Carbon’s central role

The sixth element on the periodic table supports life as we know it

The more we explore our planet, the greater the diversity of life we encounter, from microorganisms that can survive inside volcanoes to fish thousands of miles below sea level. Some forms of life that have been discovered look almost extraterrestrial.

The wide range of biodiversity on Earth relies largely on four major building blocks: hydrogen, oxygen, carbon and nitrogen. (Sulfur and phosphorus are also important but in smaller amounts.)

Chemical structure

Many scientists describe life as we know it as ‘carbon-based’. Fundamentally, without carbon, life on Earth would not be possible.

Carbon is a relatively small atom: its nucleus contains six neutrons and six protons. It has a full inner shell (two electrons) and four electrons in its outer shell. Having four electrons means it can form many different types of bonds.

Carbon also forms covalent bonds with several other atoms, such as hydrogen, oxygen, nitrogen, and sometimes sulfur and phosphorus. Carbon readily forms single, double or triple bonds, chains, branched chains and even rings. It can bond with itself, as well, to form strong substances like diamond and graphite.

This versatility and ability to form many bonds enables carbon to form the many different shapes adopted by the complex organic compounds that make up the bodies of animals and plants. Some of the carbon chains needed for life are millions of atoms long.
Carbon in biomolecules

Living things use carbon in a vast number of molecules in their bodies.

Carbohydrates, lipids, proteins and nucleic acids all contain carbon. This means that we find carbon in everything from cell membranes to hormones to DNA.

Carbon's versatility means that it is the basis of many of the complex organic compounds vital to life, such as the glucose ring (along with a single oxygen molecule), and the backbone of the polypeptide chains that form the different proteins in the bodies of living things.

**Polypeptide chain**

![Diagram of a polypeptide chain, highlighting the carbon atoms that forming its 'backbone'](CC BY Big Picture/Bret Syfert)

Carbon bonds with different elements in different kinds of molecule. To make carbohydrates and lipids, carbon usually bonds with hydrogen and oxygen. For proteins, carbon will bind with hydrogen, oxygen and nitrogen (and sometimes sulphur). For nucleic acids, carbon binds with hydrogen, oxygen, nitrogen and phosphorus. (See 'Big Picture: Proteins' for more information.)

**Sucrose**

![Diagram of a sucrose molecule, highlighting the carbon rings](CC BY Big Picture/Bret Syfert)

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The carbon cycle

Living things get almost all of the carbon they need from carbon dioxide, found in the Earth’s atmosphere or dissolved in water. Even though carbon is vital to life, carbon dioxide is only a small part of our atmosphere. The most common gases in the Earth’s atmosphere are nitrogen (78 per cent) and oxygen (21 per cent). The remaining 1 per cent is made up of carbon dioxide, noble gases and water vapour.

On Earth, carbon is continually recycled between the atmosphere, plants and animals. This system is called the **carbon cycle**. The cycle involves several key processes:

- photosynthesis
- respiration
- combustion
- decomposition
- fossilisation.

The proportion of carbon dioxide in the Earth’s atmosphere has remained much the same for the past 200 million years, thanks to the biological and geological processes that form the carbon cycle.

Atmospheric carbon dioxide gas (CO₂), found in the atmosphere, is absorbed by green plants. Green plants use carbon dioxide during photosynthesis, in which carbon dioxide and water are used to produce glucose (which gives the plant energy) and oxygen. Plants are known as carbon sinks because they absorb carbon dioxide from the atmosphere and ‘fix’ or hold onto carbon in the form of glucose within their tissues.

Plants are then eaten by consumers. When this happens, the carbon, now in the form of carbohydrates, moves from plants to animals. These carbohydrates are used by the consumers during respiration, in which glucose and oxygen are converted into carbon dioxide, water and energy. The consumer uses this energy for all the processes in its body (but note that all organisms – even plants and decomposers – use carbohydrates during respiration).

The processes of combustion (burning fossil fuels) and decomposition (breaking down dead organic matter) also release locked-up carbon dioxide back into the atmosphere.
Meanwhile, another major pathway takes place in the sea. Marine organisms use carbonates to make their shells. These organisms die and their shells fall to the sea floor, eventually forming limestone rocks. During volcanic eruptions and natural weathering, carbon dioxide is released back into the atmosphere.

However, human activities can disrupt the carbon cycle, and we are now changing the level of carbon dioxide in the atmosphere. Carbon dioxide is released into the air when fossil fuels are burnt. As energy use increases across the world, the amount of carbon dioxide entering the atmosphere increases too. In addition, forests are being cleared to make way for farms and other uses of land, reducing the amount of carbon dioxide absorbed by trees. In this way, human actions are increasing the amount of carbon dioxide in the atmosphere, causing widespread changes to the Earth’s climate.

To find out more about human interaction with the carbon cycle, see our Health and Climate Change poster.

REFERENCES

- CGP AS-level Biology Revision Guide
- Open University: An Introduction to Astrobiology
- Big Picture: The heat is on
- Video: That’s why carbon is a tramp
- National STEM Centre: Climate Change
- GCSE Bitesize (BBC): The Earth’s atmosphere
- Royal Society of Chemistry: Resources on carbon
- Royal Society of Chemistry: Carbon video