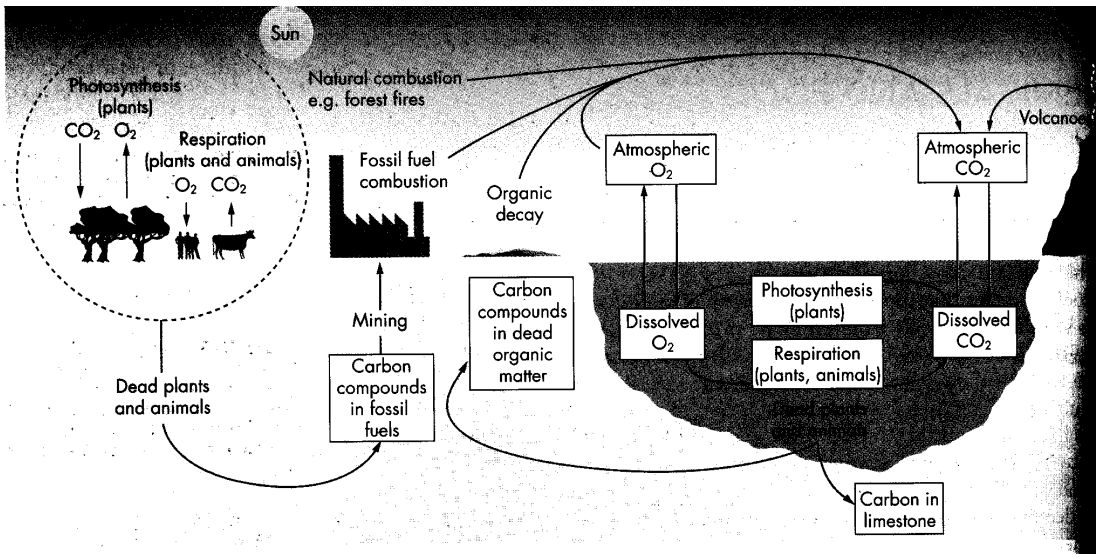
THE CYCLING OF MATTER THROUGH THE BIOSPHPHERE

The number of atoms present on Earth today is theoretically exactly the same as the number present millions of years ago when the Earth was formed. The only difference is that the atoms have been rearranged into different compounds due to chemical reactions and moved around the **biosphere** by the action of water and the atmosphere. An understanding of the mechanisms by which certain atoms move around the atmosphere is of great importance for improving agriculture and dealing with water and air pollution. The cycling of carbon, oxygen and nitrogen in the biosphere is of great interest for this reason.

THE CARBON-OXYGEN CYCLE

Carbon and oxygen are often combined in compounds so the cycling of these 2 elements in the biosphere is linked.

This diagram summarises the mechanisms by which carbon and oxygen move around the biosphere.



During photosynthesis, green plants take in carbon and oxygen in the form of CO_2 and H_2O. The main product of photosynthesis, $C_6H_{12}O_6$, is converted into other organic compounds such as complex carbohydrates, lipids and proteins. The carbon and oxygen present in these compounds are passed along the food chain when animals eat plants.

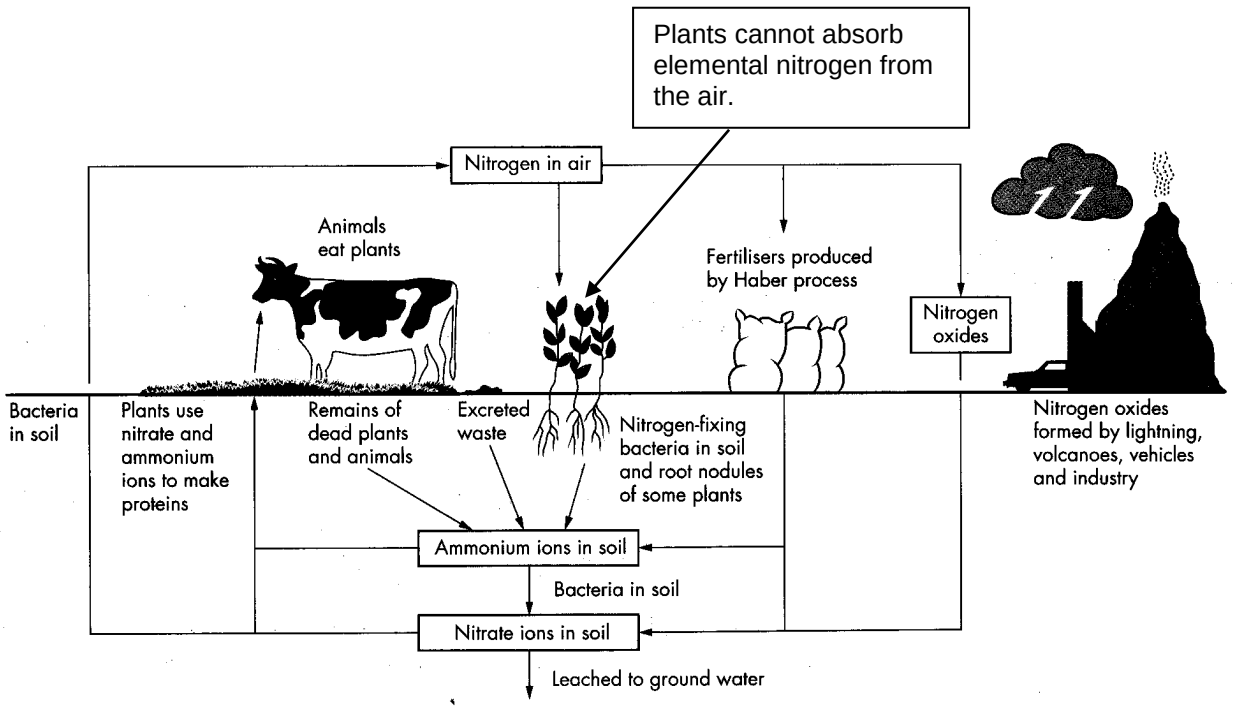
The carbon and oxygen in plants and animals are returned back into the atmosphere in the form of CO_2 during respiration and decay when these organisms die.

If the conditions are right, organisms will not fully decay and carbon is not directly released into the atmosphere. Fossil fuels such as coal, natural gas and oil are formed over a period of millions of years as the remains of organisms decay.

On the ocean floor, the dead remains of coral and skeletons of marine animals change into limestone ($CaCO_3$).

THE NITROGEN CYCLE

All living creatures require nitrogen which is found in protein. Living organisms need nitrogen to synthesise compounds such as essential amino acids and DNA. Most organisms cannot extract nitrogen directly from the air. Only a few species of bacteria are able to convert elemental nitrogen from the air into nitrogen containing compounds. The conversion of elemental nitrogen into nitrogen containing compounds is known as **nitrogen fixation.** Plants absorb these compounds through their roots and produce protein. All other living organisms obtain protein by eating plants or eating animals that feed on plants. The diagram below shows the main features of the nitrogen cycle:



Nitrogen fixation can occur in 2 ways:

1. Lightning strikes:

When lightning flashes through the air, nitrogen and oxygen molecules in the vicinity of the lightning absorb the activation energy required to react with each other. The 2 main reactions are:

$N_2\,(g) + O_2\,(g) \rightarrow 2NO\,(g)$

$2NO\,(g) + O_2\,(g) \rightarrow 2NO_2\,(g)$

NO/NO_2 can also be produced by volcanoes.

The NO_2 gas produced can react with rainwater to form a mixture of nitrous (HNO_2) and nitric acid (HNO_3):

$2NO_2\,(g) + H_2O\,(l) \rightarrow HNO_2\,(aq) + HNO_3\,(aq)$

When this rainwater reaches the ground it can act as a fertilizer by providing NO_2^- and NO_3^- ions to the soil. Plants can absorb these ions and use them to manufacture proteins.

2. Nitrogen fixing bacteria:

These bacteria are also known as **nitrifying bacteria.** They are found in soil and in the root nodules of leguminous plants and are able to fix elemental nitrogen into compounds:

N_2 (g) $\rightarrow$ NH_3 (g) $\rightarrow$ NH_4^+ (aq)

NH_3 (g) / NH_4^+(aq) $\rightarrow$ NO_2^- (aq) $\rightarrow$ NO_3^- (aq)

- Plants absorb NO_3^- and NH_4^+ ions and convert them to protein.
- Plants can also obtain nitrogen containing compounds from the remains of dead plants and animals.

In order for the cycle to continue, nitrogen containing compounds must be reconverted back into elemental N_2. This is the function of **denitrifying bacteria:**

NO_3^- (aq) $\rightarrow$ N_2O (g) $\rightarrow$ N_2 (g)

FERTILISERS

A fertiliser is a natural or synthetic substance added to soil to provide plants with a rich supply of nutrients such as nitrogen.

The growth of plants whether they be naturally occurring or agricultural is dependant upon the amount of fixed nitrogen compounds in the soil.

The most widely used fertilizer is manure which is mainly composed of the faecal remains of farm animals. Urea **(**$(NH_2)_2CO$**)** can also be used as a fertilizer.

Some synthetic fertilisers are:

- Ammonium nitrate (NH_4NO_3)
- Ammonia (NH_3)
- Ammonium sulfate **(**$(NH_4)SO_4$**)**
- Ammonium dihydrogen phosphate ($NH_4H_2PO_4$)

EUTROPHICATION

Over use of fertilizers, especially artificial ones can have adverse effects on the environment. Nitrate (NO_3^-) and ammonium ions (NH_4^+) are highly soluble in water and will dissolve into rainwater and leach out of the soil and run off into ground water. From here ions are transported to rivers, lakes, streams and even the sea. An abundance of these ions in water will cause algae to flourish as they feed on these nitrogen rich ions. The algae will eventually die and decompose. The amount of dissolved oxygen in the water will decrease due to the action of bacteria on the decomposing algae. Other marine plants and animals will die due to a lack of oxygen.