

EWCE 105

ENVIRONMENTAL CHEMISTRY

Lecture – 5

Lecture Outlines

- Atmospheric State Variables
- Concepts of Elementary Cycles

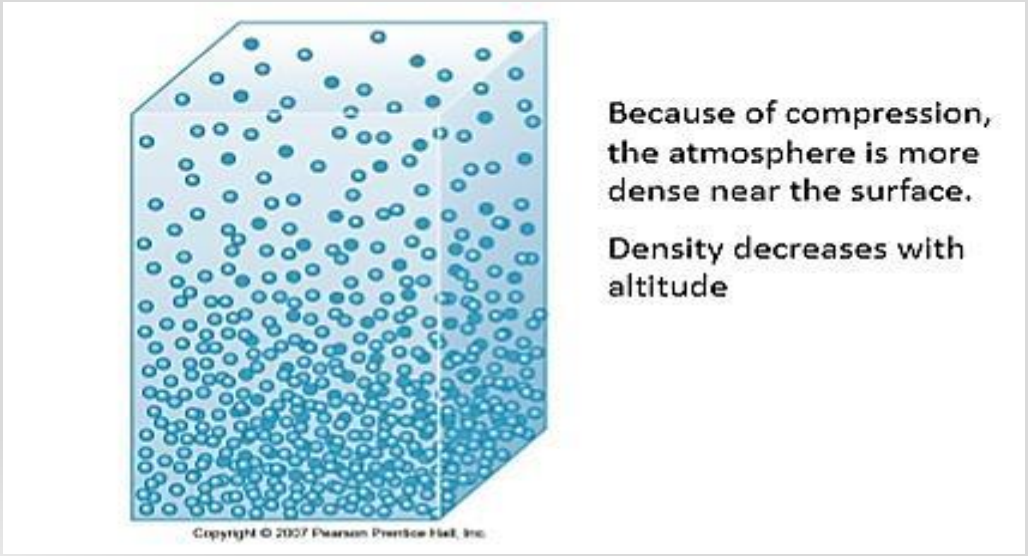
Atmospheric State Variables

State variables include:

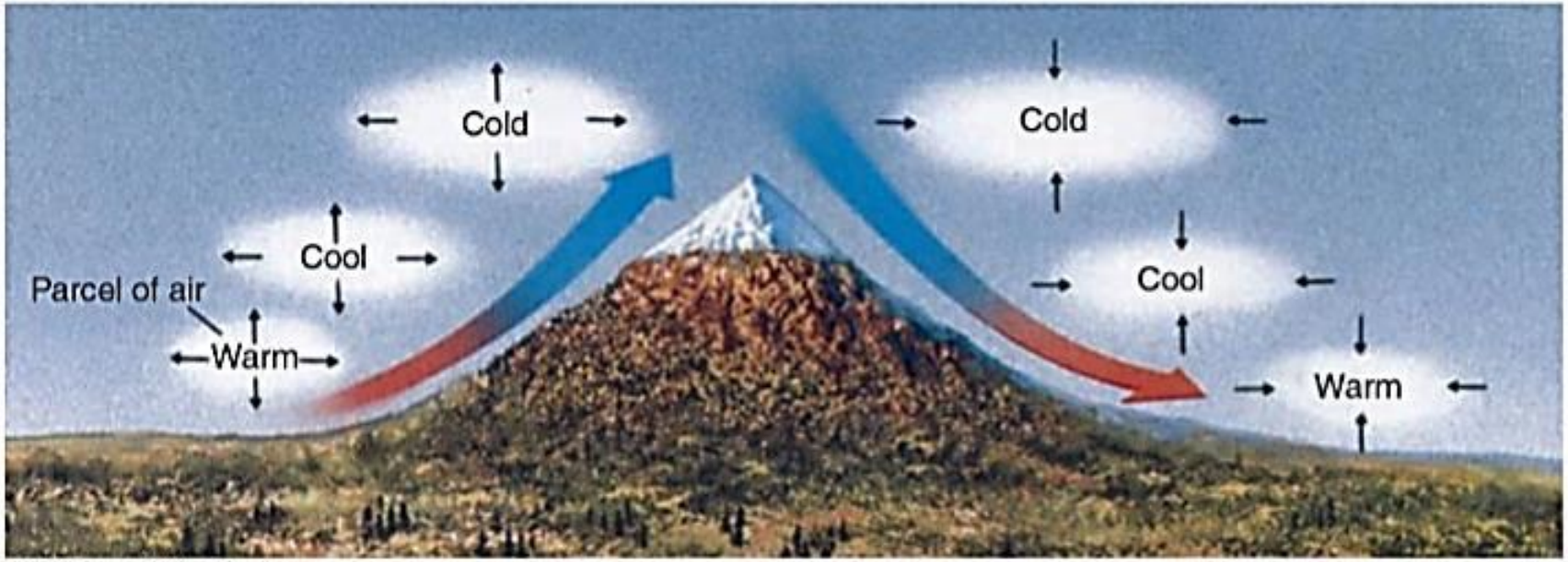
- Pressure
- Temperature
- Density

- State variables are related to one another by the Ideal Gas Law (IDL).
- Ideal Gas Law often referred to as the "**Equation of State**".

Density and Pressure with Height



Temperature Change with Altitude



- As a parcel of air rises, it expands due to lower pressure.
- Work done by molecules to expand causes temperature to decrease (cools).
- As air sinks, the parcel experiences compression due to higher pressure.
- Air molecules have work done on them, temperature increases (warms).

Temperature Change with Altitude

Summary :

Rising → Expansion → Cooling

Sinking → Compression → Warming

Concepts of Elementary Cycles

Environmental interactions

- Every sphere of the environment interact with one another for survival.
- Certain elements are required for the survival of all living things e.g. **C, N**, O, P, etc.
- Each has fixed quantity which are **recycled continuously** within and among **various components** of the environment.

Concepts of Elementary Cycles

Cycles of matter

Movement of matter through different spheres of the environment (**Biogeochemical cycles**).

- Examples: carbon, nitrogen, sulphur, phosphorous cycles etc.
- Biogeochemical cycles can be **endogenic** or **exogenic**.

- **Endogenic**: These are **cycles occurring** at different sub-surface rocks **below the earth's surface** (e.g. phosphorous cycle)

- **Exogenic**: These cycle occurs **on the surface of the earth** (e.g. C, N, S cycles).

Concepts of Elementary Cycles

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Carbon Cycle

Carbon - is the basic building block of life. It anchors all the organic substances starting from coal & oil to DNA (deoxyribonucleic acid - it carries the genetic information of living organisms)

- Although of central importance of life, carbon is not one of the most abundant elements in earth's crust.
- It contributes only 0.032 % of the weight of the crust.

Carbon Cycle

Carbon cycle – It is the biogeochemical cycle by which carbon is exchanged among atmosphere, hydrosphere, lithosphere and biosphere of the earth.

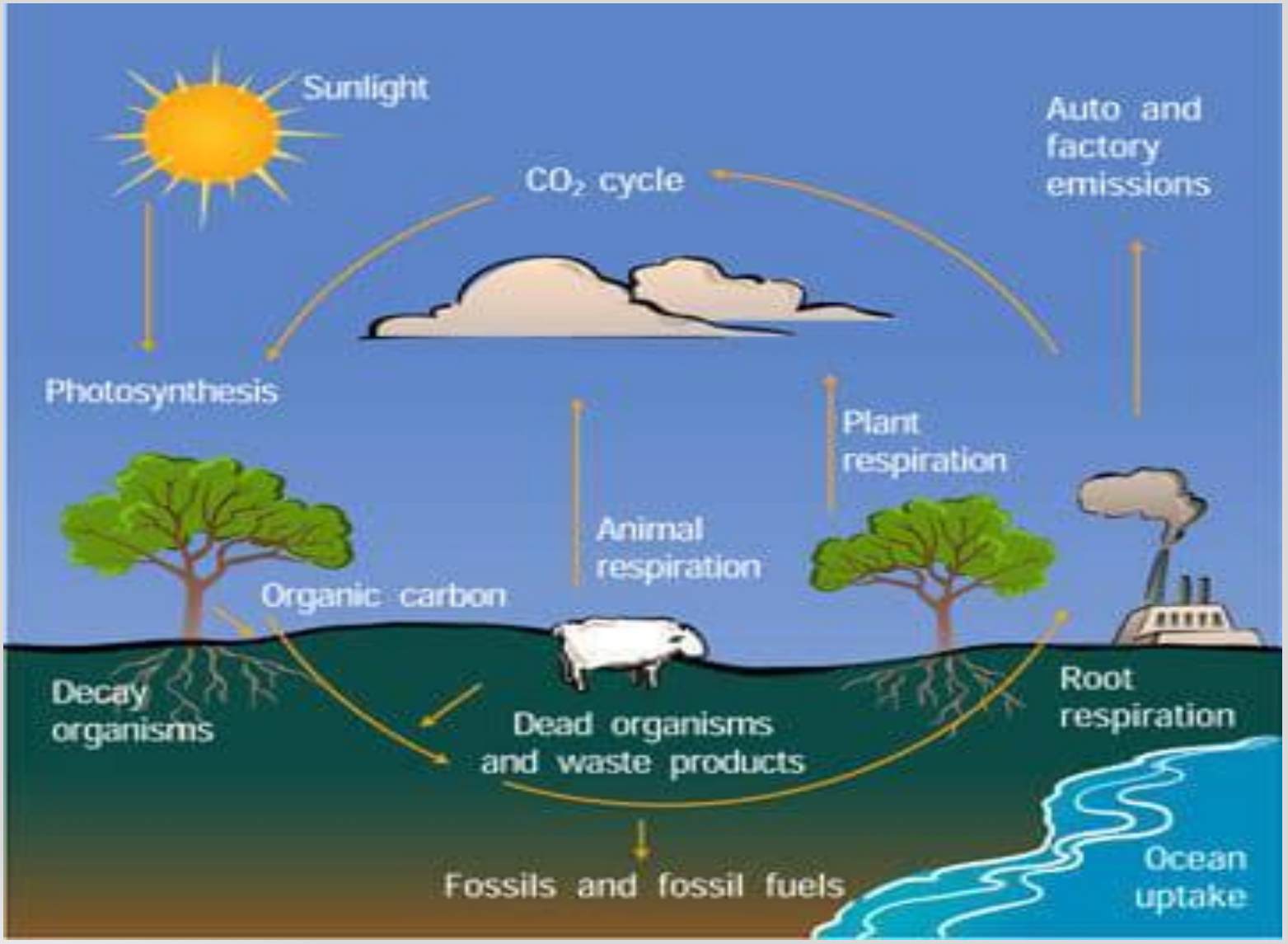
- Reservoir

Atmosphere as (CO_2 & CH_4)

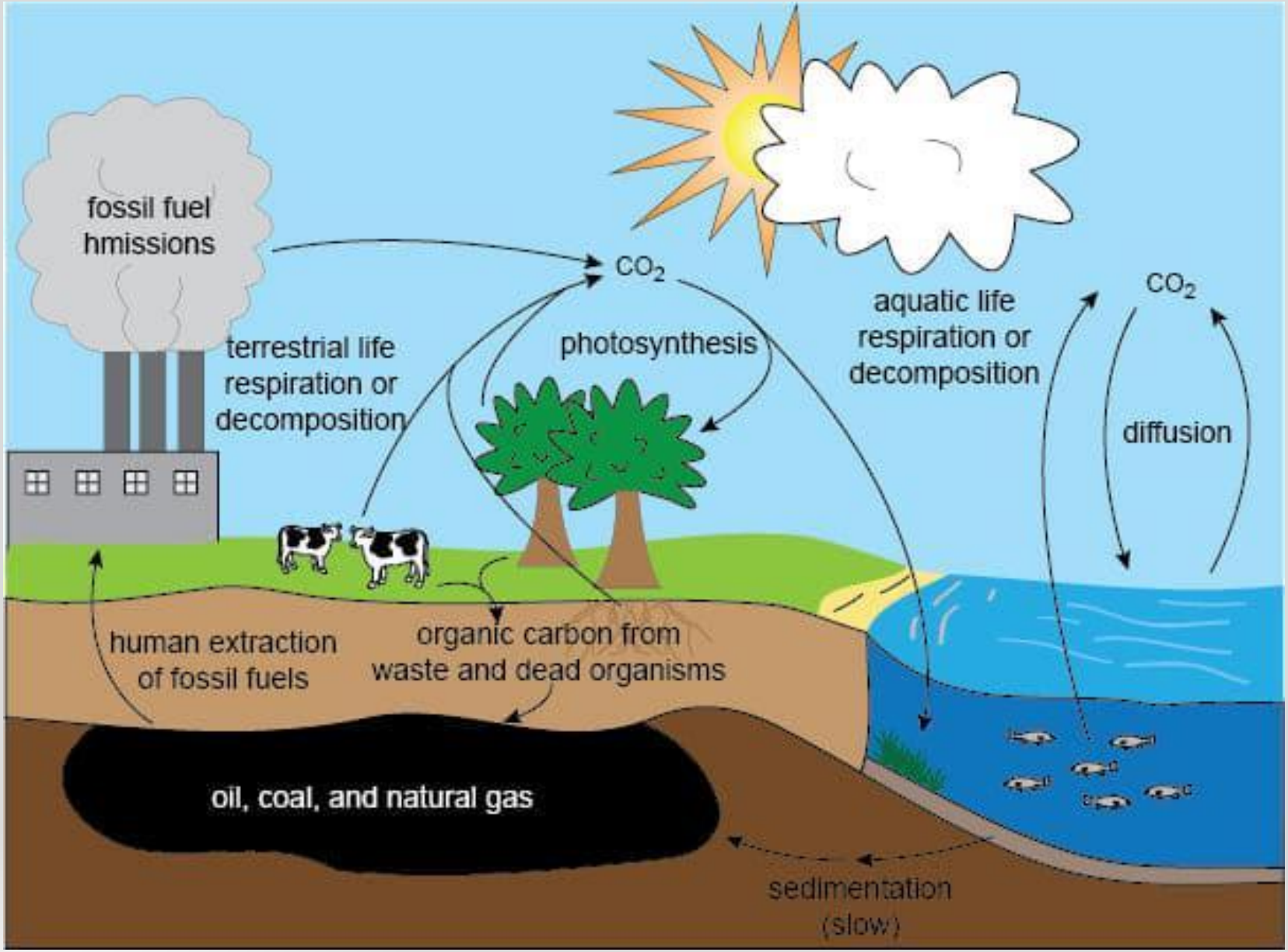
Fossil fuels (Oil & Coal)

Durable organic materials (Cellulose)

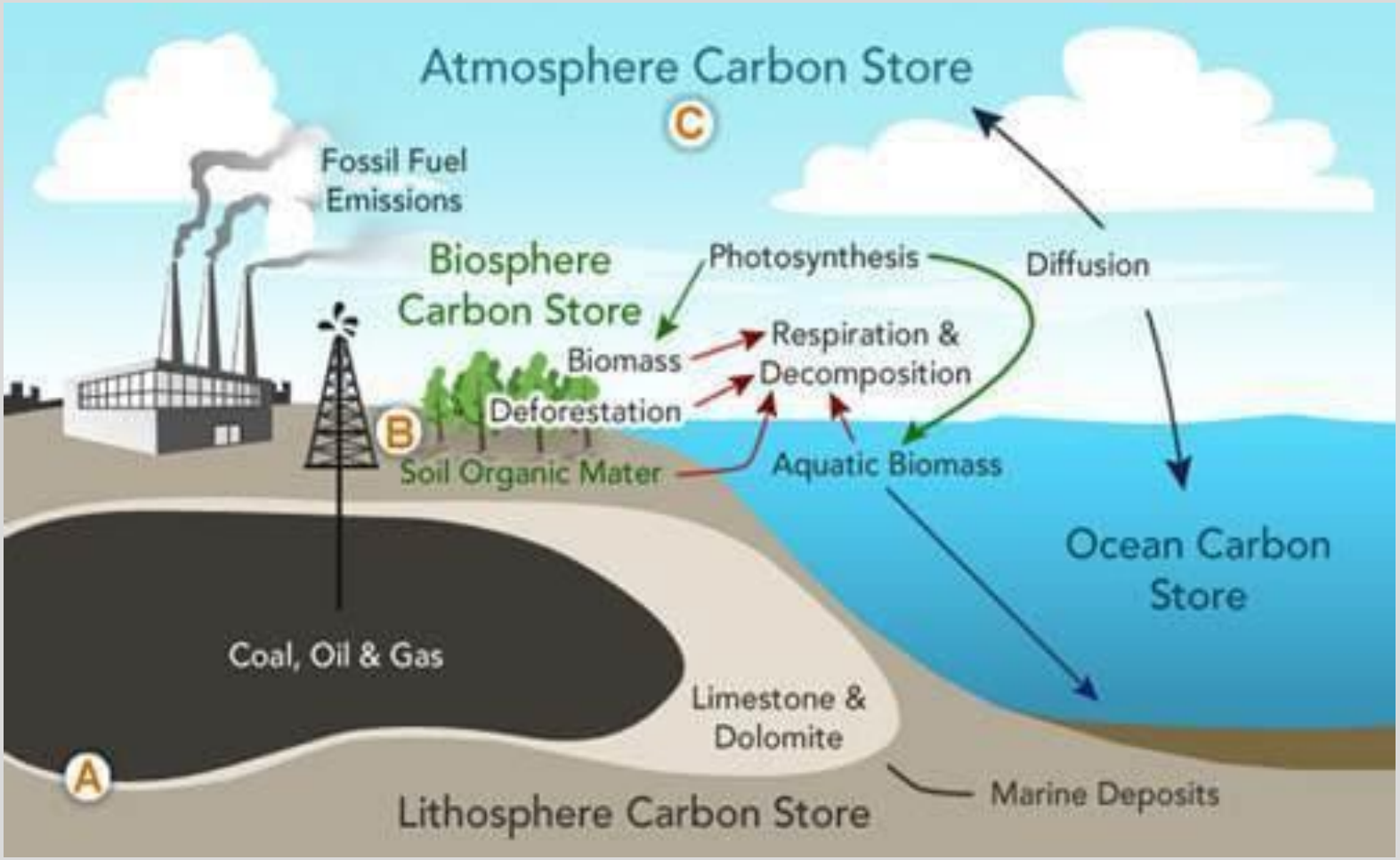
Carbon Cycle



Carbon Cycle



Carbon Cycle



Carbon Cycle

Carbon Assimilation or Carbon Fixation – is the conversion process of inorganic carbon (CO_2) to organic compounds by living organisms. The most prominent example is the photosynthesis.

- Photosynthesis -Photosynthesis is a process used by plants and other organisms to convert light energy into chemical energy that can later be released to fuel the organisms' activities.



Carbon Cycle

- Chemosynthesis - is another form of carbon fixation that takes place in absence of sunlight.

For example – Synthesis of organic compounds by bacteria. It is done by oxidation of inorganic or sometimes methane as source of energy,

Carbon assimilation (in simple words) – plants use CO_2 in photosynthesis and animal consumes those plants.

Carbon Cycle

- Release

Respiration (some types of plants & animals)

(Some plants as they have a respiratory biochemistry as animals.

Decomposition of plants & animals.

CO_2 release from burning of fossil fuels.

Atmospheric Carbon

Carbon has a gaseous phase as part of it's cycle, occurring in the atmosphere such as CO_2 & CH_4 (both greenhouse gas).

- Carbon enters atmosphere through the respiration of living things, burning of organic compounds and by diffusion from ocean.
- It is removed from atmosphere by photosynthesis (green plants, algae and photosynthetic bacterial.
- Also enters the ocean by simple diffusion of CO_2.

Aquatic Carbon

- CO_2 dissolves into ocean from atmosphere state - CO_2 (aq). Most of which are converted to $CO3^{2-}$ & HCO^{3-}.
- Marine algae and photosynthesis bacteria obtain the required CO_2 from the water as one of these three forms.
- Carbon is transferred from the land to the ocean/rivers as dissolved carbon, which includes organic particulates (fine particles). For example: Seashell & other forms of $CaCO_3$.

Carbon in Biota

- Carbon enters the biota through photosynthesis & returns to the atmosphere by respiration.
- When a organism dies, most of it's organic materials decomposes into inorganic compounds including CO_2.
- If there is lack of sufficient oxygen or temperature is too cold for decomposition the organic matters are stored for decades and centuries.
- It can be in wetland lake basins or deep sea sediments. Ultimately it results in sedimentary rocks & fossil fuels

Carbon in Biota

- Most carbon stored in the lithosphere exists as sedimentary rocks, mostly carbonate such as limestone ($CaCO_3$), much of which has direct biological origin.

Impacts of Human Activities on Carbon Cycle

- Alteration of carbon cycle – By adding excess CO_2 to the atmosphere by means of
  # Burning fossil fuels.
  # Deforestation (clearing vegetation faster than it is replaced).
  # Excessive extraction of fossil fuels from lithosphere.

Nitrogen Cycle

Information about Nitrogen

- Nitrogen is essential to life as it is one of the constituents elements in proteins & DNA.
- Free or diatomic nitrogen (N_2 uncombined with any other elements) makes up approximately 78 % of the earth's atmosphere.
- However no organism can use molecular nitrogen directly.

Nitrogen Cycle

Information about Nitrogen

For example :

Some organisms, such as animals require nitrogen in an organic compound. (e. g. Phenyl-ethylamine (mostly found in chocolate).

Others, including plants, algae and bacteria can take up nitrogen either as nitrate ion or ammonium ion.

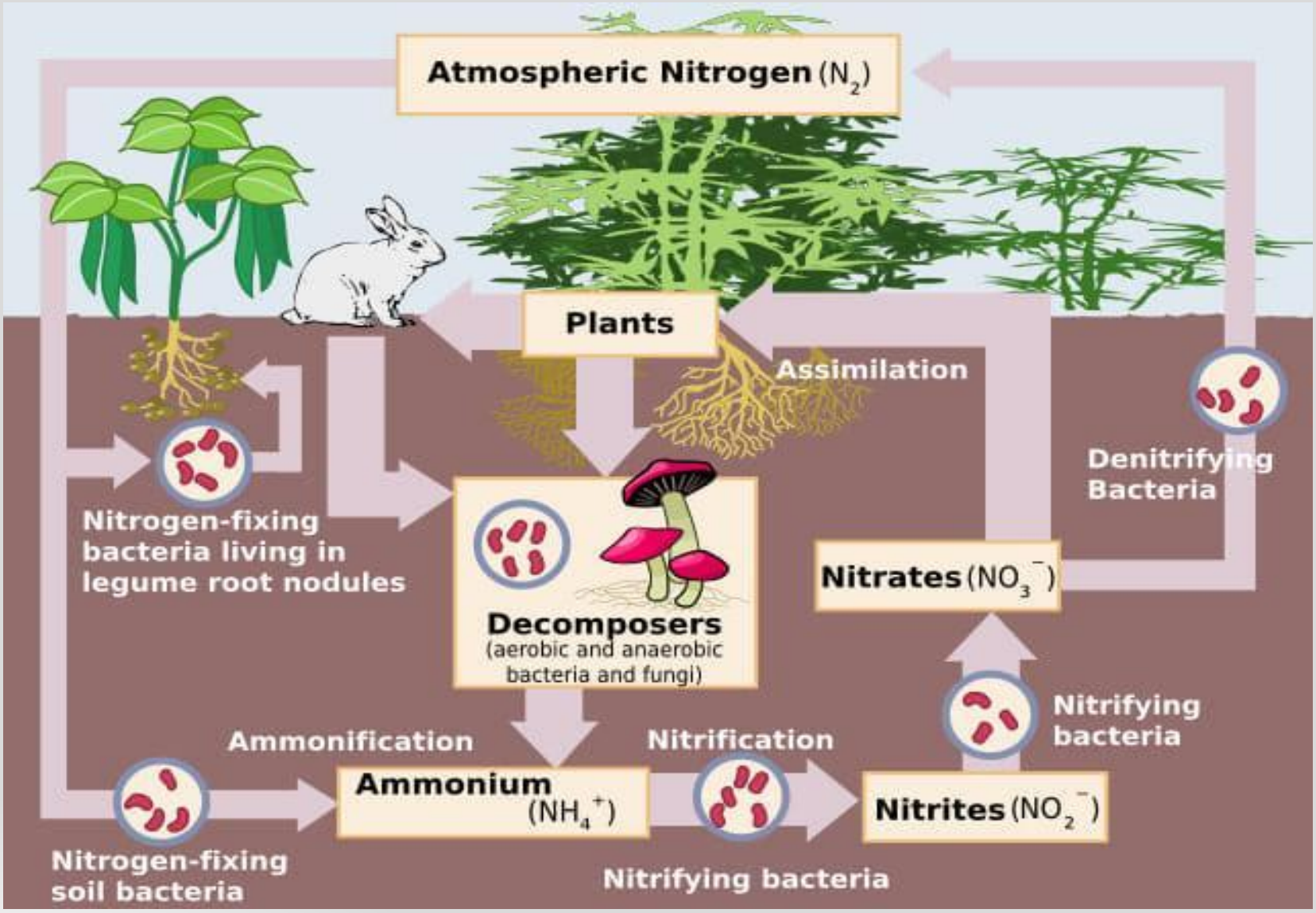
Nitrogen Cycle

Nitrogen cycle – It is one of the most influential/important & most complex of the global cycle.

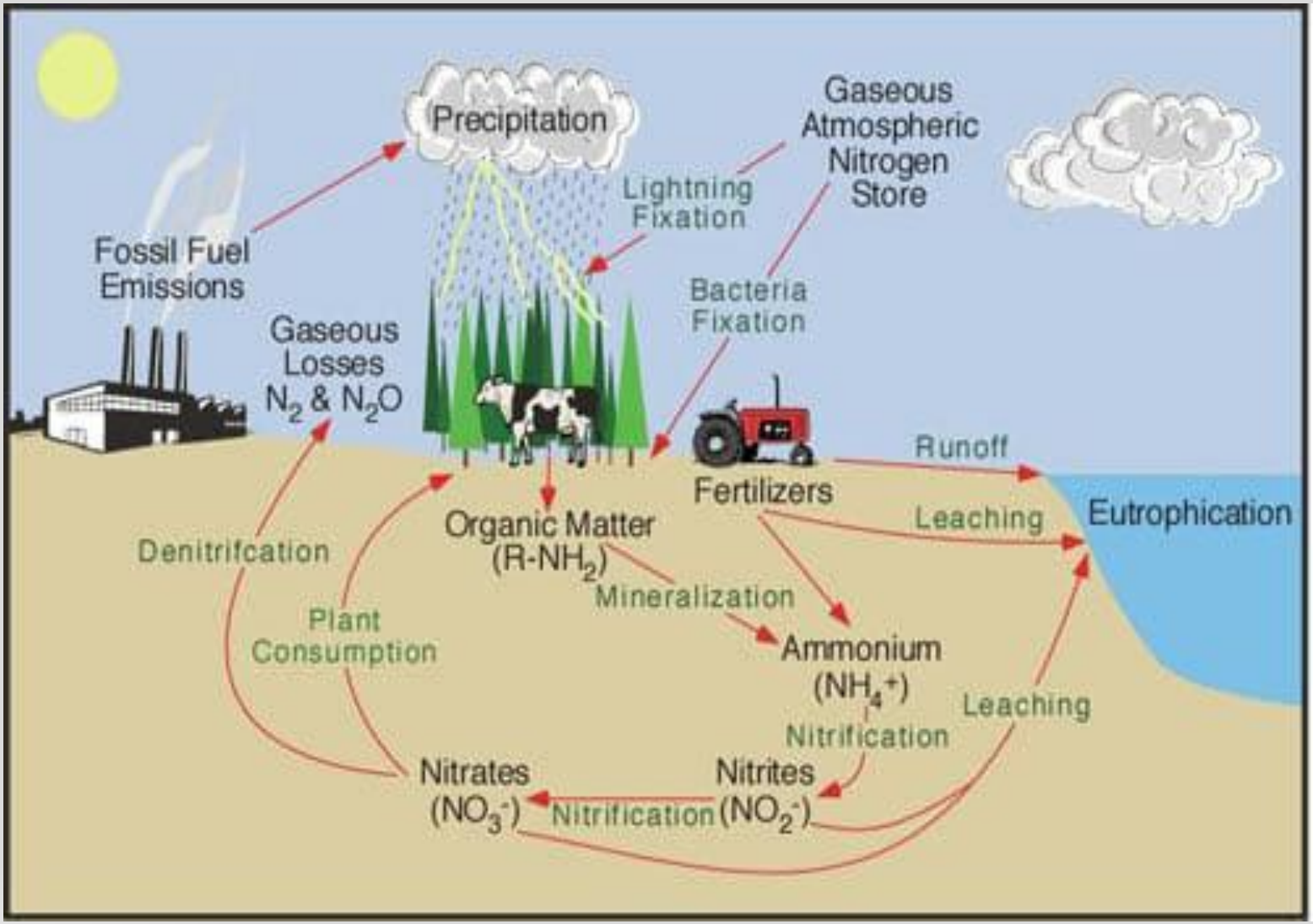
Nitrogen cycle process involves the following steps:

- Nitrogen Fixation
- Nitrification
- Ammonification
- Denitrification

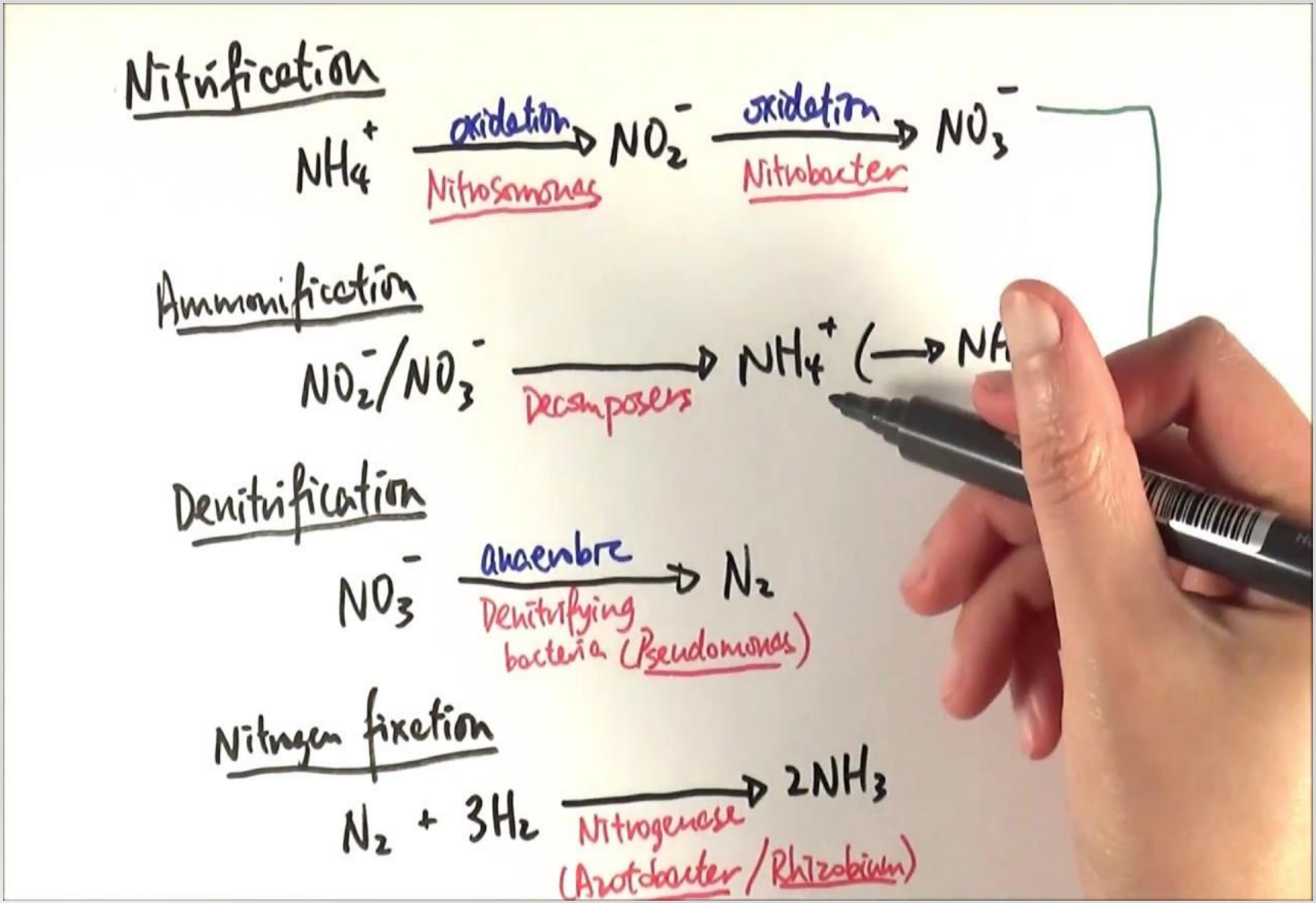
Nitrogen Cycle



Nitrogen Cycle



Nitrogen Cycle



Nitrogen Cycle

- Nitrification is a process that converts ammonia into nitrate by bacteria. Initially, the ammonia is converte to nitrite (NO_2–) by the bacteria Nitrosomonas, or Nitrococcus, etc. and then to nitrate (NO_3-) by Nitro Bacterium.

- Ammonification occurs during decomposition of organic matter, where ammonifying bacteria convert organic nitrogen into inorganic components like ammonia or ammonium ions.

- Denitrification is the process of converting the nitrate back into molecular nitrogen by bacterias (Pseudomonas, Thiobacillus, Bacillus subtilis etc.)

Nitrogen Cycle

- Nitrogen is abundant in the atmosphere, but it is unusable to plants or animals unless it is converted into nitrogen compounds.

- Nitrogen-fixing bacteria play a crucial role in fixing the atmospheric nitrogen into nitrogen compounds that can be used by the plants.

- The plants absorb the usable nitrogen compounds from the soil through their roots. Then, these nitrogen compounds are used for the production of proteins and other compounds in the cell.

- Animals,Humans assimilate nitrogen by consuming these plants or other animals that contain nitrogen. and then, the nitrogen assimilates into our system.

- During the final stages of the nitrogen cycle, bacteria and fungi help decompose organic matter, where the nitrogenous compounds get dissolved into the soil which is again used by the plants.

- Some bacteria then convert these nitrogenous compounds in the soil and turn it into nitrogen gas. Eventually, it goes back to the atmosphere.

- These set of processes repeat continuously and thus maintain the percentage of nitrogen in the atmosphere.

Nitrogen Cycle

Symbiotic relationship means close & long term biological interaction between two different biological organism.

Example of symbiotic relationship – The roots of pea family have nodules that provide habitat for these bacteria. Bacteria takes organic compounds for food from the plant

Nitrogen Cycle

Reservoirs – Atmosphere (N_2)

Soil (NH_4^+, NO_2^- & NO_3^-)

Assimilation – Plant absorbs nitrogen as either NH_4^+ or NO_3^-.

Animals obtain nitrogen by feeding on those plants or other animals.

Stages of assimilation

Nitrogen Fixation

- N_2 to NH_4^+ (by nitrogen fixing bacteria)
- N_2 to NO_3^- (by lightning or UV radiation)

Nitrogen Cycle

Stages of assimilation

Nitrification

- NH_4^+ to NO_2^- & then NO_2^- to NO_3^- (by various nitrifying bacteria).

Release

- NO_3^- to N_2 (by various denitrifying bacteria).
- Bacteria converts organic compound back to NH_4^+ (Ammonification).
- Animals excretes NH_4^+ or NH_3 or uric acid.

Nitrogen Cycle

Impact of human activities on nitrogen cycle :

- Adding gases that contributes to the acid rain - NO_x -> NO_2 or NO (nitric oxide)
- Adding N2O (nitrous oxide – a greenhouse gas) to atmosphere through farming practice.
- Contamination of ground water by nitrate ions from inorganic fertilizers.
- Releasing nitrogen into troposphere through deforestation.

Nitrogen Cycle

Impact of human activities on nitrogen cycle :

- Right now production of fertilizers fixes more nitrogen than all natural source combine.

Lecture Summary

- Atmospheric State Variables
- Concepts of Elementary Cycles

The End