Lesson Plan
Chloe the Clownfish Sleeps Well

A product of the CO_2 Learning Center project and the CO_2 Coalition

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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.

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

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.

Understanding NGSS:

LS: Life Science

PS: Physical Science

ES: Earth Science

1-5 indicates standard for grade level (1-first grade, 2-second grade, 3-third grade, 4-fourth grade, 5-fifth grade). MS indicates Middle School.

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

Lesson Plan: *Chloe the Clownfish Sleeps Well*

Grades K-8

Student Learning Goals

After reading the book, students will be able to:

- Explain what a clown fish is and where it lives.
- Identify what the Great Barrier Reef is and where it is located.
- Describe how the temperature of the oceans has changed over the last 100 years.
- Locate the Coral Triangle on a map of the world.
- Explain how the growth of corals on the Great Barrier Reef has changed since 1985.
- Explain why warm oceans are good for coral growth.
- Identify whether ocean water is acidic or alkaline.

Background Information

The Great Barrier Reef is a giant reef system that is found off the northeastern coast of Australia. It is composed of about 3,000 individual reefs and is roughly the length of California, about 2,300 kilometers (1,400 miles) long.[1]

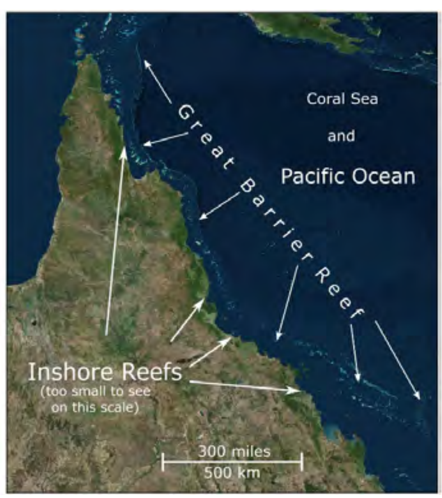
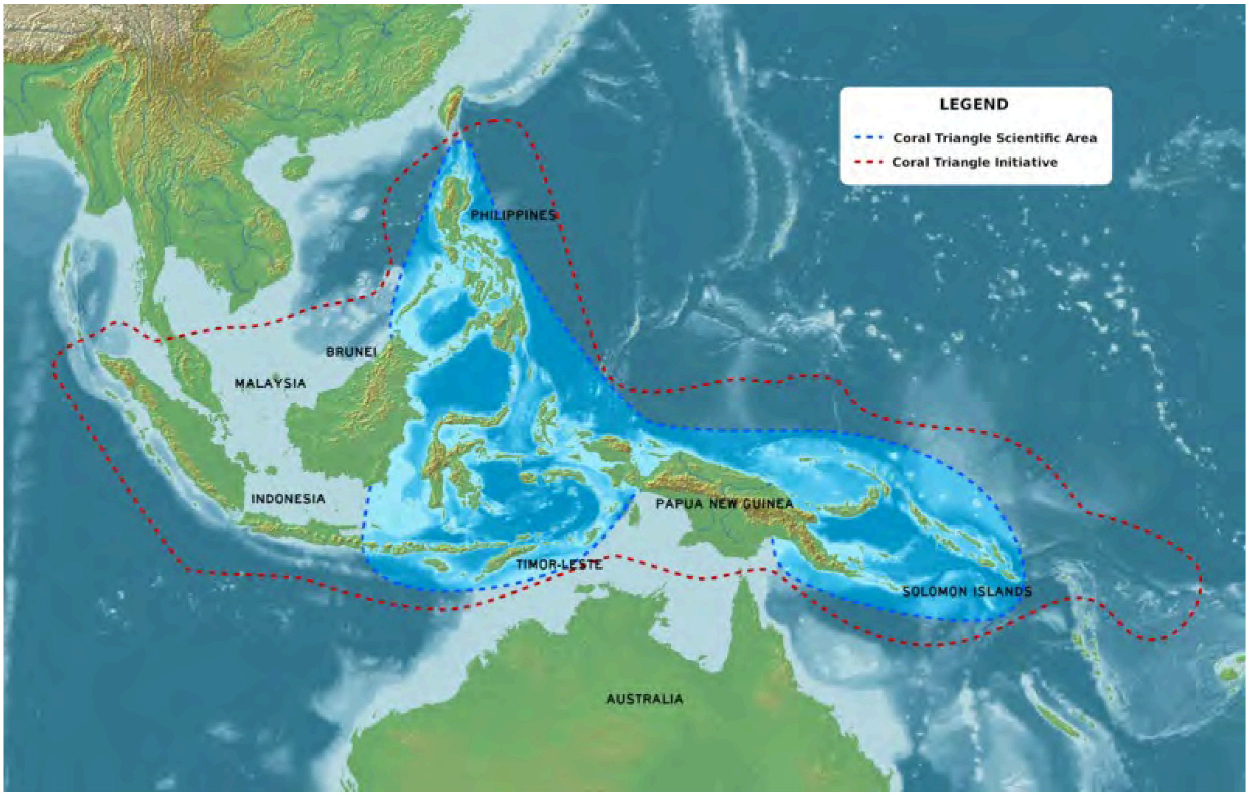


Image J. Vlok[1]

Although there are many reefs found in oceans all over the world, this is the largest. Coral reefs are most common in the Coral Triangle, which is found in the warm waters near Indonesia and New Guinea in an area called the Indo-Pacific Warm Pool by oceanographers.



Source: Obsidian Soul, map derived from File:WorldMap-B with Frame.png (created from DEMIS Mapserver), CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Coral_Triangle_and_countries_participating_in_the_Coral_Triangle_Initiative.png

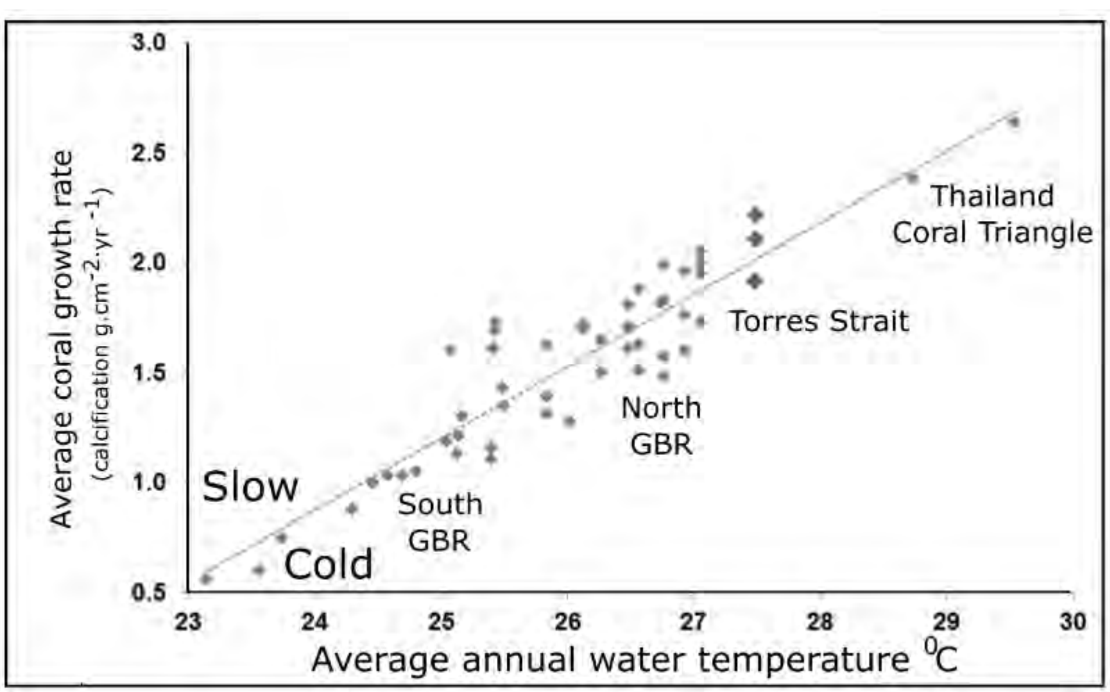
Corals are a colony of very small animals called coral polyps. Coral polyps build a house, or structure for themselves, using calcium carbonate that they extract from the ocean.

Source: https://coralreef.noaa.gov/

Corals are amazing animals in that they not only can feed themselves by eating small plankton in the water; they also have a symbiotic (mutualistic) relationship with tiny algae called zooxanthellae that are able to photosynthesize. The polyps benefit by getting extra necessary nutrition from the zooxanthellae, and the zooxanthellae benefit by getting nutrients from the polyp and by having a safe place to live, protected from predators. The zooxanthellae have pigments and give the coral polyps their color. Corals come in a large variety of species, some of which live for hundreds of years and others that only live a few decades. Some species prefer shallow water while others can be found in fairly deep water (from 5 to 100 meters).

Coral reefs, because they are composed of living organisms, will change in size and shape as their environment changes. When sea levels are low, as they are during a period of glaciation, the reefs die and become dry land. As the climate warms and the sea level rises, the corals will once again be underwater and will grow back. In fact, sea level on the Great Barrier Reef has risen by about 100 meters (over 300 feet) since 18,000 years ago. Reef systems have been on Earth since the Devonian Period.

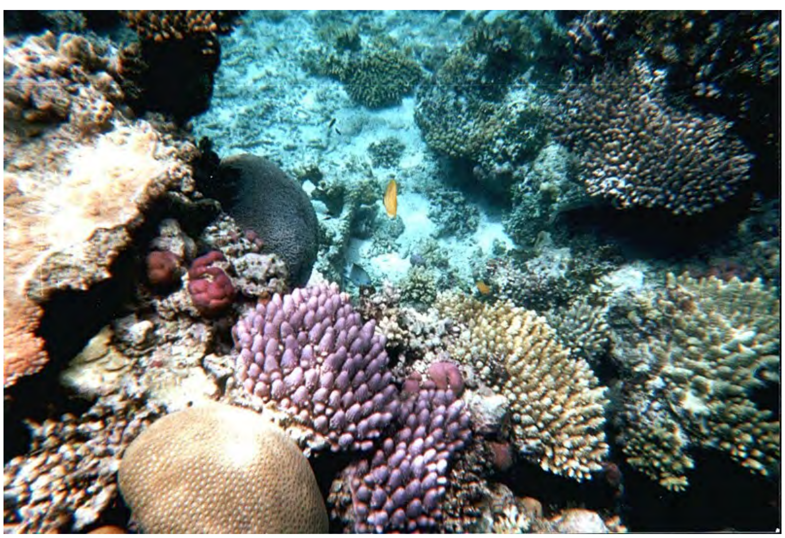
The amount of coral on each reef within the Great Barrier Reef changes over time. This reef system is so large that it has been divided into three sections: north, central and south. In Australia, the north section exists in the warmest waters and grows the fastest, whereas the south section is in the coldest waters and grows the slowest. None of the coral reefs in the Great Barrier Reef grow as rapidly as the reefs in the Coral Triangle do, however. This is because the waters closer to the equator are much warmer than the waters off the coast of Australia.[1]



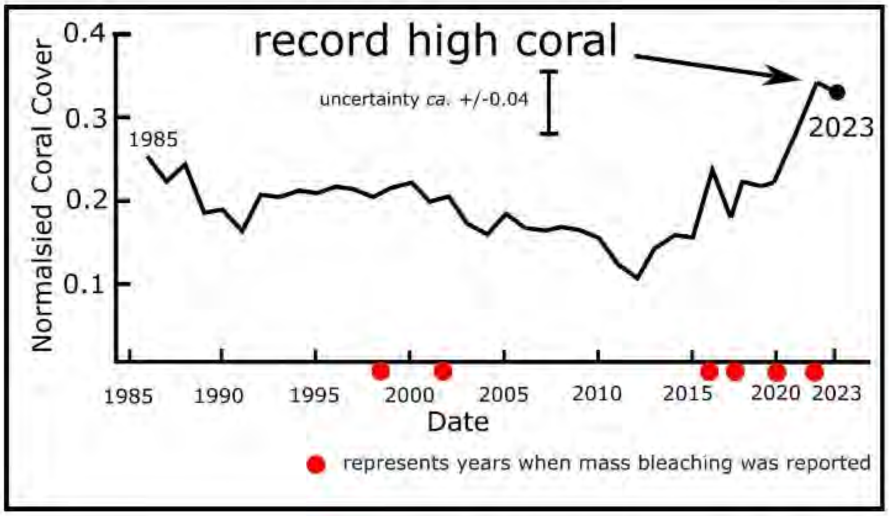
Coral growth rate vs average water temperature for *Porites* coral[2]

Porites coral. *Source: Philippe Bourjon, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons,* *https://commons.wikimedia.org/wiki/File:Porites_lutea.jpg*

Recent measurements of the Great Barrier Reef coral cover by the Australian Institute of Marine Science have shown that the current amount of cover is the highest it's been since 1985 and has twice as much cover as it did in 2012.[3] Coral cover is defined as the fraction of the seabed on a reef that is covered with hard coral. There are other types of organisms on the reef, such as soft coral or coralline algae. There are also large areas of sand composed of small pieces of broken-up coral.



Variety of corals on the Great Barrier Reef, including areas of sand and other types of organisms. *Source: Cookaa, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons,* *https://commons.wikimedia.org/wiki/File:Great_Barrier_Reef_4.JPG*



Composite coral cover data of major regions of the Great Barrier Reef[1]

Occasionally, parts of the Great Barrier Reef (as well as other reefs) will undergo a bleaching event, whereby the coral polyps expel their zooxanthellae as part of a process to reduce physiological stress, usually brought on by changes in temperature, sunlight, or salinity. This is a process that has been identified as early as 1929 and possibly earlier.[1] When the zooxanthellae no longer provide an advantageous relationship with the coral polyps, they are expelled. Since the coral must have these specialized algae to survive, they will eventually reabsorb a type of zooxanthellae that will help them survive the changes in their environment. Bleaching events do not indicate the death of the reef, as most of the corals will survive the event. Also, many surveys that report bleaching only measure the corals closest to the water's surface since they are easiest to observe but do not check the corals that live in deeper, cooler water. In this respect, the data can be skewed to represent the bleaching event as being more widespread and devastating than it is.

NOAA scuba diver surveying bleached corals. *Source: National Oceanic and Atmospheric Administration - U.S. Federal Government (all work done by the U.S. Federal Government is in the public domain), CC0, via Wikimedia Commons*

Crown of thorns starfish are a major predator of corals and are native to the Indo-Pacific region. Their populations go through boom-and-bust cycles, as do many organisms, and are affected by environmental conditions as well as the size of the populations of their predators. There are many crown of thorns starfish, but they are all characterized by their thorny appearance and their love of coral polyps. At times when the population of crown of thorns starfish is high, they can do a large amount of damage to a reef. But because the Great Barrier Reef is so large, their effect on the entire reef system is usually very small. Individual events of starfish infestation usually result in the coral cover rebounding after a few years.

Crown of thorns starfish *Acanthaster planci* devouring coral on part of the Great Barrier Reef. *Source: AIMS - LTMP, CC BY 4.0 <https://creativecommons.org/licenses/by/4.0>, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Acanthaster_planci_GBR.JPG*

Finally, large tropical cyclones cause a tremendous amount of damage to coral reefs, especially those close to the surface with a delicate structure, such as species of staghorn coral. Cyclones can reduce coral cover by 50% or more. Usually, the fast-growing pioneer species, such as *Acropora,* will be the first to return. The sturdier, deeper water coral are usually much less affected by storms.

Staghorn coral (*Acropora cervicornis*). *Source: Adona9 at the English Wikipedia, CC BY-SA 3.0 <http://creativecommons.org/licenses/by-sa/3.0/>, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Staghorn-coral-1.jpg*

Periodic bleaching events, crown of thorn starfish outbreaks, and large tropical cyclones will temporarily damage parts of the coral reef. The long-term research on the Great Barrier Reef, however, has provided data that indicate that the corals are able to recover from damaging effects. Also, since the Great Barrier Reef is so massive, only relatively small areas usually are subjected to severe damage. Additionally, some corals are more susceptible to damage from storms and bleaching than others. The corals that grow back quickly typically are the first to fill in open areas in the reef and recolonize them, restoring the coral cover in those areas.

Ocean acidification is frequently listed as a threat to coral reefs. The argument is that as carbon dioxide levels increase in the atmosphere, the amount of this gas that dissolves into the oceans also increases, thereby lowering the pH of the oceans and making them more acidic. For review, pH is a measure of the acidity or alkalinity (basicity) of a substance, usually a liquid. A pH below 7 indicates acidic solutions, while pH numbers above 7 indicate basic solutions. A neutral solution, which is neither acidic nor basic, has a pH of 7.

pH	Examples of solutions
0	Battery acid, strong hydrofluoric acid
1	Hydrochloric acid secreted by stomach lining
2	Lemon juice, gastric acid, vinegar
3	Grapefruit juice, orange juice, soda
4	Tomato juice, acid rain
5	Soft drinking water, black coffee
6	Urine, saliva
7	"Pure" water
8	Sea water
9	Baking soda
10	Great Salt Lake, milk of magnesia
11	Ammonia solution
12	Soapy water
13	Bleach, oven cleaner
14	Liquid drain cleaner

Source: OpenStax College, CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:2713_pH_Scale-01.jpg

Ocean water is basic, with an average pH of 8, while fresh water has an average pH of 6.5, which is slightly acidic. The acidity of fresh water is caused by the dissolving of carbon dioxide gas by rain drops as they fall from the sky. Also, turbulent water, such as found in fast-moving rivers and streams, will also increase water's ability to dissolve carbon dioxide gas. Ocean water also dissolves carbon dioxide gas and is considered one of the major reservoirs of carbon dioxide on Earth. So why isn't ocean water acidic? It is because ocean water contains many dissolved minerals. The mixture of these minerals in water act as a buffer solution, which means that the solution resists changes in pH.[4] Buffered solutions are frequently used in medical and pharmaceutical applications to maintain the pH of a solution, such as eye drops or contact solution. The amount of carbon dioxide in the air does not significantly change the pH of ocean water. Since the oceans are not acidic, there is no acidification of the oceans even if the pH of ocean water is lowered slightly. The slight lowering of pH of ocean water is well within the range of tolerance of the organisms that live there and poses no threat to coral reefs. The oceans have not been acidic for at least 60 million years.[5]

References

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3. Annual Summary Report of Coral Reef Condition 2021/22, Australian Institute of Marine Science. https://www.aims.gov.au/monitoring-great-barrier-reef/gbr-condition-summary-2021-22
4. R. Cohen and W. Happer. Fundamentals of Ocean pH. https://co2coalition.org/publications/fundamentals-of-ocean-ph/
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Suggested Activities

1. **Find pictures of corals online and make a book of the different types of corals.** For younger children, the idea of a coral reef may be difficult, especially if they have never been to the ocean. One way to allow children to get a better idea of what corals are and where they are located is to have the students make their own book about coral reefs. Possible pictures might include where the Great Barrier Reef is located on a globe or a map of the Earth, where the Coral Triangle is located, different species of corals that represent different shapes (branching or stag horn corals, massive corals, soft corals, brain corals, etc.). Have the students write the common name for the corals along with their scientific names. Older children could research the different kinds of corals and where each kind is found, or perhaps just identify the species of corals that are found on the Great Barrier Reef. If the student has been to a coral reef in Hawaii or somewhere in the Caribbean, perhaps a book of the types of corals the student has seen would be interesting. Some students may enjoy researching from books. For these students, the educator could assign a report, which could either be written or given as a presentation.

2. **Compare data among several different reefs that are part of the Great Barrier Reef. Determine whether the reef is under a serious threat of extinction, or if the reef is subject to change based on the natural variability of its environment.** The Capricorn-Bunkers sector, one of the eleven sectors into which the GBR is divided, has a record high coral cover, around three times its lowest value in 2011. This sector has been through two cycles of crash and recovery since 1985. Data is available for this sector here. Pick four individual reefs at random from this sector. Examine the graph for each of the individual reefs and answer the following questions:

a. Were any of these reefs affected by natural disasters? If so, which reefs, what disasters, and how many times?
b. What happened to the coral cover of each reef after each natural disaster?
c. What is the average amount of time required for a reef to return to the coral cover measured before the disaster, based on these four reefs?
d. Did any of the reefs not recover from the disaster? If so, which ones and what criteria were used to determine this?

Prepare a report or presentation that summarizes the conclusions from the above questions. Make sure the report includes copies of the data obtained from the website.

3. **Compare and contrast species of coral and how they were affected by natural disasters.** Data for One Tree Island Reef can be found here. This reef has been damaged by both starfish infestations and cyclones. Examine the line graph and answer the following questions:

    a. What happened to the coral cover after back-to-back cyclones in 2008 and 2009?
    b. Scroll down to the bar graph underneath the line graph and move the mouse over the population of corals measured in the year 2011. What were the species of coral, and how much of each were there?
    c. What were the species of coral present in 2022, and how much of each were there?
    d. What happened to the coral cover from the years 2011 to 2022?
    e. Did the relative populations of the coral species change over this time? If so, how? Why might a change have occurred in the relative populations of coral?
    f. What natural disaster is currently affecting the coral population on this reef?
    g. In general, did the coral cover on this reef recover from the cyclones? What is the supporting evidence for your conclusion?
    h. On this coral reef, which had a greater effect on coral cover, cyclones or starfish? What is your evidence?
    i. If you had started monitoring coral cover on this reef only from 1993 until 2011, what might your conclusions be about the reef's ability to recover from the devastating cyclones?

4. **Examine the history of coral cover on Helix Reef.** Examine the data for Helix Reef here. This reef has also been damaged by both starfish infestations and cyclones. Examine the line graph and answer the following questions:

    a. Which disaster has had a larger effect on the Helix Reef, starfish infestations or cyclones? Use data from the graph to support your answer.
    b. Did the disaster permanently affect the coral cover on the reef? Why or why not? Use data to support your answer.

5. **Examine the effect of coral bleaching on a reef sector.** The Cairns Reef sector, located in the Central section of the Great Barrier Reef, has multiple reefs that have been

affected by a major bleaching event that occurred in 2016-2017. Pick any four reefs from this sector and examine their data. Give a report or presentation on whether bleaching events in this reef sector caused permanent, irreparable harm to the reefs. Use data from the website to support your argument. Your report should include the following sections: title, introduction, presentation of data, data analysis, and conclusion.

Formative and Summative Questions

1. What is a clownfish? Where are clownfish found?
2. What is the Great Barrier Reef? Where is it located?
3. Has the temperature of the Earth's oceans changed over time? If so, how?
4. Where is the Coral Triangle? Is it the same thing as the Great Barrier Reef? If not, how are they different?
5. In general, how has the growth of corals on the Great Barrier Reef changed since 1985?
6. Do corals prefer warm oceans or cold oceans? How do you know?
7. Is ocean water acidic or basic?

Next Generation Science Standards (NGSS) Learning Objectives

Please note that the standards that cover the material in this lesson plan are only found in the 5th grade and middle school curricula. The standards here are written exactly as they are written in the NGSS.

5-PS3 Energy. Students who demonstrate understanding can:

5-PS3-1. 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. This standard includes the following Disciplinary Core Ideas:

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).

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.

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. This standard includes the following Disciplinary Core Ideas:

LS1.C: Organization for Matter and Energy Flow in Organisms

- Plants, algae (including phytoplankton) and many microorganisms use 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.

PS3.D: Energy in Chemical Processes and Everyday Life

- The chemical reaction by which plants produce complex food molecules (sugars) uses sunlight as an energy input. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.

MS-LS1-7 From Molecules to Organisms: Structures and Processes. Students who demonstrate understanding can:

MS-LS1-7. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. This standard includes the following Disciplinary Core Ideas:

LS1.C: Organization for Matter and Energy Flow in Organisms

- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules to support growth or to release energy.

PS3.D: Energy in Chemical Processes and Everyday Life

- Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.

Source: https://www.nextgenscience.org

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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, policymakers 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.