

Carbon Cycle

Carbon

All life is based on the element carbon that has the symbol 'C' and the atomic number 6. Carbon is the major chemical constituent of most living matter including human-beings. Yet by weight, carbon is not one of the most abundant elements on the Earth's crust. In fact, the lithosphere is only 0.032% carbon by weight. In comparison, oxygen and silicon respectively make up around 45% and 29% of all rocks.

Carbon is stored on the planet in the following major reservoirs: (1) as organic compounds (e.g. sugar, starch) in living and dead organisms in the biosphere; (2) as the gas carbon dioxide (CO₂) and methane (CH₄) in the atmosphere; (3) as organic matter in soil; (4) in the lithosphere as fossil fuel and sedimentary rocks such as limestone (including chalk) and dolomite; (5) in the oceans as dissolved hydrocarbons and as calcium carbonate in the shells of marine creatures (e.g. coral).

The movement of carbon, in its many forms, between the atmosphere, hydrosphere, biosphere, pedosphere and lithosphere is described by the carbon cycle (see figure right).

The carbon cycle is the great natural recycler of carbon atoms. The same carbon atoms in your body today have been used in countless other molecules since time began. The wood burned just a few decades ago could have produced carbon dioxide which through photosynthesis became part of a plant. When you eat fruit and vegetables, the same carbon from the wood, which was burnt, can become part of you. Ultimately, the same carbon atom can move through many organisms and even end in the same place where it began. Herein lies the fascination of the carbon cycle; the same atoms can be recycled for millennia!

The global carbon cycle, one of the major biogeochemical cycles, can be divided into a geological and a biological component. The geological carbon cycle operates on a time scale of millions of years, whereas the biological carbon cycle operates on a time scale of days to thousands of years.

The Geological Carbon Cycle

Since the formation of the Earth, geological forces have slowly produced carbonic acid, (a weak acid formed by the reactions between atmospheric CO₂ and water):



In some conditions, carbonic acid will break down to produce water and CO₂. This oscillating reaction continues until a chemical equilibrium is achieved.

Carbonic acid is important in controlling the acidity (pH) of the oceans by releasing of hydrogen ions and bicarbonate:

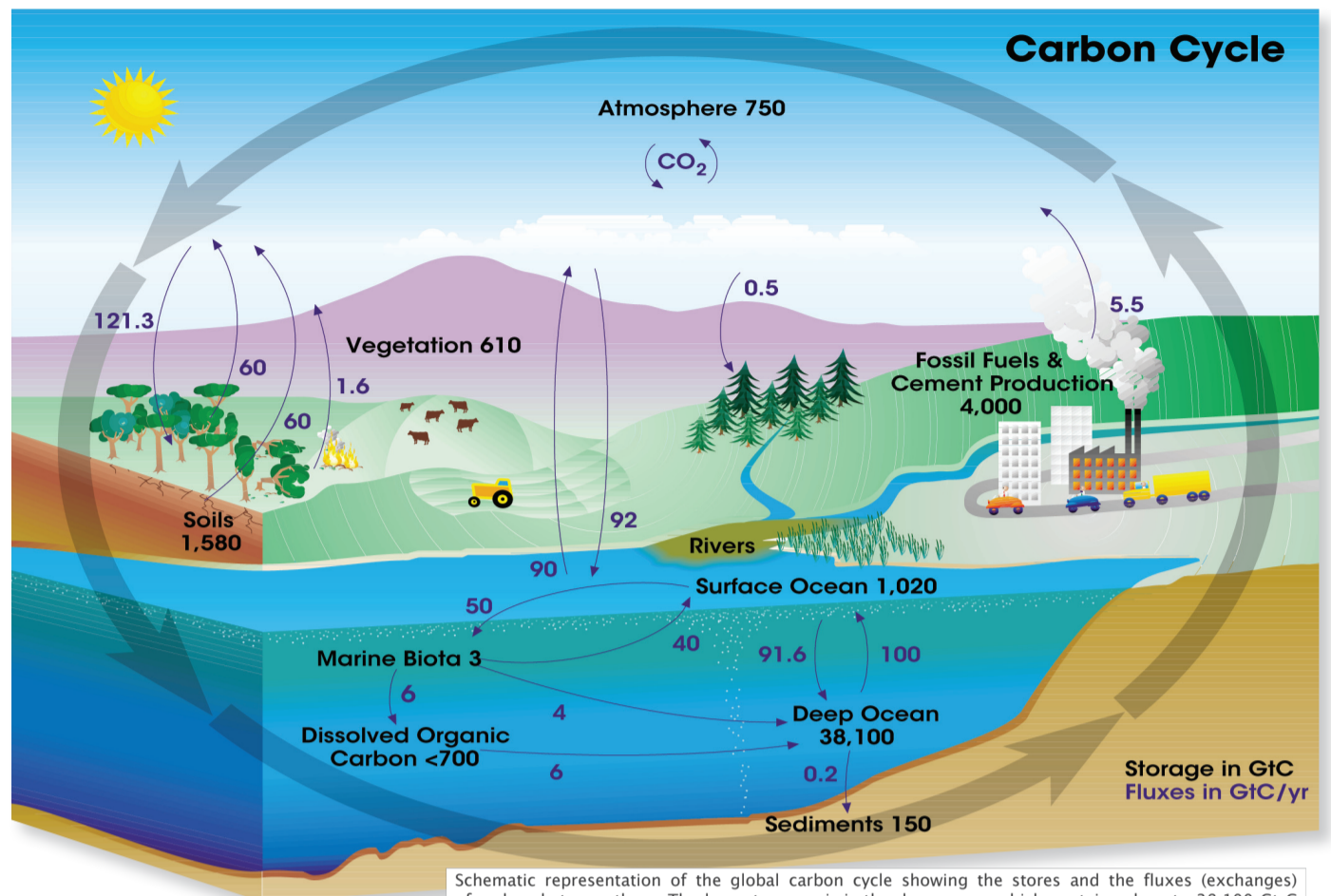


Certain forms of sea life biologically fix bicarbonate with calcium (Ca²⁺) to produce calcium carbonate (CaCO₃). This substance is used to produce shells and other body parts by organisms such as coral, crustaceans, some protozoa, and some algae. When these organisms die, their shells and body parts sink to the ocean floor where they sediment as carbonate-rich deposits (see photo below) and form reefs.

Over long time-scales carbonic acid slowly combines with minerals at the Earth's surface. These reactions form carbonates (carbon-containing compounds) through a process called weathering. Erosion can transport carbonates into rivers which are eventually washed into the ocean, where they settle to the sea bed.



Limestone (calcium carbonate) blocks separated by deep fissures resulting from chemical weathering by rainwater. Limestone is one of the commonest rocks on the Earth. (AB)

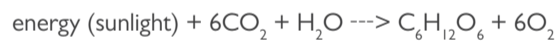


Schematic representation of the global carbon cycle showing the stores and the fluxes (exchanges) of carbon between them. The largest reservoir is the deep ocean which contains close to 38,100 Gt C compared to around 2,190 Gt C on land, 750 Gt C in the atmosphere and 1,020 Gt C in the upper ocean (1 Gt is one billion tons). The atmosphere, biota, soil and the upper ocean are strongly linked. The exchange of carbon between this fast-responding system and the deep ocean takes much longer (several hundred years). Recent studies show that even more carbon is locked in soils – see page 121. (NASA)

The Biological Carbon Cycle

Biology plays an important role in the movement of carbon between the land, ocean, and atmosphere through the processes of photosynthesis and respiration.

Through photosynthesis, green plants use solar energy and water to turn atmospheric CO₂ into carbohydrates (i.e. sugars, starch and cellulose):



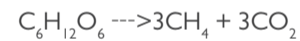
Carbohydrates are the principle compounds that are necessary to build up biomass for plants or the bodies of animals. Most carbon leaves the biosphere through respiration, the decomposition of dead organic matter (e.g. litter fall), which is the opposite process of photosynthesis.

When oxygen is present, aerobic respiration occurs, which releases carbon dioxide into the surrounding air or water, following the reaction



Respiration frees the energy contained in the sugars for use and transforms carbohydrate 'fuel' back into carbon dioxide, which in turn is released back to the atmosphere. The amount of carbon taken up by photosynthesis and released back to the atmosphere by respiration each year is about 1,000 times greater than the amount of carbon that moves through the geological cycle on an annual basis.

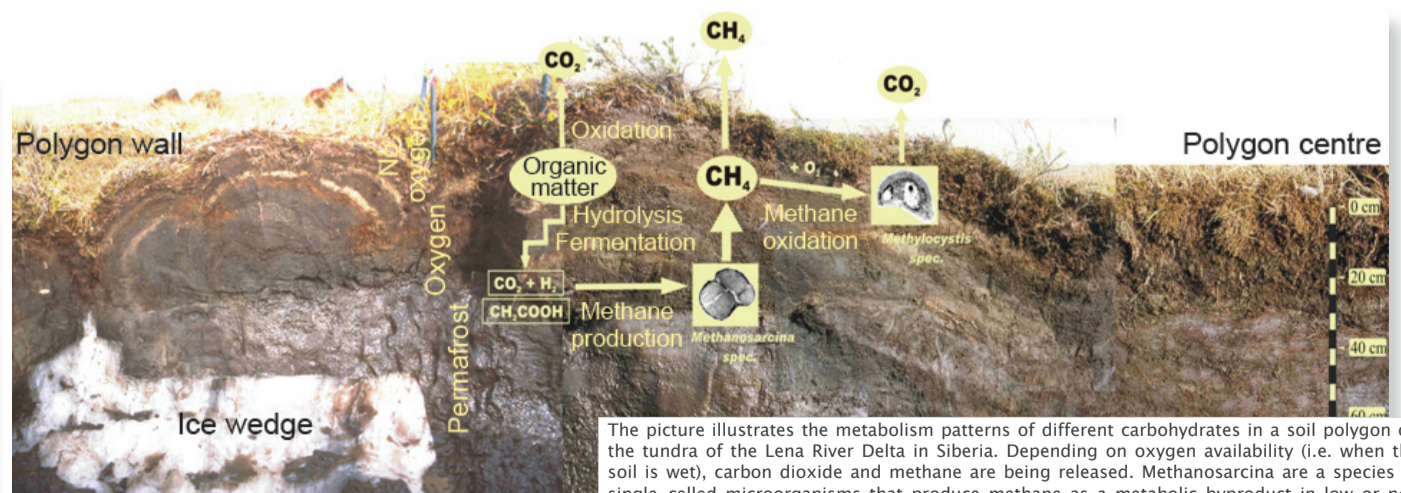
When oxygen is lacking, for example, in soil that is stagnant due to poor drainage (often showing the characteristic olive and blue colours of gleyic conditions), then the breakdown of carbon compounds is carried out by microbial communities (e.g. Methanobacterium-, Methanosaeta- and Methanosarcina-like groups) that catalyze the breakdown of organic matter without oxygen (anaerobically) to produce methane and carbon dioxide following the equation below:



Carbon dioxide and methane are important greenhouse gases that affect the Earth's climate. Their production makes soil an important component in the study of climate change.



Soil regulates a number of life-sustaining natural biological, geological and chemical cycles. Soil provides food resources, space for natural habitats and maintains a unique biodiversity of flora and fauna. A clear understanding of the functional capability of the northern soils is vital for planning the sustainable development of global environmental resources. The dark patches in the soil directly under this vibrant moist, acidic tundra from northern Alaska are organic matter accumulations that are rich in carbon. (CP)



The picture illustrates the metabolism patterns of different carbohydrates in a soil polygon on the tundra of the Lena River Delta in Siberia. Depending on oxygen availability (i.e. when the soil is wet), carbon dioxide and methane are being released. Methanosarcina are a species of single-celled microorganisms that produce methane as a metabolic byproduct in low or no-oxygen conditions. They are common in wetlands, where they are responsible for marsh gas. Methylocystis is a type of bacteria that is capable of obtaining carbon and energy from methane. Fermentation, oxidation and hydrolysis are all processes which describe the breakdown of organic matter to carbon or compounds of carbon with hydrogen or oxygen. (EP, DWA, SK, LK)