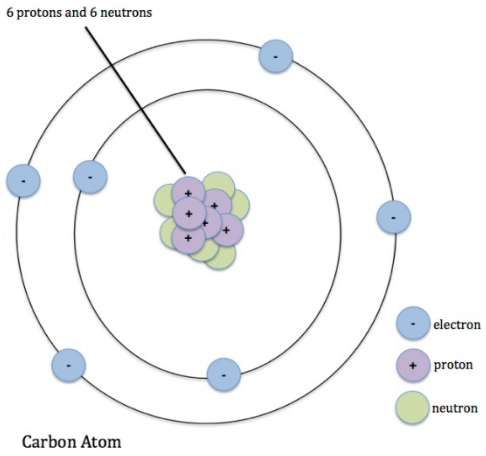
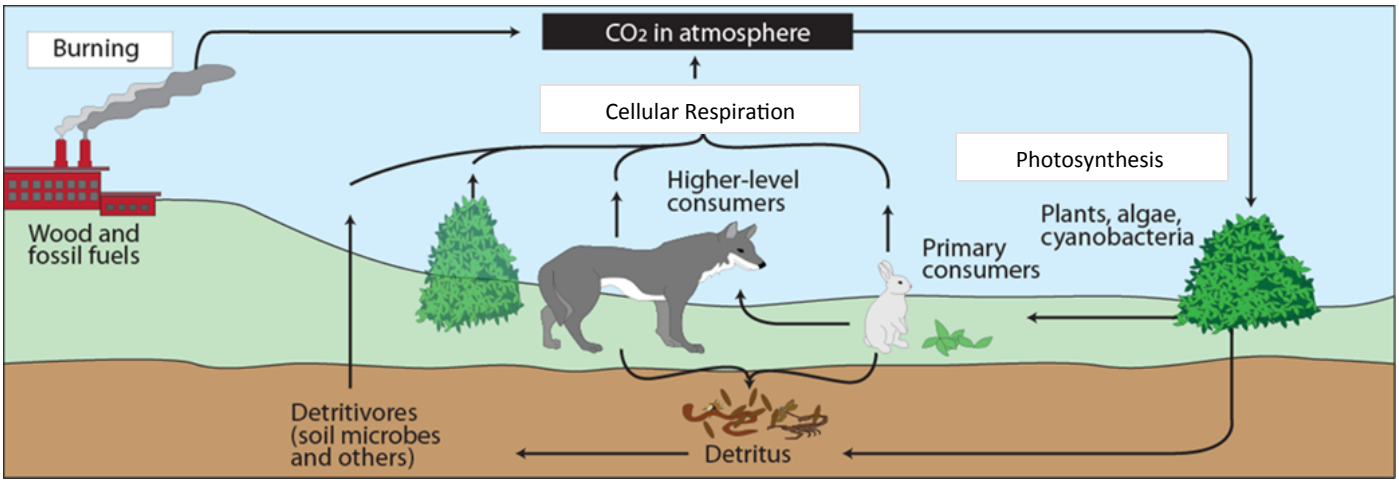
Student Reference Sheet: Carbon, the Element

The element carbon is one of the most essential elements on our planet. All living organisms contain carbon, making it a critical component of all life on planet Earth. In fact, the element carbon makes up close to half of the "dry weight" of all living things!

Carbon is also recycled through the decomposition of organic materials in soil. Carbon sources may also be stored under ground as coal or petroleum, two forms of fossil fuels. When carbon sources are released to the atmosphere, this is known as carbon emissions. The growing amount of the number of carbon atoms emitted as a result of chemical combustion has had an effect on global climate change, which is the belief that Earth's climate is changing at a rapid pace as a result of an imbalance in human contributions to the atmosphere.

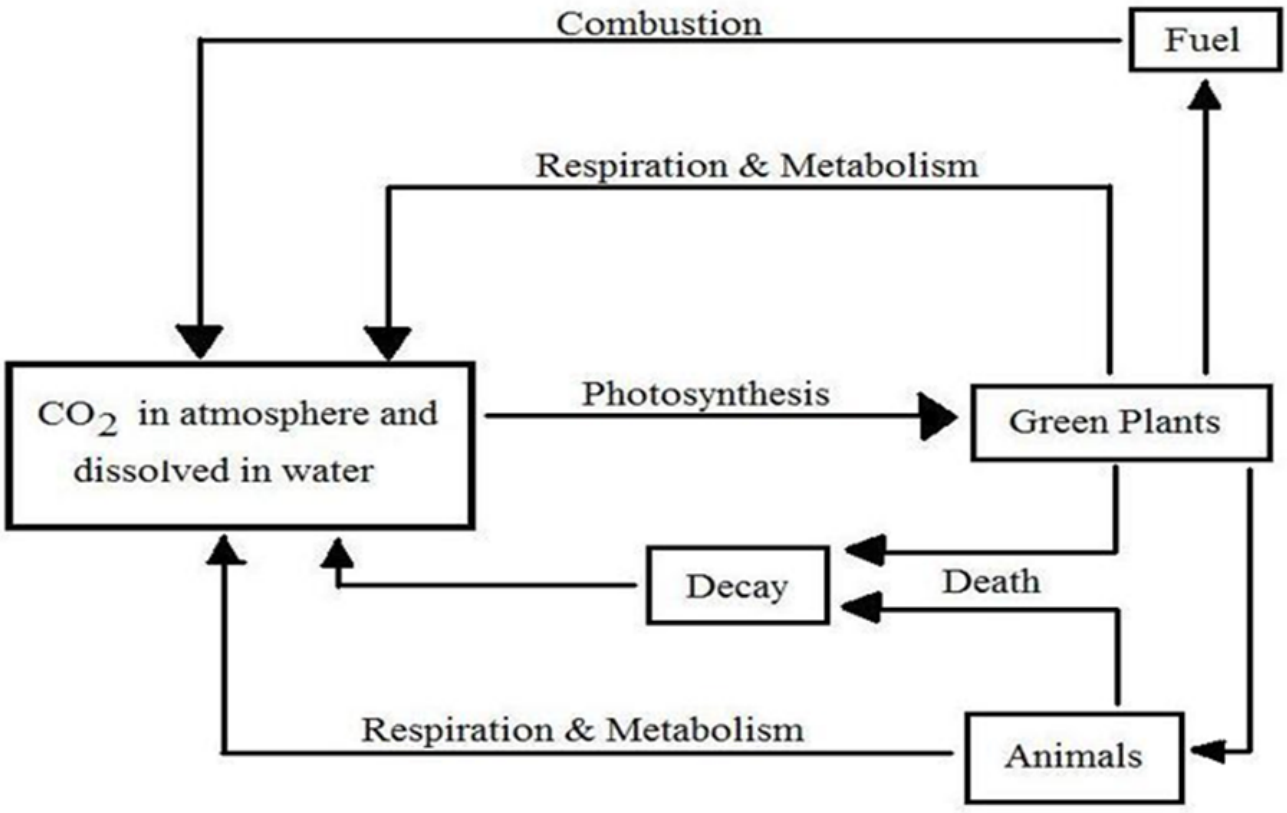




Student Reference Sheet: Carbon Cycle

The carbon cycle is one critical cycle that links the atmosphere, the hydrosphere, and the lithosphere. The element carbon is a form of matter that is recycled through these "spheres" fairly evenly, and it is essential that this element remain balanced in the biosphere.

Plants have a high demand for the carbon dioxide available in the atmosphere for the process of photosynthesis. The rate of removal of carbon dioxide from the atmosphere is roughly balanced by the cellular respiration that occurs in both plant and animal cells, which releases carbon dioxide back into the atmosphere.



Basic Carbon Cycle Flow Diagram

Student Reference Sheet: Carbon Cycle, continued

The element carbon cycles through systems on planet Earth in these processes:

- from the atmosphere to plants (photosynthesis)
- from plants to animals (food web)
- from plants and animals to the ground (decomposition and waste)
- from living things to the atmosphere (respiration and metabolism)
- from fossil fuels to the atmosphere when fuels are burned (combustion)
- from the atmosphere to the oceans, and vice versa (diffusion)
- from volcanic eruptions and other geothermal processes that release gases into the atmosphere

Carbon may be found in these nonliving forms:

- in the atmosphere as carbon dioxide (**C**O_2)
- dissolved in water as hydrogen carbonate ions (H**C**O_3^-)
- in limestone, or as calcium carbonate in rocks (Ca**C**O_3)
- in sedimentary deposits (coal, oil, etc.) made from once living organisms
- as dead organic matter, such as found in peat moss in the soil

Carbon moves from the atmosphere to the terrestrial biosphere (hydrosphere and lithosphere) by these means:

- Plants use the carbon found in carbon dioxide (**C**O_2) and convert it to sugars (**C**$H_2O)_n$ through the process of photosynthesis.
- Animals eat the plants, and the carbon moves through the food chain.
- When living organisms die, their bodies return to the soil through the process of decay, releasing carbon (**C**) and other carbon byproducts directly into the ground.

Carbon returns to the atmosphere by these means:

- As carbon dioxide (**C**O_2) through respiration or burning (of organic matter or fossil fuels).
- From the process of decay as carbon dioxide (**C**O_2) or methane (**C**H_4).
- By volcanic eruptions or other emissions from the interior of the planet.

Student Reference Sheet: Carbon and the Atmosphere

Carbon makes up a very small portion of Earth's atmosphere, yet this element can have dramatic effects on Earth's climate. Carbon dioxide (CO_2) is considered a greenhouse gas because it has the ability to absorb infrared radiation. At pre-industrial levels (around 280 ppm), this compound's ability to hold heat was critical to supporting life on Earth, as this effect helped trap the Sun's energy in the form of heat. However, at elevated levels (around 400 ppm as of 2012), carbon dioxide's ability to absorb heat could contribute to elevated temperatures on Earth's surface, which may potentially cause global climate change.

Sources of CO_2 emissions may be natural, such as volcanoes, forest fires, the decay of organic matter, or animal respiration. At normal CO_2 atmospheric concentrations, the oceans are able to absorb and remove carbon from the atmosphere. Sources that remove carbon are known as carbon sinks. Plants are another carbon sink. Since the industrial revolution, the burning of fossil fuels has added CO_2 to the atmosphere at a rate faster than the sinks can keep up with. Deforestation, caused by industry, forest fires, or pine beetle kill* has also removed a large part of Earth's carbon sink system, making the problem of above normal CO_2 levels in the atmosphere worse.

*The mountain pine beetle carries a fungus on its body. When it bores into trees, the fungus will interfere with the water transport system of the trees, thereby killing the trees. This has become an increasing problem in the northern Rocky Mountain region over the past decade.

Student Reference Sheet: Carbon and the Lithosphere

Carbon dioxide (CO_2) taken from the atmosphere is used for photosynthesis in the leaves during the day, creating sugars $(CH_2O)_n$. At night, the leaves release carbon dioxide (CO_2) back into the atmosphere as a product of cellular respiration. When leaves or fruit fall from a plant, or when the plant dies, carbon (C) is released into the ground through decomposition.

Carbon is ingested by animals when they eat plants. The carbon could be in the form of sugars and carbohydrates ($(CH_2O)_n$), nucleotides (the building blocks of DNA and RNA), amino acids (the building blocks of proteins), or fatty acids. As animals eat sugars and other carbon sources, they produce carbon dioxide (CO_2) as a waste product of cellular respiration and release this back into the atmosphere.

Animals also produce waste (feces), which releases carbon (C) back into the ground. When animals breathe, they release carbon dioxide (CO_2) back into the atmosphere. Livestock and other animals release methane gas (CH_4) in to the atmosphere. When animals die, solid carbon (C) is released into the ground through decomposition, and methane gas (CH_4) is released to the atmosphere. Microorganisms and fungi also release carbon dioxide (CO_2) as they decompose organic matter.

Fossil fuels are often locked underground for millions of years. Fossil fuels are found in sedimentary rocks. These types of rocks may be found between the surface of Earth and the upper mantle, both on land and at the bottom of the ocean as marine sediments. The types of fossil fuels found in sedimentary rocks include oil, coal (C), natural gas or methane (CH_4), and peat. Burning fossil fuels (coal, oil, natural gas) releases carbon dioxide (CO_2) that has been stored for millions of years back into the atmosphere.

Volcanoes and other geothermal systems release carbon stored in Earth's crust and mantle to the atmosphere in the form of carbon dioxide (**C**O_2).

Forests can store up to 86% of the total carbon found on the surface of Earth, and they store up to 73% of the carbon found in the soil of Earth. When forests burn, whether caused by man or nature, massive amounts of carbon dioxide (**C**O_2) are released to the atmosphere.

Student Reference Sheet: Carbon and the Hydrosphere

The upper portion of the ocean is known as the "mixed layer" of the ocean. It ranges from the surface to 75 m water depth (below the surface). The mixed layer is where most life exists in the oceans and includes marine plants that use carbon dioxide (CO_2) for photosynthesis. The mixed layer of the ocean "soaks up" a lot of the carbon dioxide (CO_2) from the atmosphere through the process of diffusion. Phytoplankton also live in this layer (microscopic plants and algae) and absorb most of this CO_2. Marine organisms eat the marine plants, keeping the food chain going.

Sediments from erosion and weathering flow from the land (lithosphere) to the rivers to the oceans. Organic materials (C) from dead or decaying matter are carried to the oceans via rivers. Many minerals and salts make their way to the oceans in this manner, but calcium carbonate ($CaCO_3$) is one of the more important compounds to reach the ocean. When these sediments reach the oceans, they dissolve into carbonate ions (CO_3^{-2}). Many sea creatures use the carbonate ions as the main building blocks for shell and exoskeleton production. In fact, many marine organisms' shells are made from calcium carbonate ($CaCO_3$).

When carbon dioxide (CO_2) diffuses into seawater, it creates a type of acid known as carbonic acid (H_2CO_3). This acid releases hydrogen ions into the water, which increases the acidity of the water. The free hydrogen ions will combine with the carbonate ions (CO_3^{-2}), creating bicarbonate (HCO_3^-). This reaction makes the required carbonate ions less available to marine organisms and greatly affects their ability to produce protective shells. As CO_2 levels increase in the atmosphere, the carbonic acid (H_2CO_3) concentration in the oceans also increases.

The bottom portion of the ocean is the "deep ocean," and it ranges from 75 m to 3700 m. The deep ocean is where much of the decaying matter falls. As marine organisms (such as an orca whale) die, they float to the bottom of the ocean, creating sediments that eventually turn into limestone ($CaCO_3$). The majority of this carbon comes from the bones and the shells of the marine organisms.

Student Reference Sheet: Carbon Cycle Disruptions

A disruption is an act that delays or interrupts the continuity of a cycle. A disruption in a cycle of matter leads to an imbalance of elements within an ecosystem, or in one of the "spheres," which could lead to an imbalance in the biosphere.

The carbon cycle is disrupted when the element is no longer in balance between the lithosphere, the hydrosphere, and the atmosphere. The amount of carbon-containing compounds in the atmosphere has been steadily increasing in recent decades. The consequences of the increase in carbon emissions are not yet fully known, but there have been noticeable changes in weather patterns, species distribution, and the warming of the poles. All of these events together may be contributing factors to global climate change. This change is reflected as a change in the balance of the biosphere.