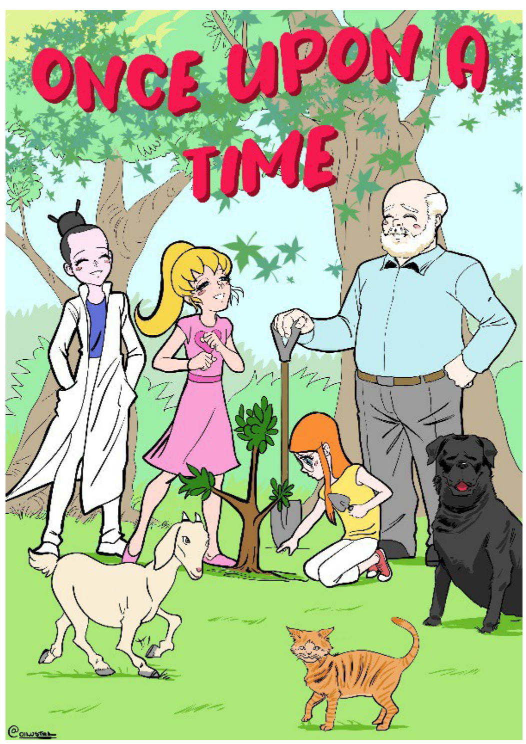
CO_2 LEARNING CENTER

Book One Lesson Plan

Once Upon a Time:

A true story about the miracle molecule carbon dioxide



This lesson plan was produced by the CO2 Learning Center, a project of the CO2 Coalition

Book One Lesson Plan

Once Upon a Time: A true story about the miracle molecule carbon dioxide

Once Upon a Time is the first in a planned series of informative and entertaining books for students on various aspects of science made available through the CO2 Learning Center. Students will learn about gases in the air, photosynthesis, properties of water and much more.

The story is told through the adventures of three young girls who live on a tree farm in Oregon. They learn from their kindly neighbor, a scientist, that carbon dioxide (CO_2) is the miracle molecule that is necessary for life on earth to exist and that increasing CO_2. is helping plants to grow faster and bigger.

> *"For years, innocent children have been terrified by threats of harm caused by humanity's use of fossil fuels. The supposed evil villain of this fairy tale, atmospheric carbon dioxide, is in fact beneficial to life on Earth. These illustrated stories give an entertaining and scientifically accurate explanation of why carbon dioxide is the 'gas of life' and why we and other living things are lucky to have more of it."*
>
> -- Dr. William Happer, Emeritus Professor, Physics, Princeton University

The CO_2 Learning Center lesson plans were created by Dr. Sharon Camp. Dr. Camp received a B.S. in Geology from the University of Georgia and a Ph.D. in Analytical Chemistry from Georgia Tech. She has 20 years' experience teaching high school, including Earth Science, Biology, Chemistry, Physics, and AP Environmental Science. She is currently a reader for the yearly national AP Environmental Science exam.

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A note about our lesson plans:

Our CO_2 Learning Center lesson plans all have the same format, which includes learning standards from the Next Generation Science Standards (NGSS), student learning objectives, background information on the science concepts covered in the book or video, suggested activities including labs to enrich the lesson and reinforce use of the scientific method, and formative and summative questions.

The NGSS are the standards on which most public-school systems have based their curriculum. We do not necessarily endorse the NGSS but have included the relevant standards for circumstances in which a teacher is required to use them. The lesson plans contain everything that a teacher might be required to submit in a formal lesson plan to a school administrator or science department head.

This lesson plan was created for the CO_2 Coalition's CO_2 Learning Center by Sharon Camp, Ph.D. Analytical Chemistry; B.S., Geology, using Next Generation Science Standards (NGSS).

Understanding NGSS:

LS: Life Science
PS: Physical Science
ES: Earth Science

1-5 indicates the standard for grade level (1-first grade, 2-second grade, 3-third grade, 4-fourth grade, 5-fifth grade)

MS: Middle School

Please note that only the parts of the outline that are relevant to this lesson have been included. If LS1.A *and* PS3.D *(example from this lesson) are shown, these NGSS segments were included as relevant to this lesson for Life Science and Physical Science.*

Lesson Plan: Book One

Grades K-8

Student Learning Goals

After reading *Once Upon a Time*, students will be able to:

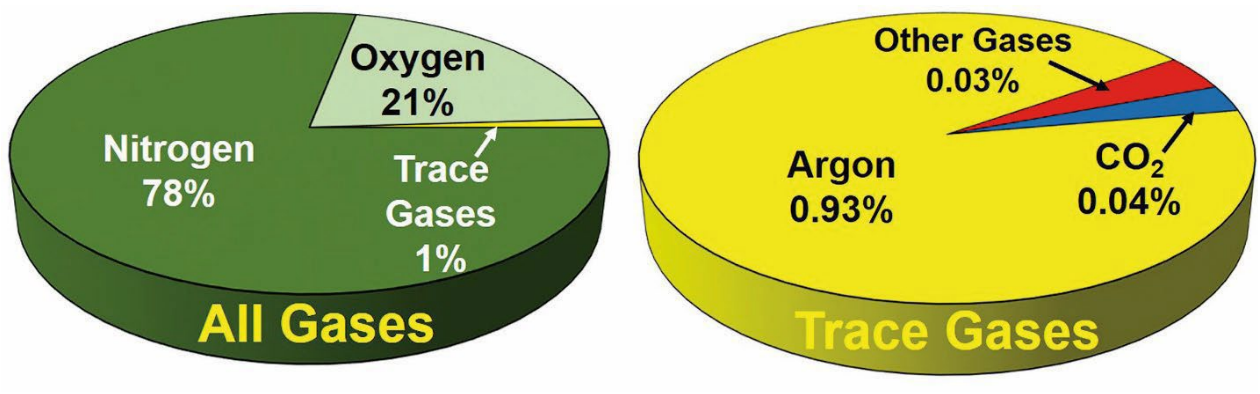
1) Explain that carbon dioxide is found in the air in very small amounts using a model (see activity #3)
2) Explain that one source of carbon dioxide is from people and animals breathing
3) Explain that dry ice is frozen carbon dioxide, and describe its appearance
4) Explain that plants use carbon dioxide to make food, and that animals eat plants to get their food
5) Explain that all living things are made of carbon that comes from the carbon dioxide in the air and describe the process by which living things obtain carbon (Aquatic organisms also need carbon dioxide, and in the oceans most of the CO_2 is absorbed from the atmosphere)
6) Describe what the earth would look like if there were no carbon dioxide in the air
7) Explain why carbon dioxide was described as "the miracle molecule" in the book

Background Information

Carbon dioxide is a colorless, odorless gas that is vital to life on earth. Living things manufacture chlorophyll, which allows plants, algae and certain types of bacteria, to be able to produce food for themselves magically from only carbon dioxide and water using energy from the Sun. Chlorophyll generates an excited electron after absorbing light energy and initiates an electron transport chain that creates ATP, which is the molecule that stores the energy from the sun. The energy powers the chemical reaction that is used to create food, or glucose, which is a process called photosynthesis. During this reaction, plants transform carbon dioxide (CO_2) and water into sugars (like glucose) and generate oxygen as a byproduct. Glucose can then be stored by the plants and broken down later to release the energy that originally came from the sun. Without CO_2, photosynthesis cannot occur; and without photosynthesis, plants can't produce oxygen.

A pollutant is something that endangers life processes. Carbon dioxide is not a pollutant but, instead, it is the reason that life exists on Earth. When the girls watch the CO_2 meter increase in their presence, it is a visible demonstration that all animals exhale carbon dioxide when they breathe. In fact, humans exhale 40,000 parts per million carbon dioxide with every breath, which means 4 out of every 100 molecules we exhale are carbon dioxide. This is the equivalent of two pounds of CO_2 every day!

Carbon dioxide is a very small component of the air. Nitrogen and oxygen are the two gases in the highest amount, with nitrogen comprising about 78% of the Earth's atmosphere and oxygen comprising about 20.9%.[1] A bit less than 1% of the air is argon, and water vapor ranges from 0.2% to 4%, depending on location. Carbon dioxide is only about 0.04% of the air, yet without it, there would be no living things on our planet. In fact, all living things in the biosphere are referred to as "carbon-based" for this reason.

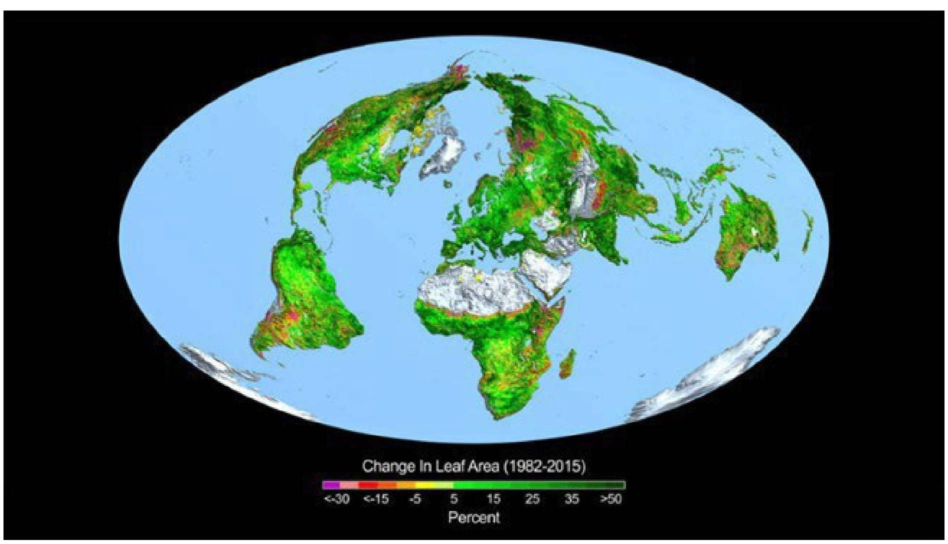


When glucose is broken down by both plants and animals, oxygen is needed, and carbon dioxide is released. Animals exhale carbon dioxide and water, but plants release these compounds through pores on the underside of their leaves (called stomata). Carbon dioxide concentrations will increase in closed areas where people and animals are. In fact, CO_2 monitoring devices are frequently used in industry to trigger and control HVAC systems to maintain air quality.[2]

Frozen carbon dioxide, or dry ice, can be easily obtained at a grocery store. Locations can be found by checking either the Penguin Dry Ice website or the Continental Carbonic website. It is most often used to keep food cold and dry, unlike water ice which melts and can get the food and food packages wet. Dry ice never melts at room temperature. Instead, it changes directly from a solid to a gas in a physical change called sublimation. Once it sublimates, carbon dioxide again is a colorless and odorless gas.[3]

Plants grow better in an environment with high levels of carbon dioxide. Many greenhouses elevate the carbon dioxide levels inside to accelerate the growth of their plants. In fact, plant growth increases steadily as CO_2 levels rise to as much as 2000 ppm parts per million, or ppm (0.2%).[4]

An increase in atmospheric carbon dioxide results in increased vegetation, or "greening", across most of the planet.[5] The green in the figure below shows the areas of the planet that are experiencing an increase in plant growth.



When plants absorb carbon dioxide, they combine it with hydrogen and oxygen to form glucose, a simple sugar. This carbon is incorporated into all living things, and all things that are derived from plants, such as wood. Since carbon dioxide is necessary for all life, without it there would be no living things or products from living things present on Earth. Therefore, carbon dioxide is considered a miracle molecule.

References

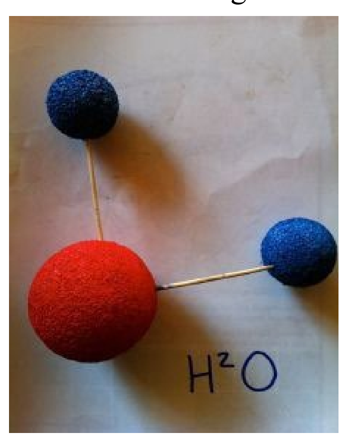
1. By Mysid - Vectorized version of w:Image:Atmosphere gas proportions.gif (originally by Brockert). I SVG' Public Domain, https://commons.wikimedia.org/w/index.php?curid=823817. Water vapor was left out because it is variable.
2. https://www.co2meter.com/blogs/news/why-measure-co2-hvac-applications
3. ProjectManhattan; cropped by Michał Sobkowski, CC BY-SA 3.0 https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons
4. Idso 2013 The positive externalities of CO2 CO2 Science https://www.co2science.org/
5. https://www.nasa.gov/feature/goddard/2016/carbon-dioxide-fertilization-greening-earth

Safety Measures

The temperature of dry ice is typically -109°F, so care should be used in its handling. Never touch or hold dry ice with bare fingers or hands, as it can freeze skin within a matter of seconds. Tongs and heavy gloves should always be used when handling dry ice. If smaller pieces of dry ice are desired, it should be wrapped in a towel and smashed with a hammer to prevent pieces of it from flying through the air. Safety goggles should be worn when handling dry ice. Also, since dry ice sublimates (gives off a vapor without melting first), it should never be put into a container with a tight-fitting lid. A simple Styrofoam container with a loose-fitting lid will work well. (https://www.dryiceadvice.com/dry-ice-safety/)

Suggested Activities

Activities that would help students understand what a gas is and how molecules can be rearranged during chemical reactions are demonstrated below.



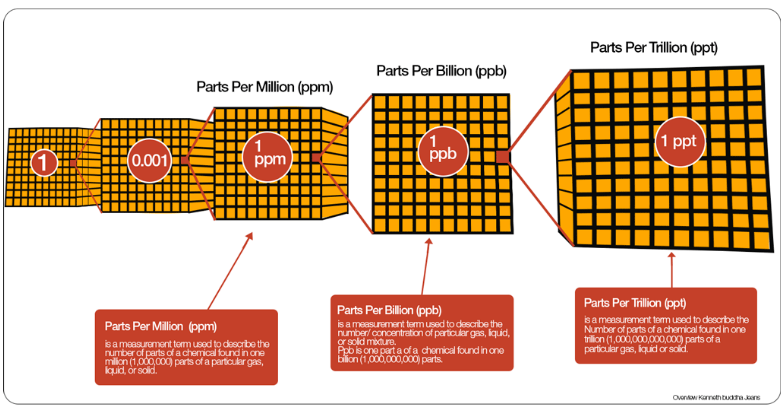
1) **Using Manipulatives as Models for Molecules:** It is often very useful to use models to represent molecules and how they can break apart and be put back together in different arrangements. This can be easily accomplished by using beads, Legos, or other items that connect interchangeably. For older students, using a separate color block for each element can work well. If you prefer, you can use Styrofoam balls to more accurately represent the shape of the molecule. Pick or paint balls in different colors and have the students break apart CO_2 to form just O2 and vice versa. If you wish to include water molecules, you can do so.

Use this reference to get the correct shapes of the molecules: CO_2:
https://images.fineartamerica.com/images/artworkimages/mediumlarge/2/carbon-dioxide-co2-molecule-model-and-chemical-formula-peter-hermes-furian.jpg
H2O: https://images.fineartamerica.com/images/artworkimages/mediumlarge/2/h2o-water-molecule-model-and-chemical-formula-peter-hermes-furian.jpg

2) **Demonstrating the Air is Made of Gas:**

a) This simple demonstration easily illustrates that the air takes up space. By taking a cup, turning it upside down and inserting it into a bowl of water, you can show that the air in the cup takes up space and prevents the water from going into the cup.
Materials: A clear plastic cup or beaker; a large bowl, preferably clear, filled with water; food coloring to make the water visible from a distance.
Procedure: *Start by asking the students what they expect to happen when you take the cup and insert it upside down into the water. Put the answers on the board, then perform the demonstration.* Ask the students to come up with other tests, such as putting the cup in sideways or upside down and predict what they expect. Ask the students for possible explanations for their observations.

b) Using your breath to blow up a balloon is another easy way to show that air exists, and also an easy way to demonstrate that the shape and volume of gases change with temperature and pressure. You can manipulate the balloon by squeezing it to show that gases change shape and size with pressure. You can also plunge the balloon into a bowl or aquarium full of ice water to demonstrate how gases change their volume according to temperature. Even though your breath is not visible, it clearly takes up space because it fills the balloon.



Demonstrate 500 ppm: Parts per million is abbreviated ppm and is used to measure very small quantities of substances in a mixture. Since 500 ppm represents 500 parts out of 1,000,000, this concept can be easily illustrated by using a diagram. A rectangle with 1,000 squares on each side represents 1,000,000 squares. Only 500 of those squares would represent 500 ppm, or 0.05% of the total number of squares. https://buddhajeans.com/encyclopedia/parts-per-million-ppm/

3) **Observation of Carbon Dioxide Gas:** Dry ice is frozen carbon dioxide. It is called dry ice because it never melts into a liquid. Frozen carbon dioxide sublimates, which means it changes phase from a solid directly to a gas without turning into a liquid first. This is one reason why it is frequently used to keep items cold because it doesn't melt as does water ice. **Students love to play with dry ice, but young children can seriously injure themselves by handling it, so this activity should be a demonstration only for children in grades K-4**. In grades 5-8, have the students form their expectations in the form of "my best guess," or hypothesis, and ask them to devise experiments that will test their hypotheses. Be sure to approve every experimental design and ensure every student understands all safety protocols before allowing them to experiment with dry ice. Their experiments should be closely monitored. Then afterward, ask them to present their findings to the class in the form of a presentation of your choice. A document could also be submitted that includes their hypothesis, experimental procedure, results and a conclusion.

   Materials: Dry ice, 10- or 20-gallon aquarium, clear cup or bowl with water, splints and matches or a lighter, tongs, a hammer or another device to break off pieces of dry ice, protective gloves and eyewear.

   Procedure: *Start by asking the students questions about what results they expect.* There are several different demonstrations you can do, so ask the students what they expect to see before you do each demonstration.

   a) Take the bulk of the dry ice, put it in the aquarium and let it sublimate until it has disappeared. Discuss what is happening.
   b) Break off a piece of dry ice and hold it with a pair of tongs up high where all the students can see it. Ask them what the white stuff is coming off the dry ice, and why does it disappear quickly. Also tell them to notice that the vapor falls to the floor instead of rising up as does steam. [The white vapor is actually water vapor from the air that instantly freezes (called deposition) as it comes in contact with the frozen carbon dioxide. It is not necessary to clarify this fact unless you want to. The vapor falls for two reasons—its density is greater than air because carbon dioxide is naturally denser than air, and its cold temperature also makes it denser than the warmer air surrounding it.] The vapor disappears quickly because the water vapor evaporates again once it gets warm enough.
   c) Fill a clear cup or bowl halfway with water, then drop a piece of dry ice into the water. Ask the students why the vapor is rising this time instead of falling. [The cold vapor is still less dense than water, so will rise to the top.]
   d) Go back to the aquarium. Once the dry ice has sublimated, it will occupy the bottom of the aquarium while pushing the air up. This is because carbon dioxide is denser than air. You may be able to see a clear boundary between the cold carbon dioxide at the bottom of the aquarium and the ambient air on top of it. [When the concentration of carbon dioxide is very high, it will push the air out of low-lying areas and will cause suffocation of any animals that are unfortunate enough to

wander into the area.] Take a burning splint (or lighter) and put it into the bottom of the aquarium; it will immediately go out because there is no oxygen in the bottom of the aquarium. This demonstration nicely reinforces the observations from the above experiment.

Source: https://volcano.oregonstate.edu/news/lake-nyos-silent-deadly

4) **Using a CO2 Detector:** Simple experiments can be performed with a CO2 meter (check the sources listed below). The experiment that Mr. Gordon performed in the book would be a good place to start. Other experiments could include covering a house plant at night, along with the CO2 meter, with a bucket. After the plant has been under the bucket overnight, check the CO2 reading from under the bucket and compare it to the CO2 levels present in the ambient air.

A similar experiment can be done if a leafy patch of woods is available. Since microbes in the soil also release carbon dioxide, a bucket can be placed over a patch of soil in the woods along with the meter and checked after a period of several hours or overnight. Finally, comparisons can be made between the levels of CO_2 in an empty room and a room with people in it. Sources of carbon dioxide meters include: https://www.amazon.com/Forensics-Battery-Quality-Incubator-Hydroponics/dp/B085VXM6P1/ref=pd_di_sccai_22?pd_rd_w=UVlAU&pf_rd_p=c9443270-b914-4430-a90b-72e3e7e784e0&pf_rd_r=35KN7CJ41JFTPA7JSZRF&pd_rd_r=623d0ddb-77eb-4813-939b-245aa709b92f&pd_rd_wg=p5qE3&pd_rd_i=B085VXM6P1&psc=1

5) **For Critical Thinking:** Earth is not the only planet in our solar system that has carbon dioxide in its atmosphere. Not only do Mars and Venus also have CO_2, a newly discovered planet outside of our solar system called HD 189733b also has carbon dioxide in its atmosphere. But if carbon dioxide is critical for life as we know it, why do these other planets not have life? Divide the students up into groups of three or four and let them develop possible explanations for this question. Have each group present their ideas to the class, then let the class decide which possible answers are the most plausible. Let the students choose the best three or four answers, then let them brainstorm in their original groups again about how to determine which answer is the best, or if all of the answers they discussed are wrong. The teacher can decide how much class time and how much time out of class the students should spend on this project. After an appropriate amount of time, let each group of students give a presentation to the class on their final conclusions. The presentations should include factual data that supports or refutes each idea along with a visual aid of some kind. One important concept that should evolve is the concept of a

limiting factor. A limiting factor is the critical resource, usually the one in the smallest supply, that determines the size of a population. For example, if a rain forest plant is planted in the desert, the limiting factor for its survival will be water. Even if all other critical resources and environmental conditions are met, the absence of one critical resource a population of organisms needs for survival will result in the population becoming extinct. That critical resource is the limiting factor. After the students have given their presentations, introduce the concept of limiting factor and have them apply it to their conclusions. Possible references include:
https://www.esa.int/Science_Exploration/Space_Science/Hubble_finds_carbon_dioxide_on_an_extrasolar_planet Formative and Summative Assessment

https://www.vanderbilt.edu/AnS/physics/astrocourses/ast201/atmospheres.html

https://www.britannica.com/science/atmosphere/The-atmospheres-of-other-planets

Formative and Summative Questions

1) There is very little carbon dioxide found in the air. Explain, using a drawing, how very small this amount is.
2) People and animals exhale when they breathe. What gases are found in their breath?
3) What is dry ice? What does it look like?
4) How do plants get the food that they need?
5) How do animals get the food that they need?
6) What things are made of carbon dioxide?
7) How do these things get their carbon dioxide?
8) Why is carbon dioxide described as a "miracle molecule"?

Next Generation Science Standards (NGSS) Learning Objectives

1-LS 1-1. Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.

- **LS1.A: Structure and Function:** All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive and grow.
- **LS1.C: Organization for Matter and Energy Flow in Organisms:** All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow.

MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

- **LS1.C: Organization for Matter and Energy Flow in Organisms:** Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (MS-LS1-6)

5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

- **LS2.A: Interdependent Relationships in Ecosystems:** The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil.
- **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems:** Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment.

5-PS-3-1. Use models to describe that energy in animals' food (used for body repair, growth, and motion and to maintain body warmth) was once energy from the sun.

- **PS3.D: Energy in Chemical Processes and Everyday Life:** The energy released [from] food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). (5-PS3-1)
- **LS1.C: Organization for Matter and Energy Flow in Organisms:** Food provides animals with the materials they need for body repair and growth and the energy they need to maintain body warmth and for motion. (Secondary to 5- PS3-1)

Source: https://www.nextgenscience.org

CO_2 Coalition Senior Education Advisor Sharon R. Camp, Ph.D., Analytical Chemistry; B.S., Geology

What is the CO_2 Coalition?

The CO_2 Coalition was established in 2015 as a 501(c)(3) for the purpose of educating thought leaders, policy makers, and the public about the important contribution made by carbon dioxide to our lives and the economy. The CO_2 Coalition is a group of the top scientists, engineers and energy experts who study and report on the important contribution made by carbon dioxide to our lives and the economy.

Learn more at CO2Coalition.org and CO2LearningCenter.com.