BIOGEOCHEMICAL CYCLES

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INTRODUCTION

- The term biogeochemical tells us that **Biological**, **Geological** & **Chemical** factors are involved.
- In earth science, a biogeochemical cycle is a pathway by which a chemical substances moves through both Biotic(Biosphere) & Abiotic(Lithosphere, Atmosphere & Hydrosphere) compartments of earth.
- A cycle is a series of change which comes back to the starting point & which can be repeated.

DEFINITION – " More or less circular pathways, through which the chemical elements, including all the essential elements of the protoplasm, circulate in the biosphere from environment to organisms and back to the environment, are known as the **Biogeochemical cycle".**

- Biogeochemical cycles always involve Hot equilibrium states: A balance in the cycling of the elements between compartments.
- As biogeochemical cycles describe the movements of substances on the entire globe, the study of these is inherently multidisciplinary.

CYCLING ELEMENTS

- **Macronutrients** : required in relatively large amounts
  "Big six": **Carbon** , **Hydrogen** , **Oxygen** , **Nitrogen**, **Phosphorous.**

other **Macronutrients**:
Sulfur, **Potassium** , **Calcium** , **Iron** , **Magnesium**

- **Micronutrients** : required in very small amounts, (but still necessary)
  Boron
  Copper
  Molybdenum

TYPES OF BIOGEOCHEMICAL CYCLE

- Biogeochemical cycles can be classed as;

❖ GASEOUS CYCLE – The term gaseous cycle refers to the transformation of gases between various biogeochemical reservoirs; **Hydrosphere**, **Atmosphere** & **Biosphere** Important gaseous cycles are;

a) NITROGEN CYCLE

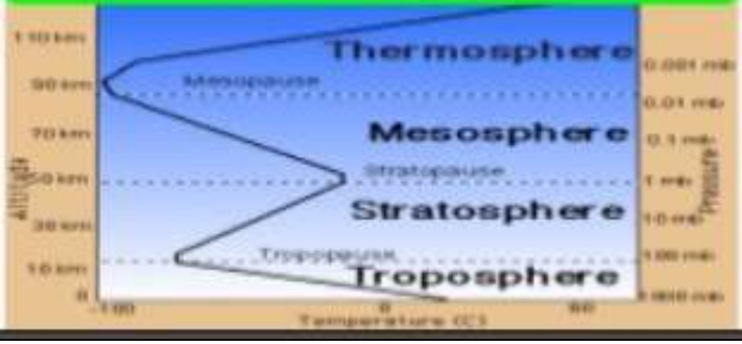
b) OXYGEN CYCLE

c) CARBON CYCLE

d) WATER CYCLE

HYDROSPHERE

ATMOSPHERE



❖ **SEDIMENTARY CYCLE** – Sedimentary cycles include the leaching of minerals & salt's from the earth's crust, which the settle as sediment or rock before the cycle repeats. Sedimentary cycle includes;

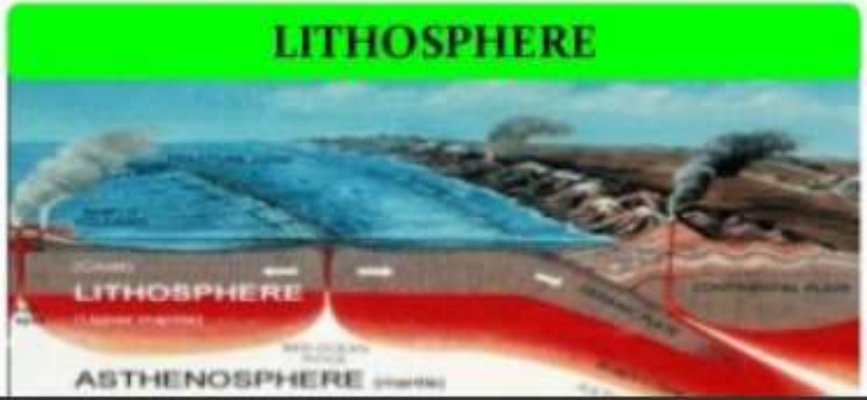
a) **PHOSPHORUS CYCLE**

b) **SULFUR CYCLE**

c) **IRON CYCLE**

d) **CALCIUM CYCLE**

- Sedimentary cycles vary from one elements to another, but each cycle consist fundamentally of a solution phase & a sediment phase.

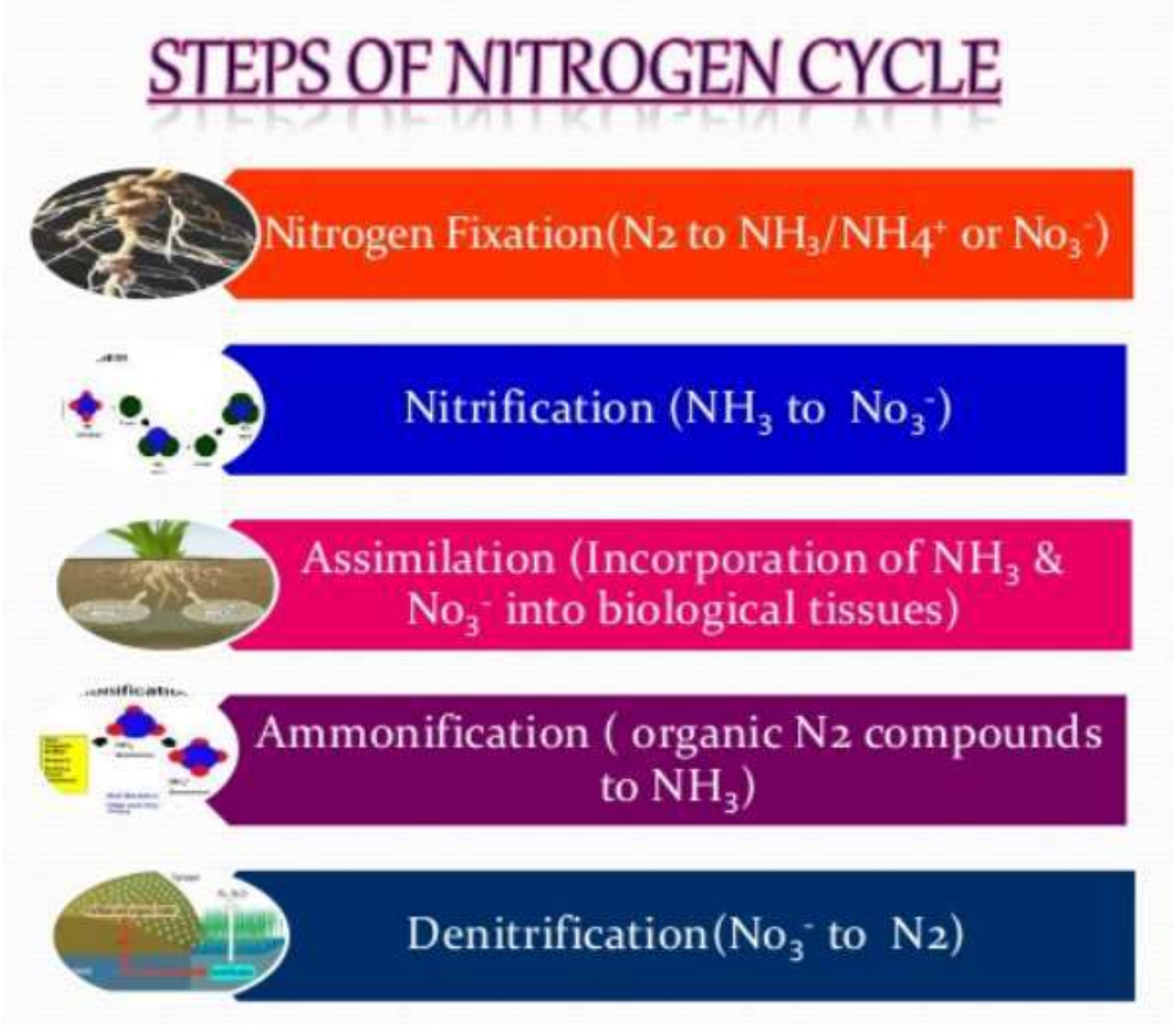


NITROGEN CYCLE

- The majority of earth's atmosphere is **Nitrogen(78%).** However, Atmospheric N_2 has limited availability for biological use, and this form is relatively nonreactive and unusable by plants.
- Nitrogen availability can affect the rate of key ecosystem processes including primary production and decomposition
- The Nitrogen(N_2) cycle is the process by which N_2 is converted between its various chemical forms.
- This transformation can be carried out through both biological & physical processes.

PROCESS OF NITROGEN CYCLE

- Nitrogen is present in the environment in a wide variety of chemical forms including **organic nitrogen**, **Ammonium(NH_4^+)**,**Nitrite(NO_2^-)**, **Nitrate(NO_3-)**, **Nitrous oxide(N_2O)**, **Nitric oxide (NO)** or **Inorganic nitrogen gas**.
- Organic nitrogen may be in the form of a living organism, humus or in the intermediate products of organic matter decomposition.
- The process of N2-cycle transform nitrogen from one form to another. Many of those processes are carried by microbes.


STEPS OF NITROGEN CYCLE
Nitrogen Fixation(N2 to NH_3/$NH4^+$ or No_3^-)
Nitrification (NH_3 to No_3^-)
Assimilation (Incorporation of NH_3 & No_3^- into biological tissues)
Ammonification (organic N2 compounds to NH_3)
Denitrification(No_3^- to N2)

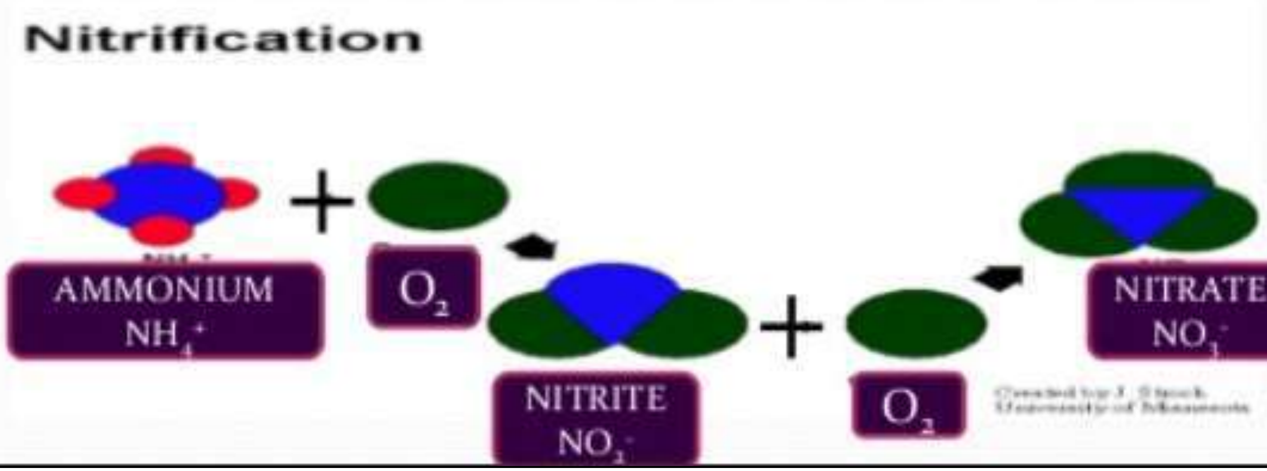
NITROGEN FIXATION

- Atmospheric nitrogen must be fixed in a usable form to be taken up by plants, mostly fixation is done by free living (eg. *Azotobacter* & *Closteridium* or symbiotic (*Rhizobium*) known as Diazotrophs.
- Symbiotic nitrogen- fixing bacteria such as *Rhizobium* usually live in the roots- nodules of legumes. Here they form a mutualistic relationship with the plant, producing ammonia in exchange for carbohydrates.
- Today about 30% of the total fixed N2 is produced industrially using the **Haber – Bosh process** which uses high temperature & pressure to convert nitrogen gas & a hydrogen source into ammonia.
- Biological nitrogen fixation can be represented by following equation;

$$N_2 + 8H + 8e^- + 16ATP = 2NH_3 + H_2 + 16\ ADP$$

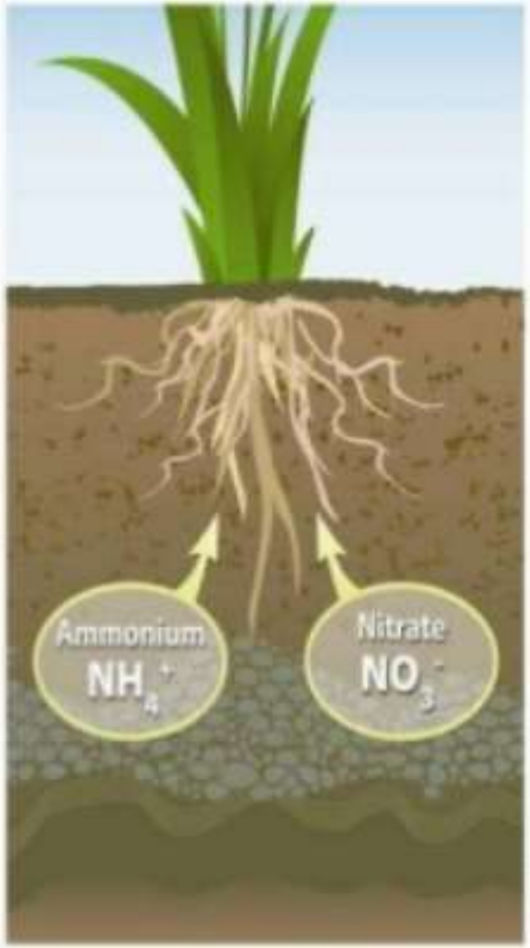
nitrification

- The conversion of ammonia to nitrate is performed primarily by soil living bacteria & other nitrifying bacteria.
- In the primary stage of nitrification the oxidation of ammonium is performed by bacteria such as the *Nitrosomonas* species, which convert ammonia to nitrites.
- Other bacterial species such as *Nitrobacter* are responsible for the **oxidation of the nitrite into nitrates**.
- It is important for the ammonia to be converted to nitrates or nitrites because ammonia gas is toxic to plants.



ASSIMILATION

- Plant take nitrogen from soil by absorption through their roots as **Amino acids**, **Nitrate ions**, **Nitrite ions**, or **Ammonium ions**.
- Plants can absorb nitrate or ammonium from the soil via their root hairs. If nitrate is absorbed, it is first reduced to nitrite ions and then ammonium ions for incorporated into amino acids, nucleic acids & chlorophylls.
- In plants that have a symbiotic relationship with Rhizobia, some N2 is assimilated in the form of ammonium ions directly from the nodules.



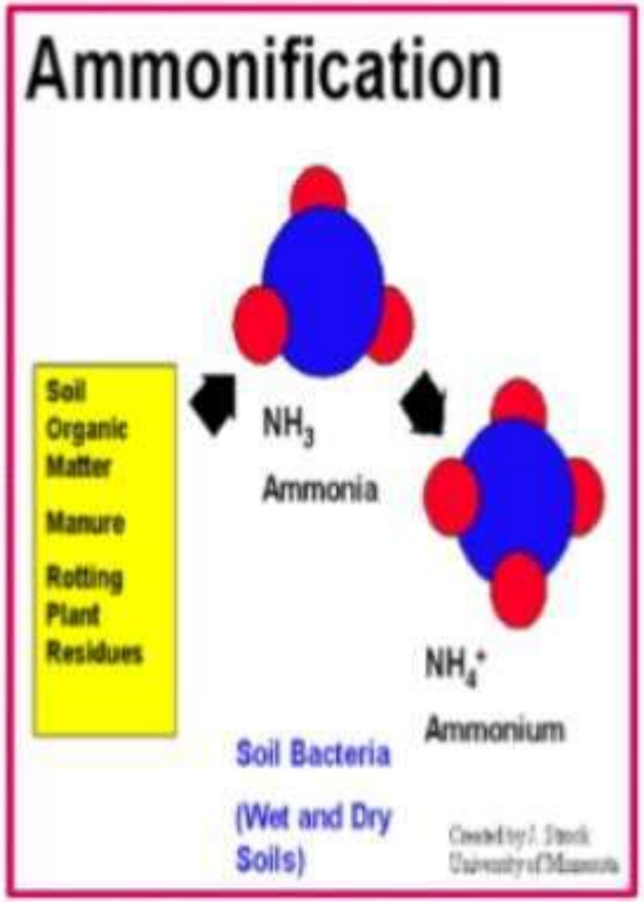
AMMONICATION

- When a plant or animal dies or an animal expels waste, the initial forms of N2 is organic.
- Bacteria or fungi convert the organic N2 within the remains back into ammonium, a process is called **Ammonification** or **Mineralization**
- Enzymes are involved are;

  GS : Gln synthetase

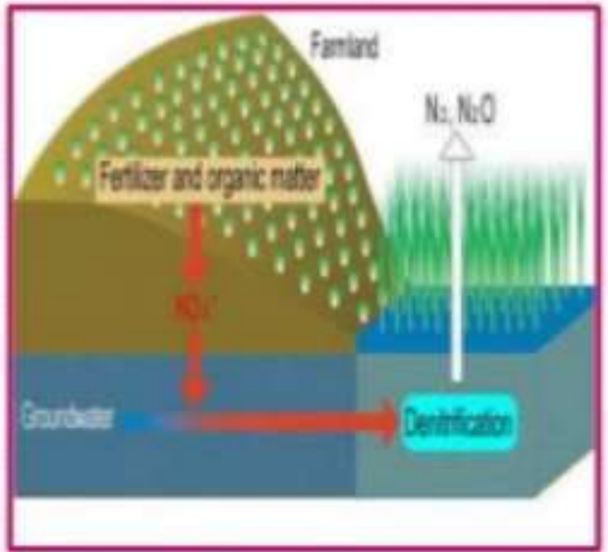
  GOGAT : Glu-2- oxoglutarate

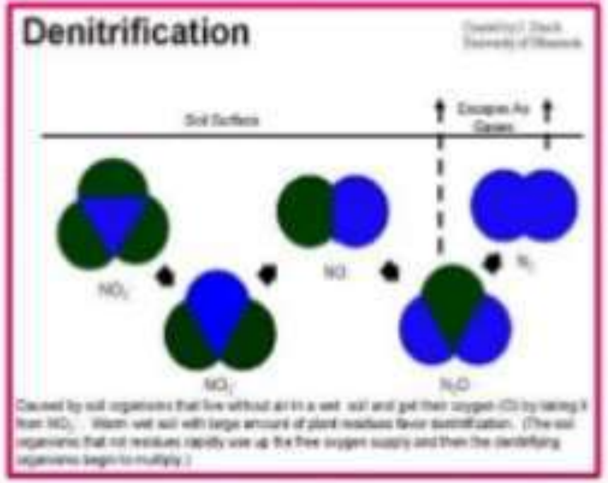
  GDH : Glu-dehydrogenase



DENITRIFICATION

- **Denitrification** is the reduction of nitrates back into the largely inert N2 gas, completing the **N2-cycle**.
- This process is performed by bacterial species such as *Pseudomonas* & *Clostridium* in **anaerobic conditions.**
- They use the nitrate as an electron accepter in the place of oxygen during respiration.
- **Denitrification** happens in anaerobic conditions eg. Waterlogged soils.

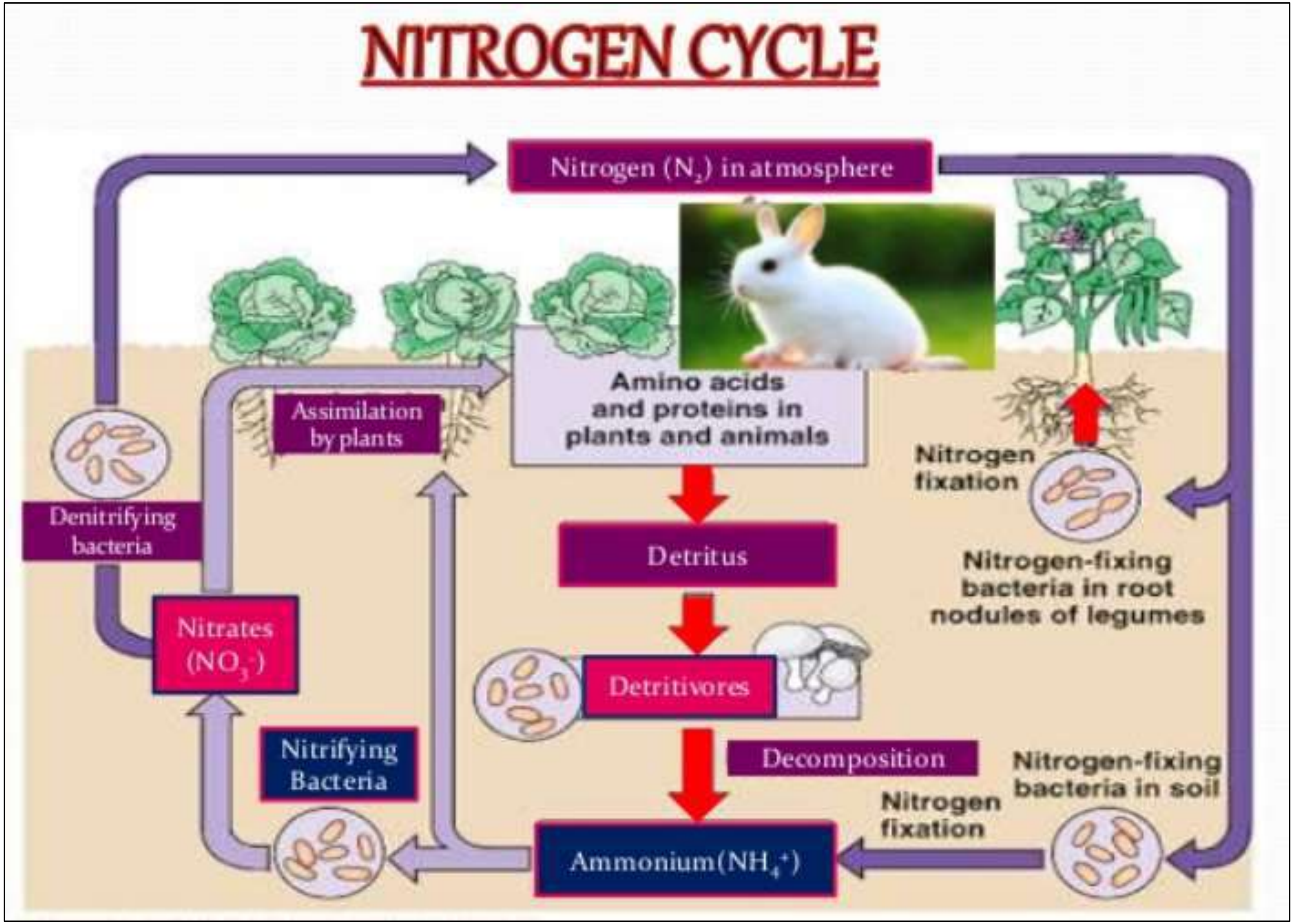




Denitrification Reaction Sequence

$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

NO_3^-	NO_2^-	NO	N_2O	N_2
Nitrate	Nitrite	Nitric Oxide	Nitrous Oxide	Nitrogen Gas


NITROGEN CYCLE
Nitrogen (N_2) in atmosphere
Amino acids and proteins in plants and animals
Assimilation by plants
Denitrifying bacteria
Nitrogen fixation
Nitrogen-fixing bacteria in root nodules of legumes
Detritus
Detritivores
Nitrates (NO_3^-)
Nitrifying Bacteria
Decomposition
Nitrogen-fixing bacteria in soil
Nitrogen fixation
Ammonium(NH_4^+)

ECOLOGICAL FUNCTION

- Nitrogen is necessary for all known forms of life on earth.
- It is a component in all amino acids as it is incorporated into proteins and is present in the bases that make up nucleic acids such as **RNA & DNA**.
- Chemical processing or natural fixation are necessary to convert gaseous nitrogen into compounds, such as nitrate or ammonia which can be used by plants.

USE OF NITROGEN

- Nitrogen is important to the chemical industry, It is used to make **Fertilizers**, **Nitric acid**, **Nylon**, **Dyes** & **Explosives**.
- Nitrogen is present in virtually all pharmacological drugs & In the form of nitrous oxide it is used as anesthetic.
- The CPUs in computers use the N2-gas to keep them from heating up. **X-ray detectors** also rely on this element.
- **Cryopreservation** also uses N2-gas to conserve blood & other biological specimen.
- The element is used in controlling pollution, many industries use it to destroy toxic liquids and vapors in industrial tools.

PHOSPHORUS CYCLE

- The phosphorus cycle is the **slowest Biogeochemical cycle** that describes the movements of phosphorus(**P**) through the **Lithosphere**, **Hydrosphere** & **Biosphere**.
- Unlike many other biogeochemical cycles, the atmosphere dose not play a significant role in the movement of **P** because phosphorus and **P** based compounds are usually solids at the typical ranges of temperature & pressure found on earth.
- Low conc. of **P** in soils reduces plant growth & slows soil microbial growth.
- Unlike other cycles P cannot be found in the air as a gas, it only occurs under highly reducing conditions as the gas **Phosphine.**

PROCESS OF PHOSPHORUS CYCLE

- Initially , phosphate weathers from rocks and minerals, the most common mineral being **Apatite** .
- Overall small losses occurs in terrestrial environment by leaching erosion, through the action of rain.
- Weathering of rocks & minerals release phosphorus in a soluble form , where it is taken up by plants & it is transformed into organic compounds.
- The plants may then be consumed by herbivores and the phosphorus is either incorporated into their tissues or excreted.
- After death of animal or plant decays then phosphorus is returned to the soil where a large part of the P is transformed into insoluble compounds.
- Runoff may carry a small part of the P back to the ocean.

STEPS OF PHOSPHORUS CYCLE

Phosphate is released by the erosion of rocks.

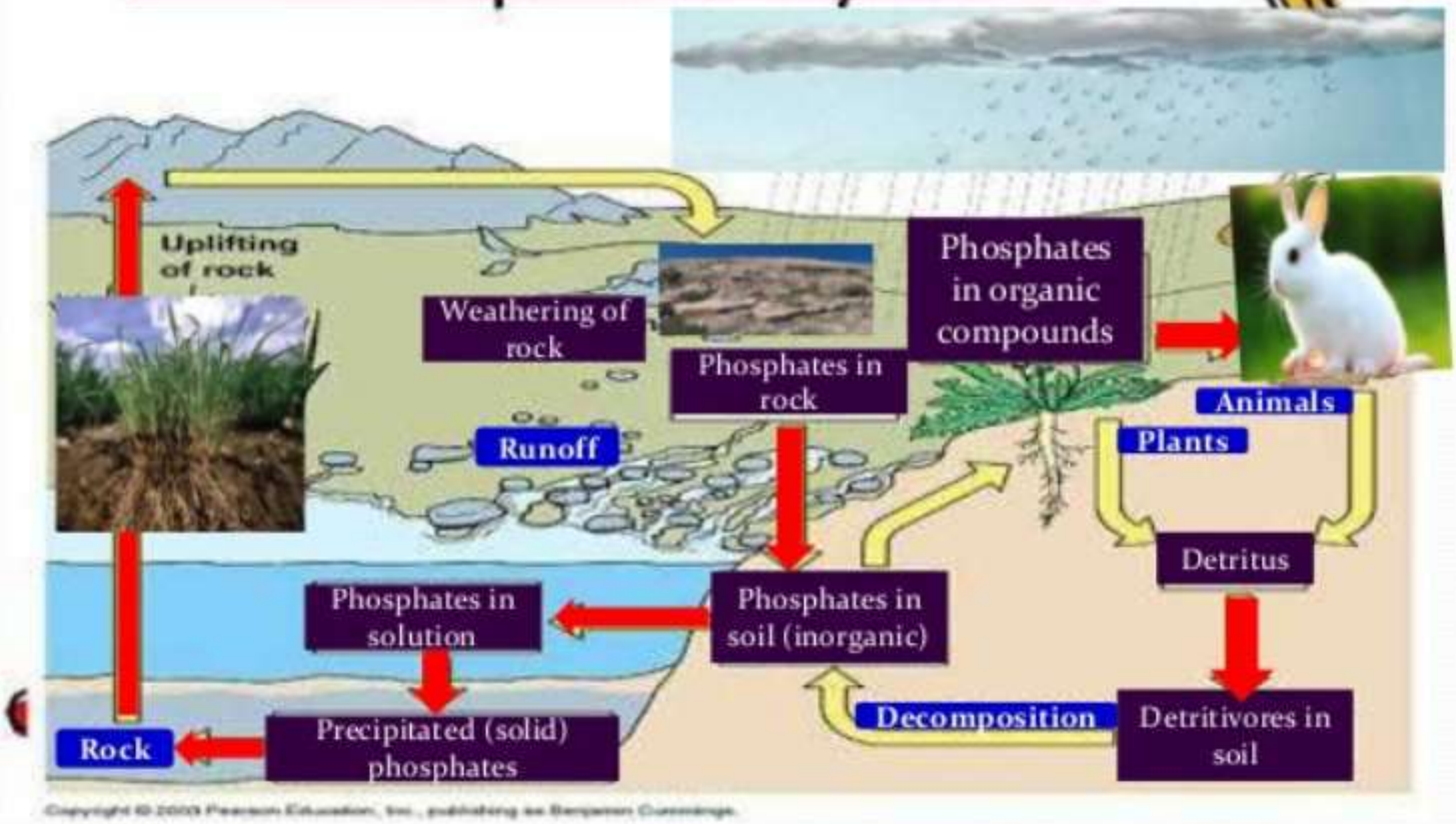
Plants and fungi take up the phosphate with their roots.

Phosphorus moves from producers to consumers via food chain.

Phosphorus may seep into groundwater from soil over time forming into rock.

When these rock erode, the cycle begins again.

PHOSPHORUS CYCLE



ECOLOGICAL FUNCTION

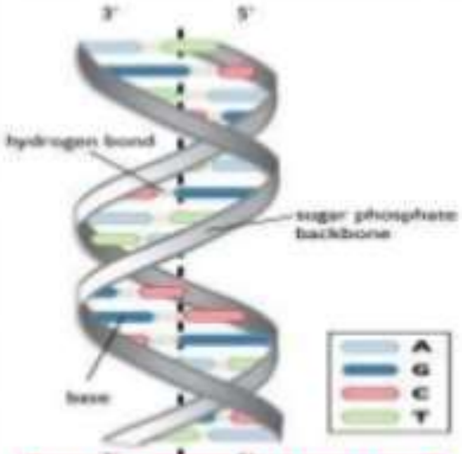
- **P** is an important nutrient for plants and animals, **P** is also limiting nutrient for aquatic organisms.
- **P** does not enter the atmosphere, remaining mostly on land, in rock & soil minerals.
- 80% of the mined **P** is used to make fertilizers. **P** from fertilizers, sewage can cause pollution in lakes & streams.
- **P** normally occurs in nature as part of a phosphate ion $(PO4)_3^-$, The most abundant forms is **Orthophosphate**

FERTILIZER

IMPORTANCE OF PHOSPHORUS

BIOLOGICAL FUNCTION-

- The primary biological importance of Phosphates is as a component of nucleotides, which serves as energy storage within cells (ATP) or when linked together form the nucleic acids DNA & RNA.
- The double helix of two strands of DNA is only possible because of phosphate ester bridge that binds the helix.
- Besides making biomoleculs, P is also found in bone & enamel of mammalian teeth, whose strength is derived from calcium phosphate in the form of Hydroxyl apatite.
- It is also found in the exoskeloton of insects & phospholipids.



DNA STRANDS

BONES

OTHER USES

- Phosphorus catches fire readily, Red phosphorus is used in all matches.
- White phosphorus and zinc phosphate are mainly used as a poison for rats.
- It is used in making incendiary (fire causing) bombs, tracer bullets and for producing smoke screen.
- Many soluble phosphates are used to remove unwanted metal salts from the water.

TRACER BULLETS

CONCLUSION

- Biogeochemical cycles are important because they regulate the elements necessary for life on earth by cycling them through the biological & physical aspects of world.
- Biogeochemical cycles are a form of natural recycling that allows the continuous survival of ecosystem.

Oxygen Cycle

Definition of Oxygen

- Oxygen – a colorless, odorless, tasteless gas
- Denser than air
- Poor conductor of heat and electricity

Oxygen

- Oxygen, one of the main components of the Earth's atmosphere, can always be found with other elements.
- Two oxygen atoms make up one oxygen molecule, and three oxygen atoms together make up the molecule called ozone.

Biological Importance of Oxygen

- Humans need it to breathe
- Needed for decomposition of organic waste
- Water can dissolve oxygen and it is this dissolved oxygen that supports aquatic life.

Ecological Importance of Oxygen

- Without oxygen at the bottom of the water body, anaerobic bacteria (those that live without oxygen) produce acids. These acids not only increase acidity, but also cause a massive release of phosphorus and nitrogen, two major fertilizers, from the organic sediment and into the water column.
- These same anaerobic bacteria put toxic gases in the water including hydrogen sulfide (that rotten egg smell), ammonia, carbon dioxide and methane. These gases are all toxic to fish, beneficial bacteria and insects.
- Lack of bottom oxygen is the cause of odors produced by anaerobic bacteria.

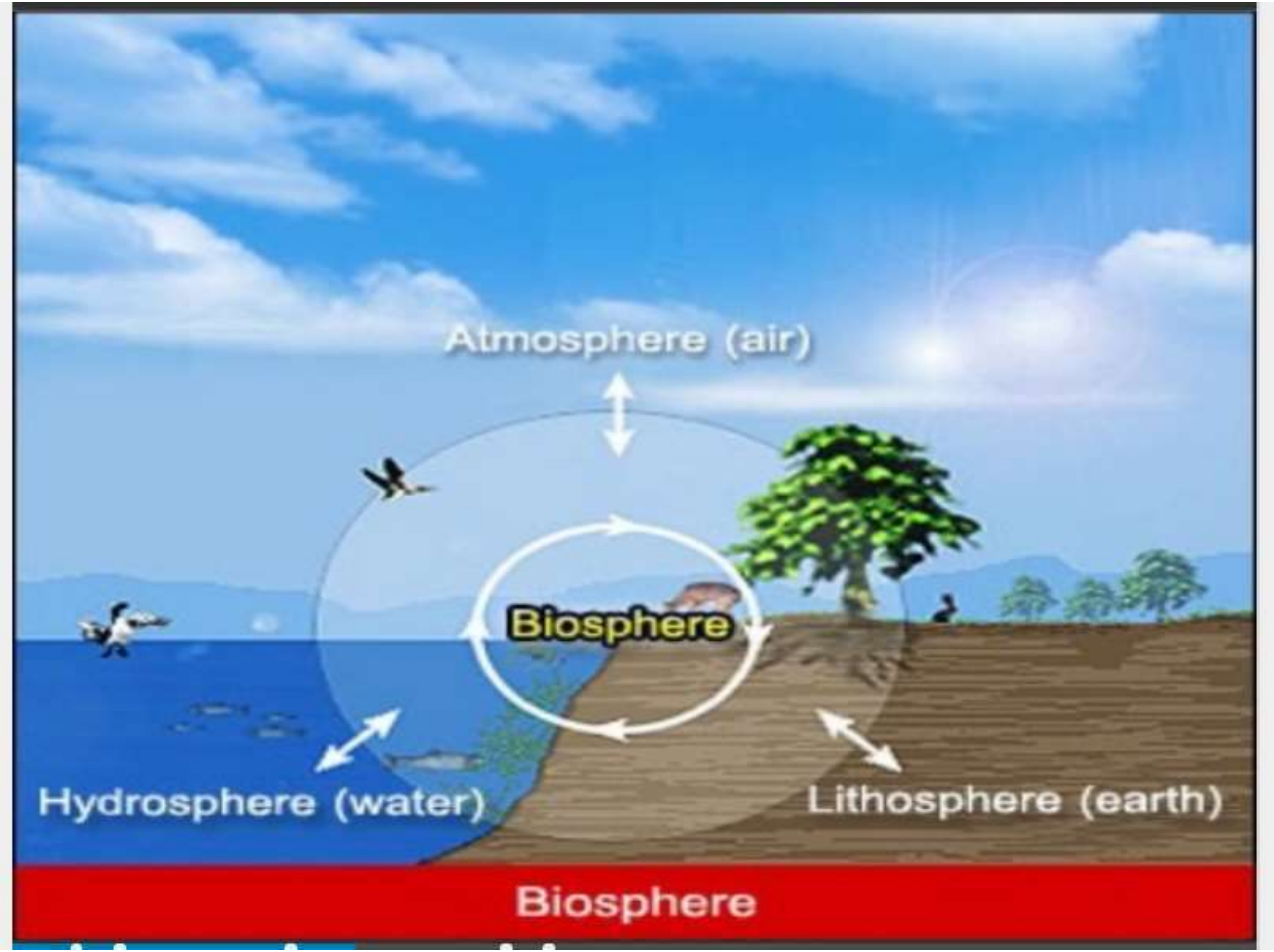
Ecological Importance of Oxygen Cont.

- Lack of fish enables disease-hosting mosquitoes to thrive, as mosquitoes are natural food for fish.
- Without oxygen at the bottom at all times, beneficial bacteri and insects cannot biodegrade the organic sediment. Large accumulations of organic sediment follow.

The Main Reservoirs

The reservoirs are the locations in which oxygen is found.

- Biosphere (living things)
- Lithosphere (Earth's crust)
- Atmosphere (air)
- Hydrosphere(water)


Atmosphere (air)
Biosphere
Hydrosphere (water)
Lithosphere (earth)
Biosphere

Earth’s Layers

- The lithosphere is Earth's surrounding layer, composed of solids such as soil and rock.
- The atmosphere is the surrounding thin layer of gas.
- The hydrosphere refers to liquid environments such as lakes and oceans that lie between the lithosphere and atmosphere.
- The biosphere's creation and continuous existence results from chemical, biological, and physical processes.

Biosphere and Atmosphere

- Within the biosphere and atmosphere, plants begin the oxygen cycle and animals continue it.
- Photolysis also donates to a large portion of the oxygen in the atmosphere, where high energy ultraviolet radiation breaks down the atmospheric water and nitrate.

Biosphere and Atmosphere

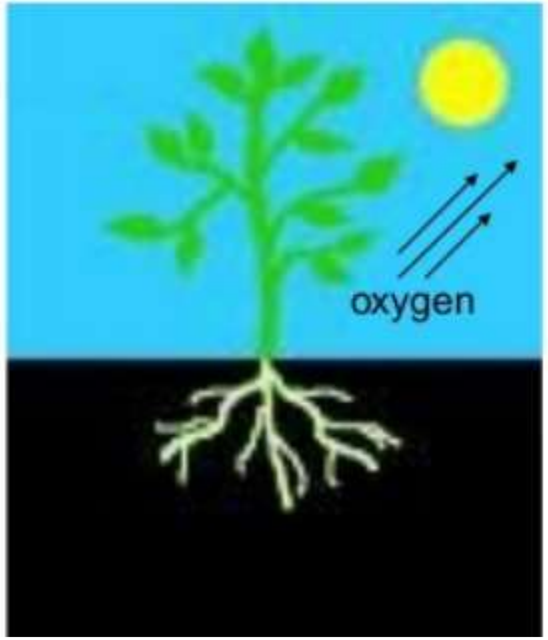
- Much of the oxygen present in the atmosphere is used during respiration and decay mechanisms, where animal life and bacteria consume oxygen and release carbon dioxide.
- Oxygen is also cycled between the biosphere and lithosphere.
- Burning.

What is the Oxygen Cycle?

- In the oxygen cycle, oxygen atoms present in the earth circulate through a series of intricate processes.
- Like the nitrogen, carbon, and water cycles, the oxygen cycle is a biogeochemical cycle.
- A biogeochemical cycle is the movement of matter through the biotic and the abiotic spheres of the ecosystem.

Step One of Oxygen Cycle

- Plant release oxygen into the atmosphere as a by-product of photosynthesis.

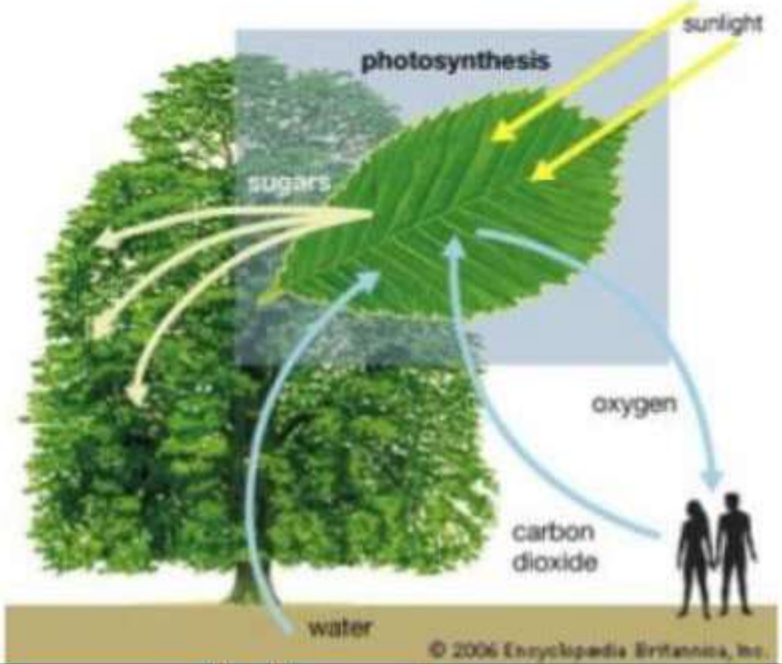


Photosynthesis

- Plants take in carbon dioxide and water and use them to make food. Their food is simple sugar — glucose.

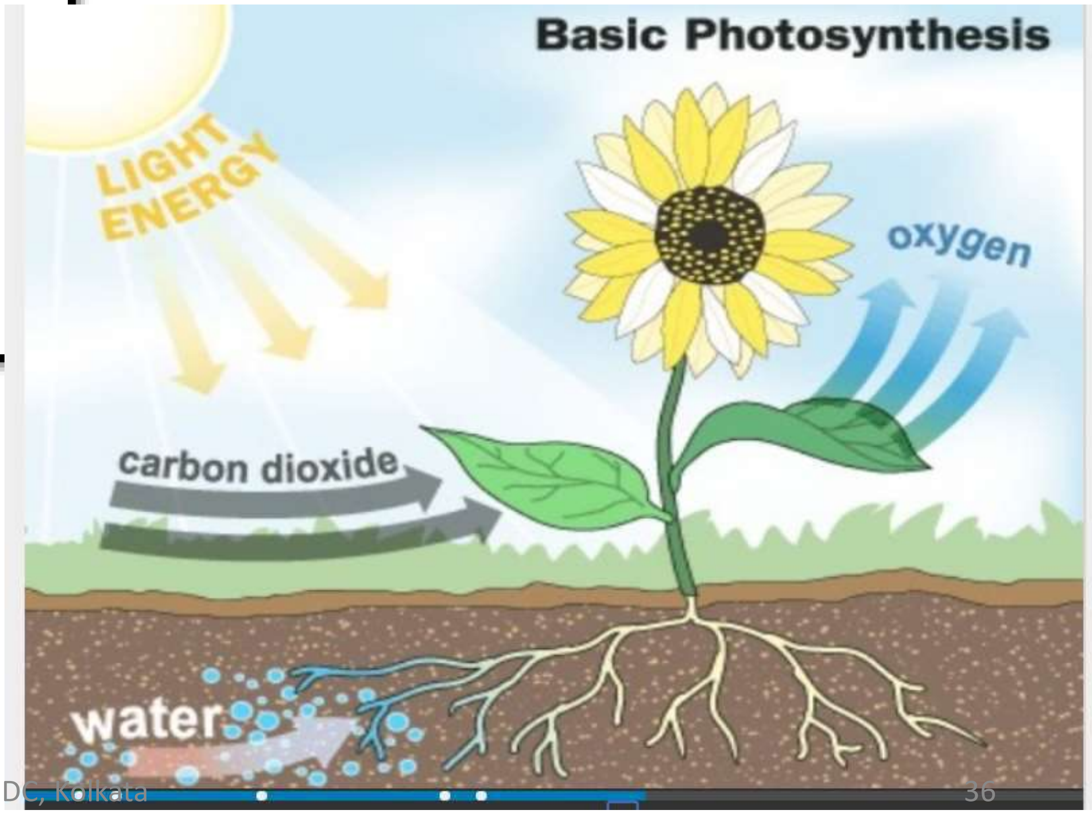
Photosynthesis

- **Definition-** process in which green plants use the energy from the sun to make carbohydrates from carbon dioxide and water in the presence of chlorophyll.



Photosynthesis (continued)

- Plants pull the carbon off CO_2 and use the carbon in glucose. (They do not need the oxygen for this. They get that from water, H_2O.)
- Plants release the oxygen (O_2) back into the atmosphere.
- Other organisms use the free oxygen for respiration.



Step Two of Oxygen Cycle

- Animals take in oxygen through the process of respiration.
- Animals then break down sugars and food.

Respiration

- Process by which an organism exchanges gases with its environment
- Process → oxygen is abstracted from air, transported to cells for the oxidation of organic molecules while CO^2 and H_2O, the products of oxidation, are returned to the environment

All Animals and Other Consumers Use Oxygen

- We use oxygen to break down simple sugar and release energy.
- This can be done through respiration or fermentation.
- Animals mainly use respiration.

Simple Sugar — Glucose

The molecule most living things use for energy — including us!

- We break down food into smaller molecules during digestion. One of the small molecules is glucose.
- Glucose leaves your intestines, goes into your blood and is taken to every cell in your body.

Respiration

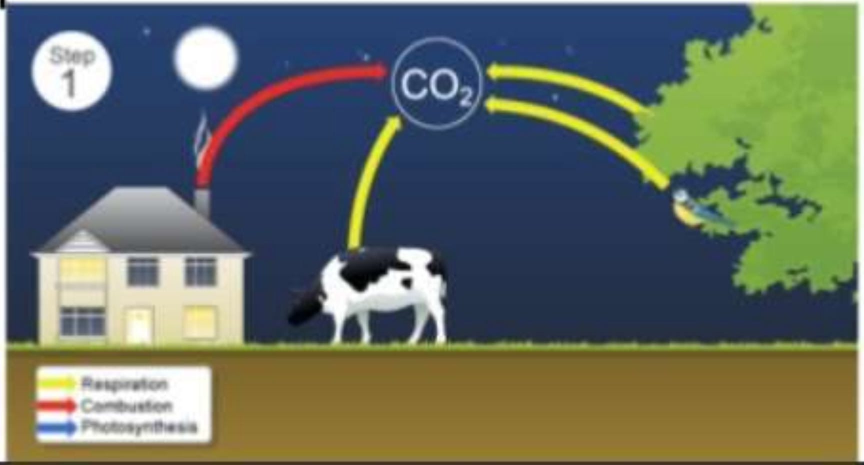
- The process that breaks apart simple food molecules to release energy.
- It occurs inside cells.
- What YOU do with the oxygen you take in.

Respiration in Cells

- In your cells, oxygen is used to split glucose apart — releasing energy, water and carbon dioxide.

Step Three in Oxygen Cycle

- Carbon dioxide is released by animals and used in plants in photosynthesis.
- Oxygen is balanced between the atmosphere and the ocean.



How do plants contribute?

- The oxygen cycle begins with plants and photosynthesis.
- Through photosynthesis, plants convert the energy from the sun and water into carbohydrates and oxygen.
- During the day: plants convert carbon dioxide into oxygen.
- During the night: plants convert oxygen into carbon dioxide to maintain their metabolism.

How do living organisms contribute?

- Humans and animals breathe in oxygen and breathe out carbon dioxide through their processes of metabolism, sparking the process of photosynthesis, once again linking back to the plants' contribution to the oxygen cycle.

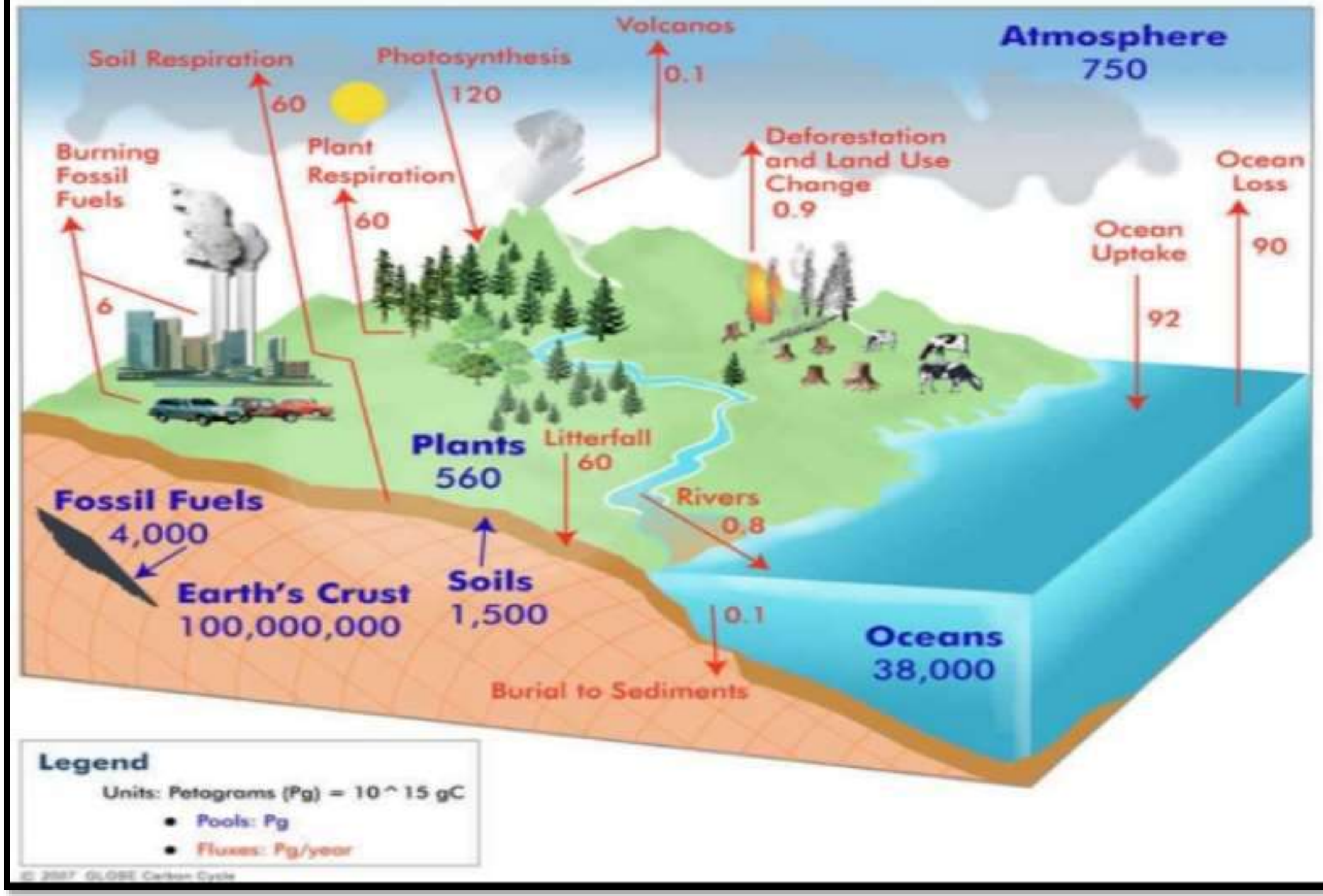
WHAT IS CARBON

- **Carbon** is virtually important molecule in the carbon cycle.
- Proteins, nucleic acids, lipids, carbohydrates, and other molecules essential to life contain carbon.

- Carbon is present in the atmosphere as the gas carbon dioxide (CO_2), which makes up approximately 0.04% of the atmosphere.
- It is also present in the ocean and fresh water as dissolved carbon dioxide. Carbons are also present in rocks such as limestone ($CaCO_3$)

The global moment of carbon between the abiotic environment, including the atmosphere and ocean, and organisms is known as the **CARBON CYCLE.**

Global Carbon Cycle



Step 1: PHOTOSYNTHESIS

- During photosynthesis, plants, algae, and cyanobacteria remove Carbon dioxide from the air and fix, or incorporate it into complex organic compounds such as glucose.

- Photosynthesis incorporates carbon from the abiotic into the biological compounds of producers.

Step 2: DECOMPOSITION, ANIMAL & PLANT RESPIRATION, SOIL MICROORGANISM RESPIRATION.

- Many of the compounds are used as fuel for cellular respiration by the producer that made them, by a consumer that eats producer, or by a decomposer that breaks down the remains of the producer or consumer.
- The process of a cellular respiration returns Carbon dioxide to the atmosphere. A similar carbon cycle occurs in aquatic ecosystems between aquatic organisms and dissolved Carbon dioxide in water.

Step 3: PARTLY DECOMPOSED PLANT REMAINS (COAL)

Millions of years ago vast coal beds formed from the bodies of ancient trees that were buried and subjected to anaerobic conditions before they had fully decayed.

Step 4: MARINE PLANKTON REMAINS

- The oils of unicellular marine organisms probably gave rise to the underground deposits of oil and natural gas that accumulated in the geologic past.
- Coal, oil, and natural gas, called **fossil fuels** because they formed from the remains of ancient organisms. Fossil fuels are non- renewable resources. The Earth has a finite or limited supply of these resources.

Step 5: COMBUSTION (HUMAN & NATURAL)

The process of burning or combustion, may return the carbon in oil, coal, natural gas, and wood to the atmosphere. In combustion, organic molecules are rapidly oxidized (combined with oxygen) and converted carbon dioxide and water with an accompanying release of light and heat.

Step 6: BURIAL AND COMPACTION TO FORM ROCK (LIMESTONE)

An even greater amount of carbon that is stored for millions of years is incorporated into the shells of marine organisms. When these organisms die, their shells sink to the ocean floor and sediments cover them forming cemented together to form limestone, a meter thick.

Step 7: EROSION OF LIMESTONE TO FORM DISSOLVED CO_2

When the process of geologic uplift expose limestone, chemical and physical weathering processes slowl erode it away. This returns carbon t the water and atmosphere where it i available to participate in the carbo cycle once again.

Thus, photosynthesis removes carbon from the abiotic environment and incorporate it into biological molecules while. Cellular respiration, combustion, and erosion of limestone return carbon to the water and atmosphere of the abiotic environment.

Thank You