon contribute to the formation of limestone?

7. How does carbon contribute to the formation of fossil fuels?

Lesson 21
Nitrogen Cycle



- **Nitrogen Cycle; Source: Wikimedia Commons; Author:** Cicle del nitrogen de.svg: *Cicle del nitrogen ca.svg: Johann Dréo (User:Nojhan), traduction de Joanjoc d'après Image:Cycle azote fr.svg.derivative work: Burkhard (talk)Nitrogen_Cycle.jpg: Environmental Protection Agencyderivative work: Raeky (talk)

Three quarters of the earth's atmosphere is Nitrogen, making it the most abundant chemical in the air. All living things require nitrogen to build DNA, RNA and proteins, which are the building blocks of organic life. However, though there's plenty in the air, plants and animals can't directly use loose Nitrogen gas. That's one of the most notable things about Nitrogen: despite the fact that the air is full of it, it can be in short supply in some ecosystems. Lack of Nitrogen is often the limiting factor in plant growth, which is why Nitrogen is used in most chemical fertilizers.

The nitrogen cycle is faster than Carbon Cycle because it doesn't rely on slow geological processes of the earth. The nitrogen cycle depends heavily on bacteria, and its speed depends on factors that affect bacteria: moisture, temperature, and food.

The nitrogen cycle is a bit complicated, and is broken down into several stages: **fixation, uptake, mineralization, nitrification, and denitrification.** We'll go over them one by one.

The basic explanation is as follows. Bacteria take Nitrogen gas from the atmosphere and turn it into ammonium, which is then absorbed and incorporated into proteins by plants. We eat the plants and absorb the nitrogen. We die, and bacteria and fungus that rot us turn it back into ammonium. Some of that ammonium is transformed by a chain of bacteria into different compounds until, finally, it ends up as Nitrogen gas again in the atmosphere. That's the nitrogen cycle.

Fixation

Fixation refers to the way loose nitrogen in the air is "fixed" to other elements. Certain bacteria combine Nitrogen gas with Hydrogen gas to form ammonium (NH_4^+). These bacteria live in the roots of plants and have a symbiotic relationship with the plants. These bacteria absorb carbohydrates from the plants while giving off some of the Nitrogen to the plants in a form the plants can use, ammonium.

Lightning can also break the triple bonds of the nitrogen gas molecule, N_2, making loose nitrogen atoms which can then combine with other things. Forest fires and hot lava flows can also do this – basically, any extremely hot phenomenon in nature can break nitrogen gas apart.

Burning fossil fuels and using artificial man-made fertilizers also fixes Nitrogen.

Uptake

Uptake refers to plants and animals making use of the fixed nitrogen. Ammonium, which contains fixed nitrogen, is used by plants and bacteria to form proteins. Animals eat plants and other animals and absorb these organic Nitrogen compounds originally fixed by bacteria.

Mineralization

When things die, bacteria and fungi break down the proteins once more producing ammonium. This is called mineralization, because it's turning organic compounds (proteins) into an inorganic compound, ammonium.

Nitrification and Denitrification

Some of this ammonium is used by plants (the uptake process), while some is converted by bacteria into nitrate (NO_3). This conversion is called Nitrification.

Other bacteria take that NO_3^- and turn it into Nitrogen gas, N_2. That's called denitrification. That's the final step; at this point the nitrogen is back where it started, as the most abundant atmospheric gas.

Homework Required: Finish the Worksheet for homework if you need more time after the Lesson.

Lesson Wrap-Up: In your journal, write a revised answer to the Engaging Question based on what you have just learned.

Lesson 21
Nitrogen Cycle

Name: ____

Date: ____

1. What is nitrogen fixation?

2. Name two ways atmospheric Nitrogen can be fixed to the ground.

3. After living things die, how does the nitrogen they contain turn back into a gas?

4. Each stage in the nitrogen cycle relies heavily on what type of organism?

5. How do humans affect the nitrogen cycle?

6. What is denitrification? What causes it?