Earth Science Student Coursebook

All in One Curriculum

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Lesson 98: Disaster Prevention Presentation
Objective: Present research findings on a natural disaster, demonstrating an understanding of scientific forecasting methods, emergency response, and prevention strategies.

Lesson 99: Assessment Review
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Lesson 100: Assessment
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Lesson 101: Entropy
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Lesson 102: Uniformitarianism
Objective: Understand the principle of uniformitarianism and its significance in Earth science. Explain how modern geological processes provide insights into Earth's past.

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radiometric dating and meteorite analysis. Understand the challenges and advancements in dating celestial objects.

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Lesson 111: Half-life Lab
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Lesson 112: Carbon Dating
Objective: Explain the principles of carbon dating and how Carbon-14 is used to determine the age of once-living organisms. Discuss the limitations and accuracy of radiocarbon dating.

Lesson 113: The Limit of Carbon Dating
Objective: Understand the limitations of carbon dating, including why it is unreliable for dating objects older than 50,000 years. Explore alternative dating methods such as uranium-lead dating.

Lesson 114: Quiz and Discussion
Objective: Assess understanding of radioactive decay, half-life, and dating methods through a structured quiz and class discussion.

Lesson 115: The Planet: Part 1
Objective: Explore the Sun, Mercury, and Venus, including their characteristics, atmospheres, and unique physical properties. Compare their differences and roles in the solar system.

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Objective: Examine the planets Mars, Jupiter, Saturn, Uranus, and Neptune. Analyze their composition, atmospheres, and weather patterns, as well as their significance in the solar system.

Lesson 117: The Moon
Objective: Learn about the Moon's structure, phases, gravitational influence, and surface features. Discuss the Moon's effect on Earth, including tides and axial stability.

Lesson 118: The Planets: Part 3
Objective: Introduce exoplanets, dwarf planets, and asteroids. Explain how exoplanets are detected and how Pluto was reclassified as a dwarf planet.

Lesson 119: The Night Sky
Objective: Explore celestial phenomena such as zodiacal light, noctilucent clouds, and blue jets. Learn how to identify planets, satellites, and meteor showers in the night sky.

Lesson 120: Space Rocks
Objective: Differentiate between asteroids, comets, meteors, and meteorites. Explain their origins, impact on Earth, and historical significance, including the role of meteors in mass extinctions.

Lesson 121: The Seasons
Objective: Explain the cause of Earth's seasons by analyzing the role of axial tilt and the Earth's orbit around the Sun. Discuss solstices, equinoxes, and seasonal variations on other planets.

Lesson 122: Newton's Three Laws
Objective: Describe Newton's Three Laws of Motion and their role in explaining everyday motion. Apply these laws to real-world examples, such as seatbelt safety, rocket launches, and planetary motion.

Lesson 123: Mass, Gravity, and the Universe
Objective: Differentiate between mass and weight. Explain how gravity governs the motion of celestial bodies and orbits in space. Analyze how mass affects gravitational pull.

Lesson 124: Quiz and Discussion
Objective: Review key concepts from Chapter 16, including planetary motion, gravitational forces, and celestial mechanics, through a structured quiz and class discussion.

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Lesson 129: Doppler Effect and Microwaves
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hydrogen atoms fuse into helium, releasing energy that powers the Sun and supports life on Earth.

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Lesson 134: Star Evolution
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Lesson 135: Multiple Star Systems
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Lesson 136: Galaxies and the Universe
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Objective: Begin a research project on a frontier topic in space exploration. Select a topic, create an annotated bibliography, and plan a research paper and presentation.

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Objective: Continue researching and organizing information for the project. Evaluate the credibility of sources and refine the research question.

Lesson 145: The Unknown Universe Project: Presentation
Objective: Present findings from the research project using a visual aid and structured presentation. Summarize key discoveries and analyze their significance.

Lesson 146: Assessment Review
Objective: Review key concepts from Unit 4, including stellar evolution, black holes, dark matter, and exoplanets. Prepare for the unit assessment.

Lesson 147: Assessment
Objective: Demonstrate understanding of space science topics through a structured assessment, covering stellar evolution, space exploration, and theoretical physics.

Lesson 148: Fossil Fuels
Objective: Explain the formation, use, and environmental impact of fossil fuels. Discuss alternative energy sources and future energy challenges.

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Objective: Investigate renewable and alternative energy sources, such as biofuels, hydrogen, and electric power. Compare their advantages and limitations.

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Objective: Explore the process of mining, its economic importance, and its environmental consequences. Discuss reclamation efforts and the future of resource extraction.

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Objective: Define air pollution and explain its sources, including natural and human-made pollutants. Analyze its effects on human health, the environment, and climate change.

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Objective: Explain the importance of the ozone layer in blocking harmful UV radiation. Investigate causes of ozone depletion, the role of CFCs, and global efforts to restore the ozone layer.

Lesson 154: Life Cycle of a Product
Objective: Analyze the environmental impact of products from raw material extraction to disposal. Introduce Life Cycle Assessment (LCA) as a tool for evaluating sustainability.

Lesson 155: Organic Farming
Objective: Compare organic and conventional farming practices, discussing environmental benefits, challenges, and food labeling regulations. Evaluate the role of organic farming in sustainability.

Lesson 156: Waste Management
Objective: Explore different waste disposal methods, including landfills, incineration, recycling, and composting. Discuss the advantages and disadvantages of each method.

Lesson 157: Nuclear Technology
Objective: Explain how nuclear power plants generate energy through fission. Discuss the advantages and risks of nuclear energy, including radioactive waste and nuclear disasters.

Lesson 158: Global Dimming
Objective: Investigate the phenomenon of global dimming, its causes, and its effects on climate, agriculture, and the water cycle. Discuss the relationship between global dimming and climate change.

Lesson 159: Space Junk
Objective: Define space junk and analyze its impact on satellites, space travel, and Earth's orbit. Explore potential solutions for space debris removal and long-term sustainability.

Lesson 160: Overpopulation
Objective: Examine the environmental and social impacts of overpopulation. Discuss factors influencing population growth and explore strategies for resource management and sustainability.

Lesson 161: Overpopulation Discussion
Objective: Analyze the ethical, social, and environmental issues surrounding overpopulation. Discuss different perspectives on population control and its implications for global resources.

Lesson 162: Environmentalism in America

Objective: Examine the history of environmentalism in the United States, including key figures, major laws, and the impact of environmental movements on policy and society.

Lesson 163: Environmentalist Groups
Objective: Research and evaluate different types of environmental organizations, including political groups, charities, and regulatory agencies, to understand their goals, funding, and impact.

Lesson 164: Corporate Responsibility
Objective: Investigate how businesses impact the environment, the role of corporate sustainability, and the balance between profit and environmental responsibility.

Lesson 165: Assessment
Objective: Review and assess knowledge from the previous lessons, covering topics such as fossil fuels, mining, air pollution, deforestation, and the ozone layer.

Lesson 166: Greenhouse Effects
Objective: Explain the greenhouse effect, how greenhouse gases trap heat, and the consequences of human activities intensifying this process.

Lesson 167: Climate Change - Part 1
Objective: Explore the causes of climate change, historical temperature trends, and the role of human activities in global warming.

Lesson 168: Climate Change - Part 2
Objective: Examine the scientific debate around climate change, methods for measuring global temperatures, and the challenges of climate modeling.

Lesson 169: Climate Change Effects and Mitigation
Objective: Identify the consequences of climate change and explore solutions, including renewable energy, reforestation, and climate policy efforts.

Lesson 170: Global Warming Discussion
Objective: Engage in a critical discussion about global warming, exploring its media portrayal, political and economic implications, and potential solutions.

Lesson 171: Quiz and Discussion
Objective: Assess knowledge on greenhouse gases, climate change, and global warming. Explore key debates on human impact on climate.

Lesson 172: Origins and Religion Debate / Environmental Morality Debate
Objective: Debate the relationship between science and religion in understanding Earth's origins. Examine the moral responsibility of individuals and corporations in environmental conservation.

Lesson 173: Assessment Review
Objective: Review key concepts from Unit 5, focusing on environmental science, human impact, and energy resources, in preparation for the assessment.

Lesson 174: Year-End Assessment
Objective: Evaluate understanding of all the student has learned in Earth Science in this comprehensive test.

Lesson 175: Earth Science Final Project – Topic Selection & Research Objective: Choose a final project topic related to Earth science, conduct research, and gather key information to build a final presentation.

Lesson 176: Earth Science Final Project – Project Development
Objective: Begin structuring and developing the final project, selecting an appropriate format for presenting findings.

Lesson 177: Earth Science Final Project – Refinement & Visuals
Objective: Improve clarity, organization, and visual elements of the final project to ensure effective communication of scientific concepts.

Lesson 178: Earth Science Final Project – Practice Makes Perfect
Objective: Practice presenting the final project, refine explanations, and enhance delivery skills to prepare for submission.

Lesson 179: Earth Science Final Project – Presentation & Submission Objective: Present the final project and submit a reflection on the research and learning process.

Lesson 180: Closing Discussion
Objective: Reflect on key learnings from the course, discuss personal growth, and explore future interests in Earth science.

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 formulate a hypothesis and perform an experiment to test it. 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 test the hypothesis. That might seem counterintuitive, but in science, hypotheses are continually tested and refined based on the results.

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. While we were in Jamaica, 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 logical fallacy, meaning it is an incorrect way to reason. Essentially, it occurs when someone assumes a hypothesis is true just because the results align with it.

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 was 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 Finisher: 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:

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 answered countless questions about the world, and many more remain unanswered, though we hope science will eventually provide explanations. 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 are those that cannot be answered through 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 alone cannot determine whether 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. The term 'supernatural' literally means 'above the natural.' Since science is the study of the natural world, supernatural claims are beyond its scope. 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.

Although science has its limits and cannot prove or disprove everything, it can still help people make informed decisions about nonscientific matters. For example, the discovery that there is no measurable difference in overall intelligence between males and females has helped challenge biases 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 Finisher: What are the three types of questions that science cannot answer, and why?

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 Democra ☐ 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 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.
>
> 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 microorganisms 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 believe science is merely a collection of facts with little practical use.

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.

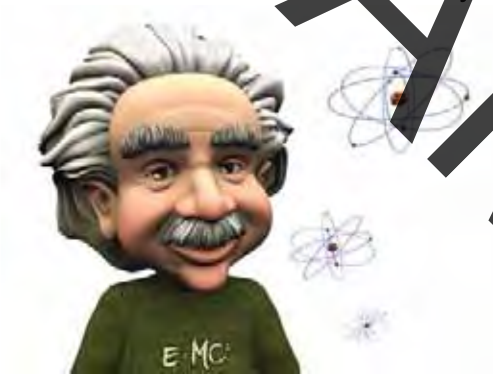
One thing that's especially alluring about science is that, unlike subjects such as philosophy and psychology, it provides concrete, testable answers. The scientific method measures results in a concrete way, and offers answers that can be verified by others.

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, but 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 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 beused to solve an everyday problem.

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 can develop into a theory when it is repeatedly tested and supported by extensive evidence from multiple experiments and observations. A hypothesis is an educated guess based on observations and prior knowledge. Scientists may propose multiple hypotheses to explain the same phenomenon. 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 statement that describes consistent relationships or patterns observed in nature. It must be repeatedly confirmed through observations and experiments under the same conditions. 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. The effects of gravity are consistently observed, leading to the formulation of laws that describe its behavior. However, gravity is also explained through theories, such as Newton's law of universal gravitation and Einstein's theory of general relativity.

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 are objective and verifiable statements, while observations are recorded perceptions that may require interpretation.

Now, complete the Levels of Certainty Worksheet.

Lesson Finisher: 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
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, encompassing multiple disciplines that study Earth's systems and processes. 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 classify the Earth as a closed system. 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.

Earth is considered a closed system because it absorbs energy from the Sun but does not exchange significant amounts of matter with its surroundings. Earth absorbs radiation from the Sun and emits it back into space. While small amounts of matter, such as meteorites and spacecraft, move in and out of Earth's atmosphere, these exchanges are negligible compared to Earth's total mass, making it functionally a closed system.

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.

The universe is often considered an isolated system because it contains all known matter and energy. However, some scientific theories suggest the possibility of external influences beyond our observable universe.

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 Finisher: 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 focuses on four main systems, called spheres. These systems are the geosphere, atmosphere, hydrosphere, and biosphere.

Geosphere
The geosphere includes all the solid parts of Earth's crust and interior, including soil, rocks, minerals, and 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 wind (atmosphere), water (hydrosphere), plants, and even bacteria (biosphere). The broken-down materials then form soil 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 studying geology, you realize how many other aspects of science are involved in explaining how rocks form and change.

Atmosphere
The atmosphere is the layer of gases surrounding Earth.

How It Affects Other Systems:
While Earth is not the only planet with an atmosphere, its atmosphere is unique in its ability to support life. The air contains both oxygen and carbon dioxide, which are essential for plant and animal life.

The atmosphere also plays several critical roles:

It allows in sunlight while filtering out most of the Sun's harmful radiation.
It helps distribute water from the hydrosphere by moving clouds, precipitation, and humidity across the land.
It provides a protective barrier that keeps Earth's temperature stable.

Hydrosphere
The hydrosphere is composed of all the water on Earth. Water is one of the most defining features of our planet. Oceans and seas alone cover more than two-thirds of Earth's surface. Rivers, streams, lakes, and underground reservoirs connect them, while water also exists in frozen glaciers, clouds, and atmospheric moisture.

If Earth's surface were completely flattened—meaning mountains were leveled and ocean basins filled in—the entire planet would be covered by water 8,200 feet deep (over 1.5 miles deep, or about six and a half Empire State Buildings stacked on top of each other!).

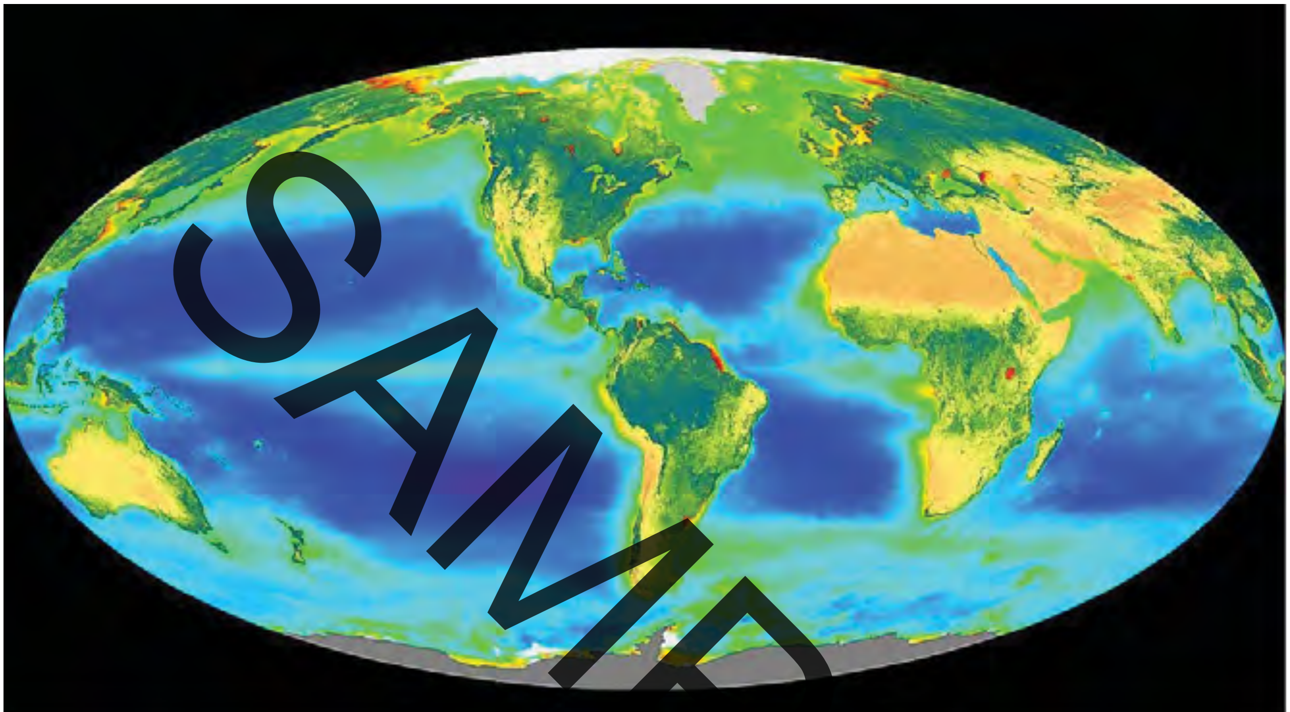
How It Affects Other Systems:
The presence of water almost everywhere on Earth provides a clear example of how connected the four spheres are:

- Geosphere: Groundwater saturates soil and rock layers, existing deep beneath Earth's surface.
- Atmosphere: Water cycles through the air as clouds, fog, and precipitation.
- Biosphere: Water is essential for all living things.

The human body is 50–80% water, and humans need to consume about two liters per day to stay hydrated.

Without water, a person cannot survive for more than a week under normal conditions. Additionally, the oceans regulate Earth's climate, which will be covered in a later chapter.

Biosphere
The biosphere is the collection of all life on Earth. Since we have not yet discovered signs of life beyond Earth, the biosphere includes all known living organisms, including microorganisms, plants, animals, and humans.



How the Biosphere Affects Other Systems:
Plants take in carbon dioxide and release oxygen, making breathable air possible for animals and humans.
Certain bacteria break down dead organisms, releasing gases into the atmosphere. This process is responsible for the odor of decaying matter.
Plants interact with the geosphere by breaking down rocks over time. However, this can sometimes become a problem for humans, as roots can damage buildings and sidewalks.
Humans, as part of the biosphere, significantly impact all Earth systems in many ways. Some of these impacts will be covered in Lesson 9.

The four spheres—geosphere, atmosphere, hydrosphere, and biosphere—are deeply interconnected. Changes in one sphere influence the others, shaping Earth's environment over time.

Once you have completed this lesson, complete the Spheres of Earth and Sphere Interaction Worksheets.

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 and its relationship with living organisms. Although it is related to Earth science, it is technically a subdivision of biology. However, ecology is broader than most biological fields. While biology often focuses on the characteristics and functions of individual organisms, ecology studies how organisms interact with their environment and how they are distributed across different ecosystems.

The Diversity of Life on Earth
If there is one word that describes life on Earth, it is variety. There are approximately 1.4 million known species on Earth, with humans being just one of them.

To put this into perspective:

If you spent just five seconds looking at each known species, it would take you 67 years to see them all!

About 250,000 species are plants.
Half of all known species (approximately 750,000) are insects, including about 300,000 species of beetles.
The famous British biologist and geneticist J.B.S. Haldane once joked that based on the vast number of beetle species, the creator of life must have had "an inordinate fondness for beetles."

Life has also been discovered in some of the most extreme conditions:

Some species survive in temperatures as cold as -41°F and as hot as 235°F—conditions that would freeze or cook most animals.
These organisms, known as extremophiles, show just how adaptable life on Earth can be.

The Balance of Ecosystems

Populations of living organisms exist in a delicate balance. When one species' population changes, it can cause a chain reaction, affecting many others in the ecosystem.

For example: Grasshoppers are usually harmless in small numbers. However, when their population grows too large, they become locusts and can destroy entire crops, leading to food shortages and even starvation in human populations.

This highlights the interconnected nature of ecosystems—a change in one species can have widespread consequences.

Biodiversity and Its Importance

One of the most important terms in ecology is biodiversity—the variety of life in a particular area. Biodiversity helps protect ecosystems from collapse. A good example of this is the Great Famine (Potato Famine) in Ireland from 1845 to 1852.

The people of Ireland relied heavily on potatoes as a primary food source. When a fungal blight infected the crops, it destroyed most of the potato harvest. Because there was little crop diversity, the loss of potatoes led to widespread starvation and malnutrition-related diseases.

This disaster demonstrates the importance of biodiversity in agriculture—growing multiple crops instead of relying on just one can prevent total food loss in the event of disease or environmental changes.

The Threat of Extinction

Extinction is an increasing threat to biodiversity. While scientists do not all agree on exact extinction rates, evidence suggests that species are disappearing faster than ever before—possibly at the highest rate in history.

Although some extinctions occur naturally, human activities significantly contribute to species loss. Habitat destruction—caused by deforestation, pollution, and urbanization—is one of the leading causes of extinction today.

Human-Caused Extinctions

In some cases, humans have deliberately caused extinction. One example is the Smallpox virus, which was responsible for millions of deaths worldwide before the development of a vaccine.

Due to global vaccination efforts, smallpox was declared eradicated in 1977. Today, the virus only exists in a few laboratory settings for research purposes. This is an example of a beneficial extinction, as eliminating smallpox has saved countless human lives.

Ecology helps us understand how living organisms interact with their environment. The diversity of life, the balance of ecosystems, and the threats to biodiversity all show how connected life on Earth truly is.

Once you have finished reading, complete the Ecology Comprehension Check on the next page.

Lesson 8
Ecology

1. Explain what ecology is without reading from the text.

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

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

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

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

____

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

____

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

____

8. 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 a complex, interconnected system where all forms of life rely on each other for survival. Because of this, Earth can be thought of as a single, self-regulating system. This idea is known as the Gaia Hypothesis.

Of course, the Gaia Hypothesis does not suggest that Earth—or "Mother Nature"—is actually a living organism. Instead, it emphasizes how Earth's biological, geological, and chemical systems work together, much like the systems of a living body.

Consider how the human body functions:

- If a vital system—such as the respiratory or circulatory system—were to fail, the entire body would die.
- In the same way, Earth's various life forms support and depend on each other, maintaining balance within the biosphere.

One of the clearest examples of this is the way plants regulate oxygen levels in the atmosphere. Instead of competing with animals for oxygen, plants absorb carbon dioxide—which is useless to humans—and release oxygen back into the air.

Without plants, Earth would eventually run out of oxygen. Why?

- Oxygen is one of the most reactive elements in the atmosphere, second only to fluorine.
- Because of this, oxygen easily bonds with other elements. Once it combines with another substance, it is no longer available for breathing.
- Water contains oxygen atoms (H_2O), but we cannot breathe water. Even fish must extract loose oxygen from the water—they do not break down H_2O molecules.

Through the chemical process called respiration, animals absorb oxygen and release carbon dioxide. If only animals existed, all the oxygen would eventually be used up. However, plants counterbalance this by absorbing carbon dioxide and producing fresh oxygen.

This natural cycle maintains stable oxygen and carbon dioxide levels, ensuring that:

- Animals and humans have enough oxygen to breathe.
- Plants receive the carbon dioxide they need for photosynthesis.

Because of this balance, the total amount of oxygen and carbon dioxide in the atmosphere remains relatively constant.

Plant Reproduction and the Biosphere
Many plants have evolved unique ways to spread their seeds, often relying on animals and humans to do so.

- Fruit-bearing plants enclose seeds inside nutrient-rich fruits.
    - Animals eat the fruit, and later disperse the seeds through their waste.
    - Even humans contribute—someone picking an apple and discarding the core is unknowingly helping the tree reproduce.
- Other plants produce burs, which attach to fur, feathers, or clothing and are transported to new locations.

These strategies ensure the survival and spread of plant species, further demonstrating the interconnectivity of Earth's biosphere.

The Lonely Humans
Are humans the dominant life form on Earth? The answer depends on how we define dominance.

Humans are undoubtedly the most intelligent species, possessing the ability to create tools, engineer solutions, and manipulate the environment to meet their needs. Human intelligence has given us control over many aspects of nature.

However, in other ways, humans are not the most dominant:

- We are not the largest creatures. Many animals, such as elephants, sharks, and lions, are much stronger than humans. Even a large dog could overpower a person in a fight.
- We are not the most abundant species. Compared to other life forms, humans are relatively rare.

The most abundant life forms on Earth are bacteria. Scientists estimate that there are around 5×10^{30} bacterial cells on Earth. That's:

5,000,000,000,000,000,000,000,000,000,000 (five trillion-billion-billion).

To put this into perspective:

- There are more bacteria in a single human body than there are human cells.
- Even in extreme environments—such as the deep ocean floor, where it is cold, dark, and high-pressure—bacteria thrive.

Some areas of the seafloor contain up to 10 billion bacteria per milliliter of water.
Anaerobic bacteria, found nearly 3,000 feet beneath the ocean floor, survive without oxygen.

Despite being outnumbered, humans stand apart from all other life forms due to their intelligence. Even our closest relatives—apes—only possess the cognitive abilities of a toddler. As far as we know, no other species is capable of abstract reasoning or engages in artistic expression. Regardless of variations in size, skin color, and culture, all humans belong to the same species, and no other life form comes close in terms of intelligence and influence.

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, barren desert. The other planets, as far as we know, appear to be lifeless masses of gas and rock. Earth, on the other hand, is full of variety. Because of the diverse landforms found on Earth, we have specific names for many of the different shapes and types of terrain.

Today, you will perform an Internet image search for each of these landforms, which are listed on the next page. Based on the pictures, write a short description of what you think each term means. After you have finished making your guesses, look up the actual definition of each word, record it, and compare it to your own description.

Lesson 10
Landform Vocabulary

Perform an Internet image search for each of the landforms listed below. Based on the pictures, write a short description of what you think each term means. After you have finished making your guesses, look up the actual definition of each word, record it, and compare it to your own description.

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 Earth's surface is covered in water. Just as there are many names for different types of land, there are also many names for bodies of water and landforms shaped by water. In this lesson, you will learn the names of various water forms and water-related landforms.

Perform an Internet image search for each of the landforms listed below. Based on the pictures, write a short description of what you think each term means. After you have finished making your guesses, your teacher will read the actual definition of each word. Write down this definition and compare it to your own description.

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
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?

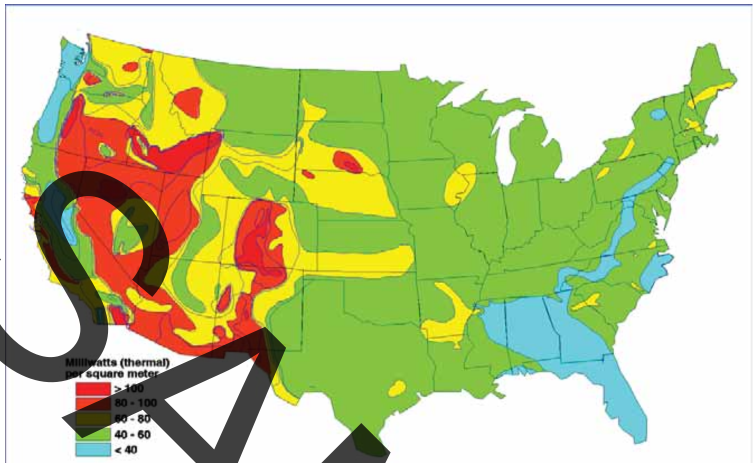
26. What's the difference between a sea and a lagoon?

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



Wikimedia Commons - Geothermal Energy Map

Geothermal Energy and Radioactive Decay
The word "geo" means Earth, and "thermal" means heat, so geothermal refers to heat from the Earth.

Geothermal energy is the warmth emitted by Earth's mass, especially from deep within the planet. The very center of Earth is believed to be hotter than the surface of the Sun, with temperatures estimated to be between 9,000 and 13,000 degrees Fahrenheit. However, since we cannot directly measure temperatures at such depths, these estimates are based on scientific models and indirect observations.

The main source of geothermal energy is radioactive decay. As unstable elements break down into more stable forms, they release energy in the form of heat. Earth's core contains dense, radioactive elements that continuously decay, generating significant amounts of heat.

Solar Energy
Ultimately, most of Earth’s energy comes from the Sun.We receive radiation from the Sun, and this energy is distributed in several ways:

- About 30% of the radiation is reflected back into space.
- Some energy is absorbed by clouds, warming the atmosphere.
- Around 50% of the Sun’s energy reaches Earth’s surface, warming the land and ocean.
- Some of this energy is harnessed for solar power.
- Plants use solar energy through photosynthesis, which then supports animals and humans as part of the food chain.

The three main sources of energy on Earth—geothermal energy, solar energy, and gravity—play essential roles in shaping our planet. From radioactive decay deep in the Earth's core to the Sun’s radiation warming the surface, these energy sources sustain life and drive natural processes.

Lesson 13
Types of Energy

Name: ___________________________________

Date: ____________________________________

1. . ltimately, 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. For example, if you place 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 ground. As objects fall, they accelerate at a rate of approximately 9.8 m/s^2, meaning their speed increases by 9.8 meters per second every second.

That might sound 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 simplify this example, we will ignore air resistance, which normally slows down falling objects on Earth.

The starting velocity is zero, because you are holding the watermelon and it is not moving. After you let go, one second later the watermelon would be traveling downward at a speed of 9.8 m/s. This speed increases by another 9.8 m/s every second. So, after ten seconds, the watermelon would be traveling at 98 meters per second. That's about 219 miles per hour!

The formula to determine how far an object falls in a certain time or how long it takes to hit the ground is more complex and better suited for a physics class. For now, simply think of this in terms of energy on Earth:

- Gravitational potential energy (PE) is converted into motion, which we call kinetic energy (KE).
- The higher an object is above the Earth, the more PE it has.
- As the object falls, its PE is converted into KE, increasing its speed.
- When the object hits the ground, its KE is transferred to the surface.

At halfway to the ground, the object has both potential and kinetic energy—what it loses in PE, it gains in KE. Just before impact, almost all of its energy is kinetic, with nearly zero potential energy remaining.

Of course, there are more useful applications of gravitational potential energy than just dropping a watermelon. Gravity plays an essential role in:
- Keeping satellites in orbit, including the Moon.
- Helping food move from your mouth to your stomach during digestion.
- Preventing us from floating into outer space every time we jump.
- Holding Earth's atmosphere in place, which provides air and rain.

Although gravity is not a very strong force, life on Earth would be impossible without it.

Lesson Finisher: 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 purposes, including electricity, heating, and transportation. Energy sources can be divided into two groups: renewable and nonrenewable.

- Renewable energy sources are naturally replenished over time.
- Nonrenewable energy sources do not regenerate fast enough to match how quickly we use them, meaning they will eventually run out.

It is important to note that whether an energy source is renewable or nonrenewable 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 2023, about 30% of the world's total energy comes from renewable sources, with the rest still relying on nonrenewable sources. In this lesson, we will briefly review examples of both categories.

Non-Renewable Sources

The biggest sources of non-renewable energy are fossil fuels, which account for about 80% of global energy consumption. These include:

- Petroleum (processed into oil and gasoline).
- Natural gas.
- Coal.

These energy sources come from ancient plants and animals, which were buried and subjected to heat and pressure over millions of years.

You might think fossil fuels should be considered renewable because new plants and animals die every day. However, it takes millions of years for organic matter to become fossil fuel, so the Earth cannot replace these fuels as fast as we use them. This makes them nonrenewable.

Nuclear Energy

Nuclear energy is also nonrenewable. It relies on uranium, a naturally occurring element on Earth. While nuclear power plants generate electricity efficiently and without carbon emissions, uranium deposits are limited and will eventually be depleted.

Renewable Energy Sources

Wind Power

Wind energy has been used for centuries, from sailing ships to windmills grinding grain. Today, wind power is a rapidly growing source of electricity.

- Wind turbines convert wind motion into mechanical energy, which is used to generate electricity.

- In 2023, wind power accounted for about 7.3% of global electricity production.
- The largest wind farm in the world, the Gansu Wind Farm in China, has a capacity of 20 gigawatts (GW).

Hydropower

Hydropower works similarly to wind power but uses flowing water instead of wind to spin turbines and generate electricity.

- Since water is 800 times denser than air, it can generate significant power, even if it is not moving quickly.
- Hydropower is currently the largest source of renewable energy, producing about 16% of the world's electricity.
- The Three Gorges Dam in China is the largest hydropower station in the world, generating 22.5 GW of electricity.

Solar Energy

The Sun sends about 174 petawatts (PW) of energy to Earth each year—far more than the total energy that could be obtained from all the nonrenewable resources on the planet.

- Solar panels convert sunlight into electricity using the photovoltaic effect, where photons (light particles) excite electrons, generating electricity.
- In 2023, solar power made up about 5% of global electricity production.
- The largest solar power plant in the world, the Bhadla Solar Park in India, covers 14,000 acres and has a capacity of 2.25 GW.

Despite its great potential, solar energy is still developing as a major source of commercial electricity.

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 Biofuel

Biomass and biofuel refer to energy from plant and animal matter. Unlike fossil fuels, biofuel comes from recently dead organisms, making it renewable.

- Burning wood and dead plants has long been a source of heat and light.
- Rotting garbage releases methane gas, which can be captured and used as fuel.
- Crops like corn and sugarcane are fermented to produce ethanol, a fuel alternative to gasoline.
- Biodiesel is a fuel made from plant and animal oils.

In 2023, biofuels provided about 3% of the world's total energy.

Geothermal Energy

Geothermal energy comes from heat stored beneath Earth's surface.

- Hot water or steam is pumped from underground to drive turbines that generate electricity.

- Iceland gets over 90% of its heating and electricity from geothermal energy.
- The largest geothermal power plant in the world, The Geysers in California, generates 1.5 GW of electricity.

The transition from nonrenewable to renewable energy sources is already underway, but fossil fuels still dominate global energy production.

Scientists and engineers continue working on new technologies to improve the efficiency and accessibility of renewable energy. The future of energy production will depend on how well we develop and implement these sustainable solutions.

Extra Credit: Investigate whether the energy used for your home is renewable or nonrenewable. You may need to call your power company or visit its website. Write down your findings.

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

Lesson 15
Energy Renewal

Name: ______________________________

Date: ______________________________

Complete the following questions

1. Define renewable energy source.

2. Define nonrenewable energy source.

Write renewable or nonrenewable next to each energy source.

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

9. natural gas ______________

10. nuclear power ______________________

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

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

13. 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 object 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 each one.

Conduction

Conduction is the physical transfer of heat through direct contact between matter. Vibrating atoms and molecules bump into other atoms and molecules, transferring kinetic energy. Conduction occurs in all forms of matter, but the rate at which heat is transferred varies. Thermal conductivity refers to how quickly a material changes temperature. A substance with high thermal conductivity heats up and cools down quickly, while a substance with low thermal conductivity slows the transfer of heat and is called an insulator.

Solids conduct heat better than liquids and gases because they are denser. Similarly, denser solid objects are often more conductive than lighter ones. Objects that conduct heat well tend to be heavier, like an iron skillet, while objects that trap heat and slow its transfer, such as blankets or coats, tend to be lighter. Metals are generally the best conductors of heat. On a molecular level, metallic bonds have free-moving electrons, which transfer heat faster than nonmetals.

Convection

Convection is the transfer of heat through the movement of fluids, which includes both liquids and gases. For example, if you boil water in a tea kettle and pour it into a cool bath, the water of different temperatures will mix. The bathwater will become warmer than before, but not as hot as the boiling water. This process involves conduction, as the vibrating particles in the liquid bump against each other to transfer heat, as well as the movement of the fluid itself, allowing the hot and cold water to mix together.

Convection is responsible for weather patterns, as warm air rises and cooler air sinks. It also plays a role in ocean currents, which help regulate Earth's climate. In heating and cooling systems, such as air conditioning, convection distributes heat efficiently by circulating air or liquid.

Radiation

Radiation is the transfer of heat through electromagnetic waves, without requiring direct contact between objects. All matter that has thermal energy emits radiation. The movement of charged particles in matter creates radiated heat. Unlike conduction and convection, radiation can transfer heat through empty space.

One example of radiation is how the Sun warms your skin. Even though there are millions of miles of empty space between you and the Sun, its energy travels through space and reaches Earth. Sitting in the Sun feels warmer than sitting in the shade, even though your distance from the Sun does not change. Similarly, a bright bonfire radiates heat, even if the surrounding air is cold.

The way matter interacts with radiation is different from conduction. Conduction requires dense matter to transfer heat, while radiation can be blocked by dense materials. Some of the best blockers of radiation are dense metals like lead.

Heat transfer occurs in three ways: conduction, convection, and radiation. Conduction transfers heat through direct contact, convection transfers heat through the movement of fluids, and radiation transfers heat through electromagnetic waves without requiring any contact. Each of these processes plays a critical role in Earth's weather, climate, and daily life.

Lesson Finisher: Think of everyday examples of conduction, convection and radiation and write them down, below..

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
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

A biogeochemical cycle may sound like a complicated term, but breaking it down makes its meaning clear. "Bio" refers to life, just as in biology, which is the study of life. "Geo" refers to Earth. If you look at the parts of the word together, you can see that biogeochemical cycle literally means something like "life-Earth-chemical cycle." It describes the movement of chemical elements between living organisms 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. These chemicals often travel through multiple spheres of Earth, including the biosphere, geosphere, hydrosphere, and atmosphere.

The law of conservation of mass tells us that the total amount of matter in a closed system remains constant. Since Earth is considered a closed system, the total amount of mass stays the same. Matter is not created or destroyed, but rather recycled and redistributed in different forms.

Atoms and molecules play an important role in these cycles. An atom is a single element, such as oxygen, which is defined by its number of protons. For example, oxygen always has eight protons. A molecule consists of two or more atoms combined to form a compound, such as water (H_2O), which consists of two hydrogen atoms and one oxygen atom.

Although atoms can change from one element to another through fusion and radioactive decay, the primary elements that sustain life on Earth's surface remain relatively constant in amount. However, these elements may form different compounds. Oxygen, for example, exists in the air as O_2 (oxygen gas) but is also a part of H_2O (water molecules).

Each biogeochemical cycle follows a cyclical process, meaning that elements continuously move through different stages before eventually returning to their original state. However, different cycles move at different speeds. For example, the phosphorus cycle is much slower than the oxygen cycle.

A reservoir is a place where a chemical element is stored for a long period of time. The study of biogeochemical cycles focuses on how these chemicals move between reservoirs, change states, and form new compounds.

The First Example: Phosphorus
Oxygen, nitrogen, and carbon all enter the atmosphere and are essential for organic life. However, phosphorus, another important element for life, does not enter the atmosphere.

Phosphates play a key role in biological molecules. They are used to form nucleotides, which store chemical energy inside cells. Nucleotides are also necessary for forming DNA and RNA, which serve as the blueprints of life.

Phosphates are eroded from rocks, a process that is partly aided by acid rain. Once released from rocks, phosphates are absorbed by plants, which are then eaten by animals. This process continues as larger animals consume smaller ones, including humans.

Oxygen, nitrogen, and carbon all have biogeochemical cycles that involve the atmosphere, plants, and animals. These cycles will be explained in more detail over the next few lessons.

Lesson 18
Cycle of Elements

Name: ______________________________

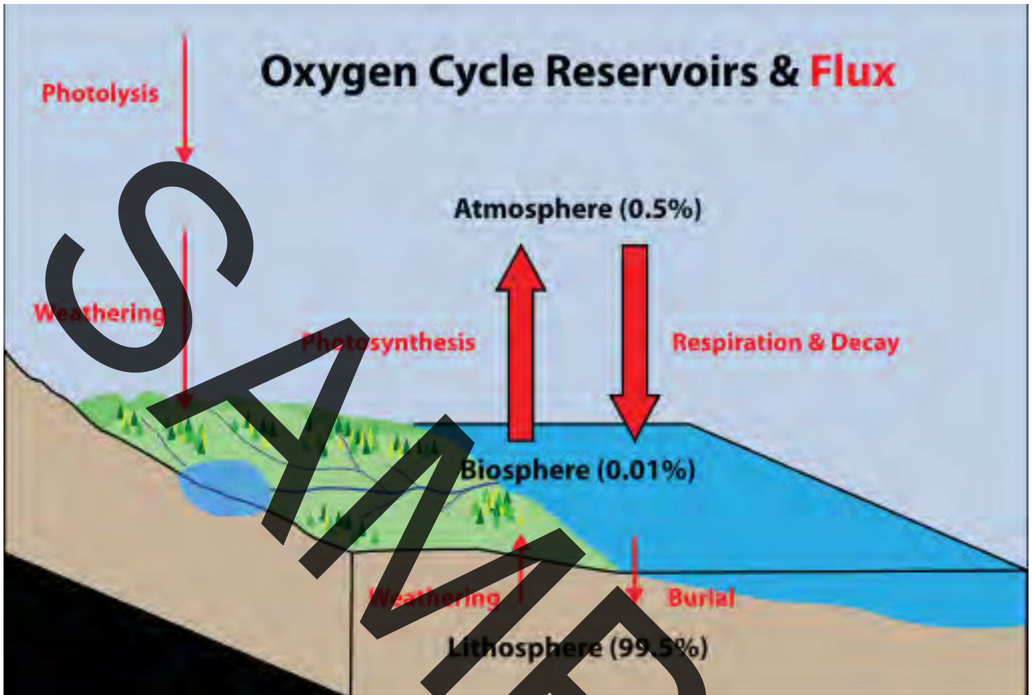
Date: ________________________________

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, biosphere, and lithosphere (the Earth's crust, which is the outer part of the geosphere).

Without oxygen, you would die in a matter of minutes. Like all animals, humans extract oxygen from the air and transport it throughout the body via the bloodstream. This process is called respiration. While respiration is commonly thought of as simply breathing, it is actually a complex biochemical process. The equation for respiration is:

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

In simpler terms, we consume carbohydrates (such as glucose) and inhale oxygen. Our cells then use these to generate energy, releasing carbon dioxide and water as byproducts. As you can see from the equation, oxygen is completely used up during respiration.

Photosynthesis and the Oxygen Cycle

We have plants to thank for continuously replenishing oxygen in the atmosphere. Plants perform photosynthesis, which is essentially the reverse process of respiration. The equation for photosynthesis is:

$6CO_2$. $6H_2O$ + energy → $C_6H_{12}O_6 + 6O_2$

Plants absorb carbon dioxide and water, using sunlight to produce carbohydrates (sugars) and oxygen. While plants do use some of the oxygen they produce for their own respiration, they generate about ten times more oxygen than they consume, making the excess available for animals and humans.

Oxygen in Water

The oxygen cycle is not limited to just the air and land—water plays a significant role as well. Oxygen can become dissolved in water, particularly in areas where rapids and waves create turbulence. As water flows over rocks and moves quickly, it mixes with oxygen from the air.

Once rivers and streams reach calmer bodies of water, such as lakes or ponds, microorganisms use the dissolved oxygen for respiration, releasing carbon dioxide in the process. This is another important component of the oxygen cycle.

The Role of the Ocean

The ocean plays one of the biggest roles in the oxygen cycle. A significant portion of Earth's carbon dioxide and oxygen is regulated by marine organisms. While fish do not have lungs, they still absorb oxygen from water through their gills.

The rate at which living organisms consume oxygen in water is called the oxygen uptake rate. Despite continuous oxygen consumption, the amount of dissolved oxygen in water remains relatively stable due to ongoing exchange with the atmosphere and photosynthesis by marine plants and algae.

Lesson Finisher: Based on what you have just learned, answer this question:

Picture an oxygen molecule in your lungs right at this moment.
Without reading ahead, try and answer: where did this molecule come from, and how will it be replaced once you've "used it up"?

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

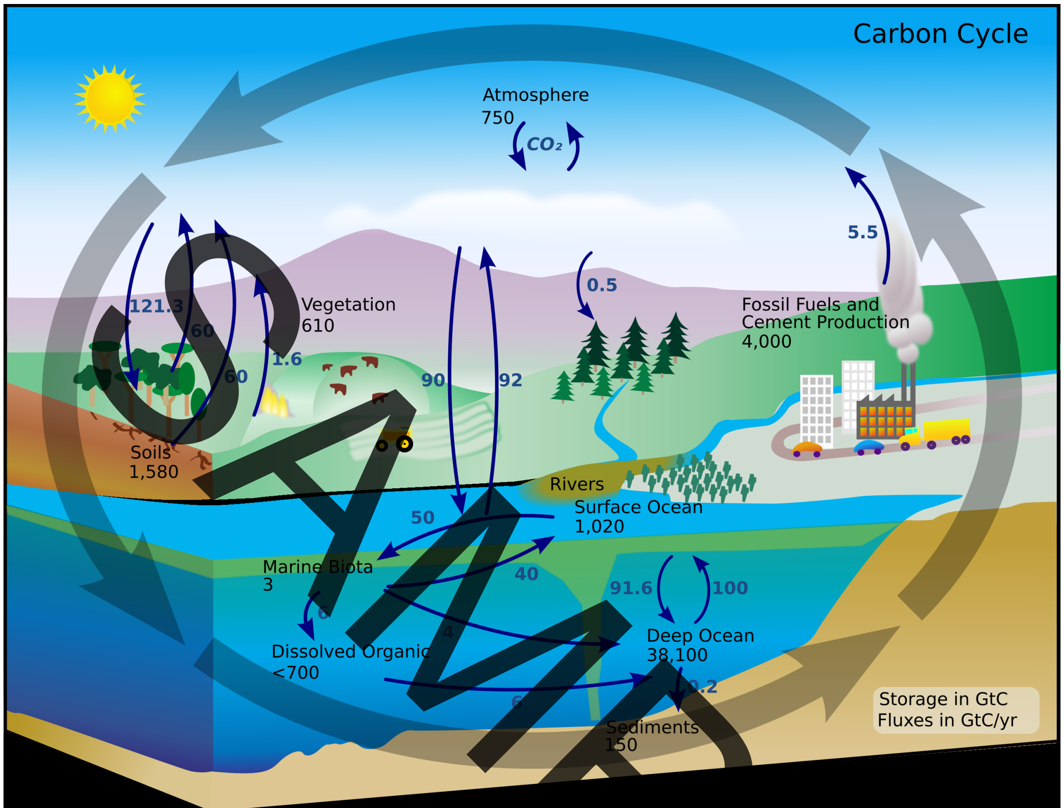
5. Is this process carried out by plants or by animals?

   ____

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 composed of about 50% carbon.

The carbon cycle is closely linked to the oxygen cycle, as both are governed by respiration and photosynthesis. In carbon dioxide (CO_2), these two elements are chemically bonded together. Carbon and oxygen are also found in equal parts in glucose ($C_6H_{12}O_6$), a carbohydrate that serves as a key energy source for living organisms. However, while these cycles are related, there are important differences between them.

One key difference is that carbon is much less abundant in the atmosphere than oxygen gas (O_2). The majority of Earth's carbon is stored in plants, with a significant portion—about 80% of Earth's above-ground carbon—found in forests.

How Animals Obtain Carbon

Even though carbon is essential for life, animals cannot extract it directly from the air like they do with oxygen. Unlike plants, animals are incapable of breaking apart carbon dioxide molecules to obtain the carbon and oxygen needed for respiration. We require both elements, but when they are chemically bonded as CO_2, neither can be directly used by animals.

That is why plants play a crucial role by releasing oxygen into the atmosphere through photosynthesis. But how do animals obtain the carbon they need?

To answer this, let's look at the respiration equation once again:

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

The carbon in this equation is represented by the C at the beginning. It is part of $C_6H_{12}O_6$, the glucose molecule. Glucose is a type of sugar, and all animals require sugars for energy.

Plants create glucose from water (H_2O) and carbon dioxide (CO_2) during photosynthesis. Animals obtain glucose by eating plants, and animals higher on the food chain consume other animals that have eaten plants. This means that respiration involves not only breathing but also eating—both are necessary to cycle carbon through living organisms.

Carbon in the Ground and Fossil Fuels

When plants and animals die, their carbon-based remains become buried in the geosphere. Over millions of years, this carbon can transform into fossil fuels such as coal, oil, and natural gas.

Coal, for example, is composed of almost pure carbon. Over time, carbon also forms graphite (used in pencils) and diamonds, depending on how its atoms are arranged.

When fossil fuels are burned, carbon dioxide is released back into the air as a byproduct of combustion. This completes the cycle, as the CO_2 originally taken from the atmosphere to support life is eventually returned to it.

Carbon in the Ocean

Some carbon from the atmosphere dissolves in oceans. Once dissolved, it can be used by marine organisms to form shells made of calcium carbonate ($CaCO_3$). When these sea creatures die, their shells settle as sediment, eventually forming limestone or, over time, even contributing to fossil fuel deposits.

This demonstrates that the carbon cycle is not a single loop but a complex series of interconnections between the atmosphere, biosphere, geosphere, and ocean.

Carbon Cycle and Seasonal Changes

One additional complexity in both the carbon and oxygen cycles is that photosynthesis only occurs during daylight hours, when sunlight is available. However, respiration occurs continuously, day and night.

This means that the concentration of CO_2 in the atmosphere fluctuates depending on seasonal changes and the length of daylight hours. During the summer, when photosynthesis is more active, CO_2 levels tend to decrease. In contrast, during winter, when plants are less active, CO_2 levels increase slightly.

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?