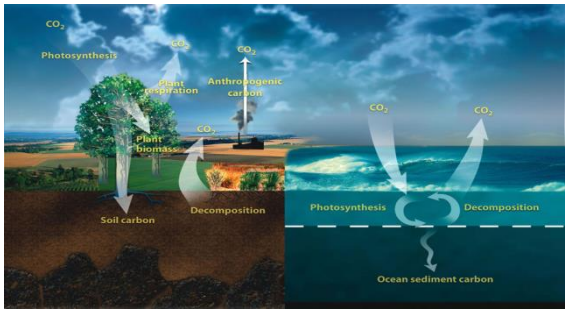
Rôles des microorganismes dans le fonctionnement des cycles biogéochimiques naturels

Laurent Mazéas

Microbial ecology for environmental sciences Module

Role of microorganisms in the functioning of natural ecosystems and biogeochemical cycles.



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Course Outline

1- What is a natural ecosystem? What are some examples?

2- What are biogeochemical cycles ?

3- Role of microorganisms on global biogeochemical cycles

4- Role of microorganisms in polluted environment

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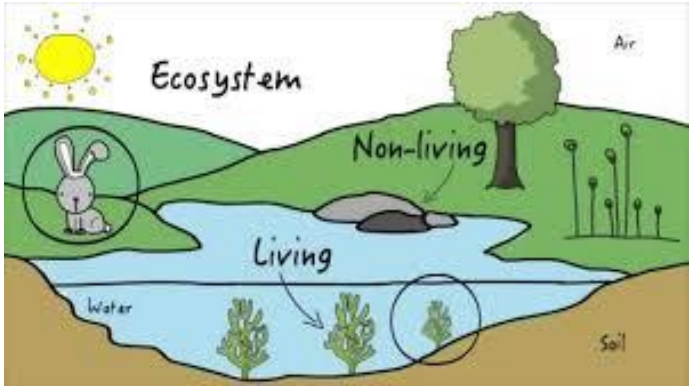
What is a natural ecosystem? What are some examples?

Environmental degradation is a major issue of our time. A basic environmental building block is the *ecosystem.*

Definition :

An ecosystem is a combination of two words: "ecological" and "system." Together, they describe the collection of biotic and abiotic (living and non-living) components and processes that comprise a defined subset of the biosphere. (The "biosphere" is the area of Earth that contains life, whether on the planet's surface or in the air.)



Natural vs. Artificial Ecosystems

Natural ecosystems may be terrestrial (such as a desert, forest, or meadow) or aquatic (a pond, river, or lake). A natural ecosystem is a biological environment that is found in nature (e.g. a forest) rather than created or altered by man (a farm).
Humans have modified some ecosystems for their own benefit. These are artificial ecosystems. They can be terrestrial (crop fields and gardens) or aquatic (aquariums, dams, and manmade ponds).

Types of Natural Ecosystems

Aquatic Ecosystems

Aquatic ecosystems cover 71% of the earth's surface. There are three different varieties, defined by the kind of water in which the system's organisms interact.

Freshwater: This type includes lakes, rivers, ponds, streams, and makes up the smallest percent of the earth's aquatic ecosystems.

Transitional communities: These are places where freshwater and saltwater come together, such as estuaries.

Marine: More than 70% of the earth is covered by marine (also called saltwater) ecosystems. These include shorelines, coral reefs, and open ocean.

Terrestrial Ecosystems

The four terrestrial ecosystems are classified by the type of land or terrestrial area in which organisms interact.

Forest: These ecosystems feature dense tree populations, and include boreal and tropical rain forests.

Desert: Deserts receive less than 25 cm of rainfall per year.

Grassland: These ecosystems include tropical savannas, temperate prairies, and arctic tundra.

Mountain: Mountain ecosystems include steep elevation changes between meadows, ravines, and peaks.

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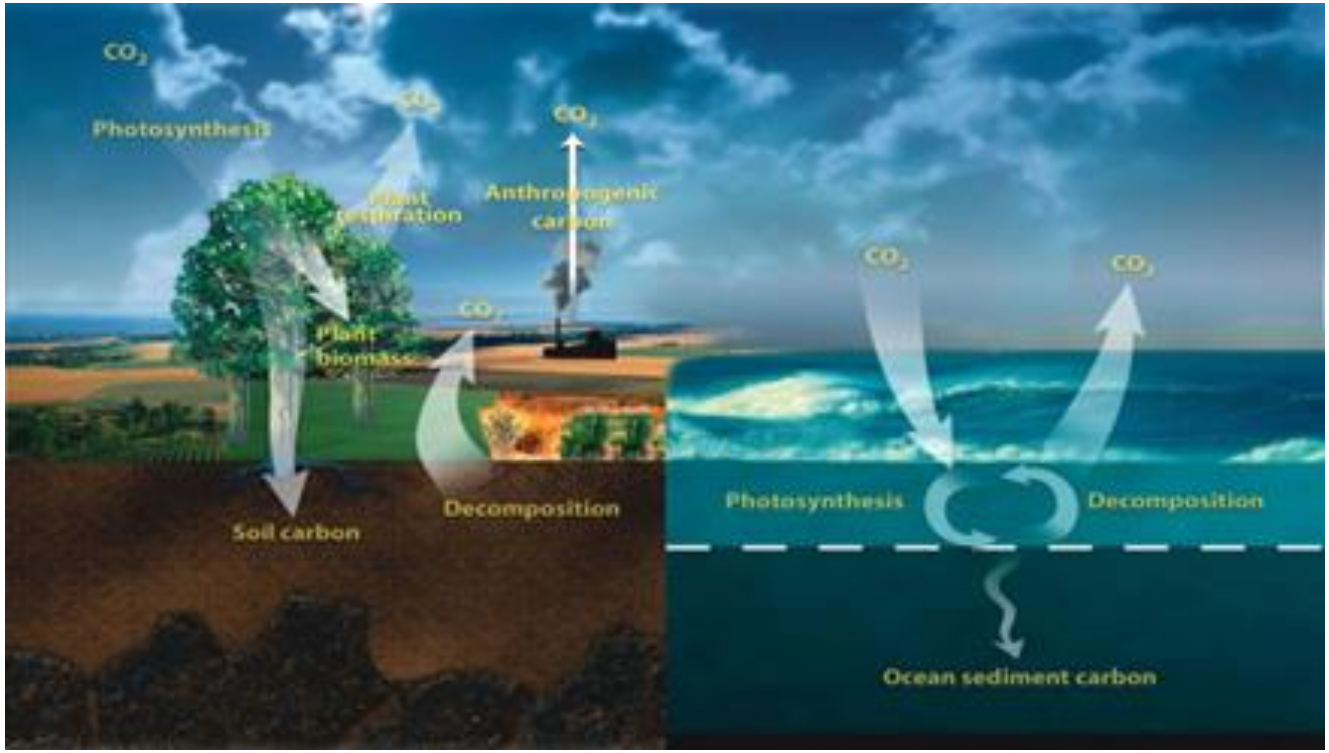
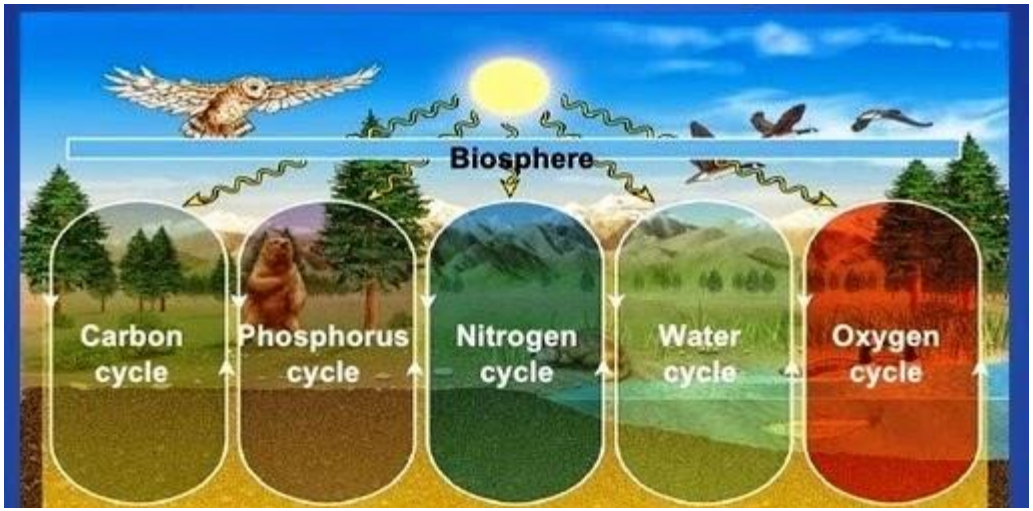
What are biogeochemical cycles ?

Biogeochemical cycles involve the fluxes of chemical elements among different parts of the Earth: from living to non-living, from atmosphere to land to sea, and from soils to plants. They are called “cycles” because matter is always conserved and because elements move to and from major pools via a variety of two-way fluxes, although some elements are stored in locations

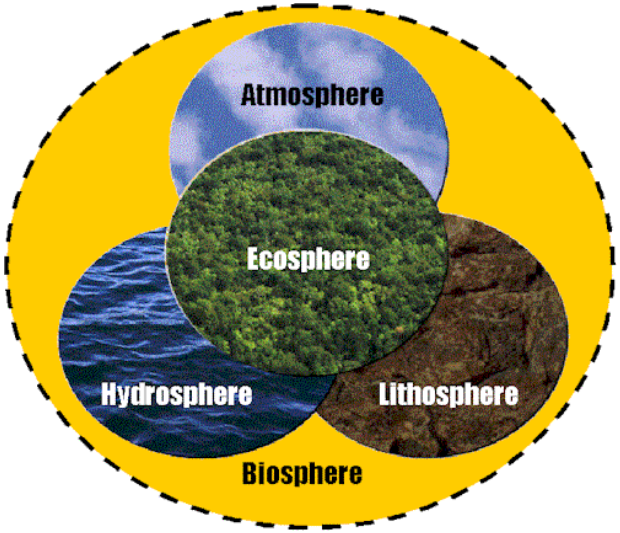


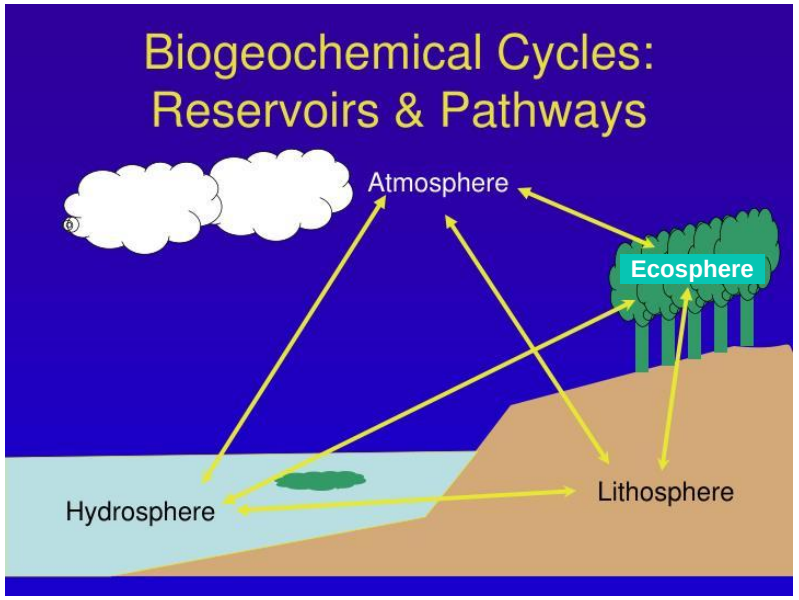
Global biogeochemical cycles ?

Exemples of global biogeochemical cycles ?



Biosphere?





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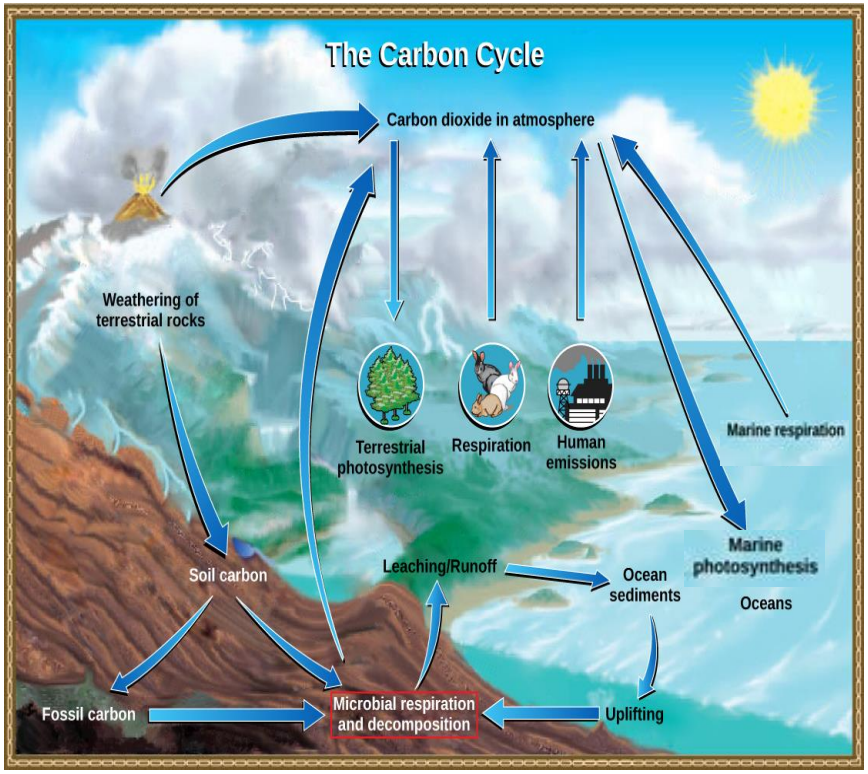
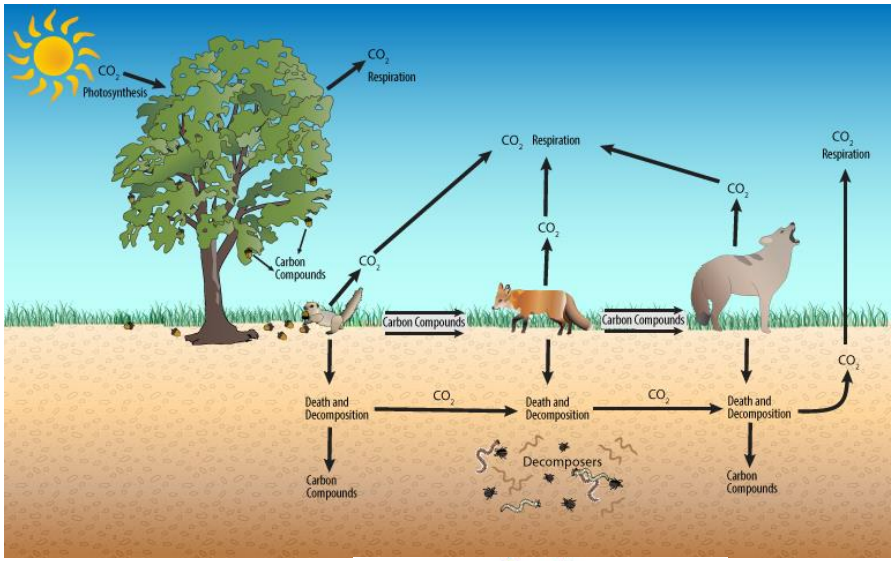
The Carbon Cycle

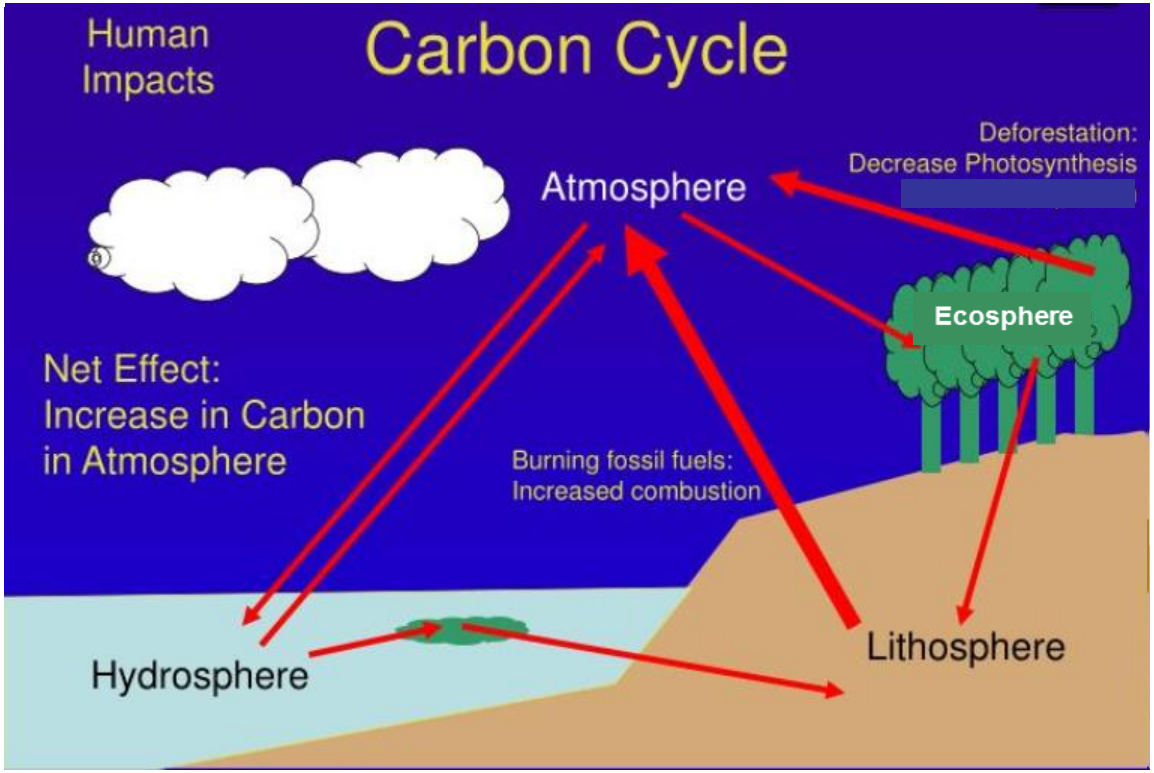
https://cnx.org/contents/ZdFkREJc@6/Biogeochemical-Cycles





Carbon dioxide gas exists in the atmosphere and is dissolved in water. Photosynthesis converts carbon dioxide gas to organic carbon, and microbial respiration and decomposition cycles the organic carbon back into carbon dioxide gas and Methane. Long-term storage of organic carbon occurs when matter from living organisms is buried deep underground and becomes fossilized. Volcanic activity and, more recently, human emissions, bring this stored carbon back into the carbon cycle

Human effect on the Carbon Cycle

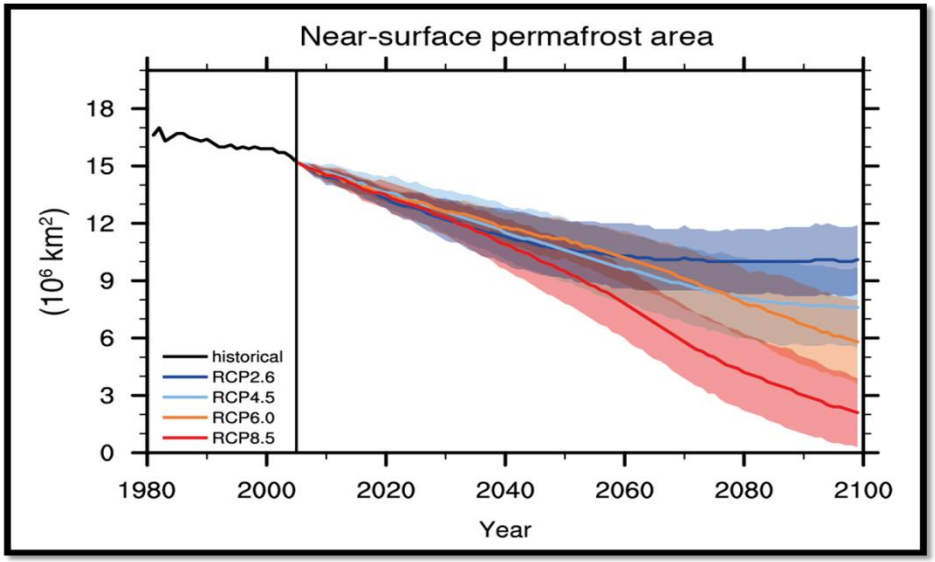


The Permafrost timebomb

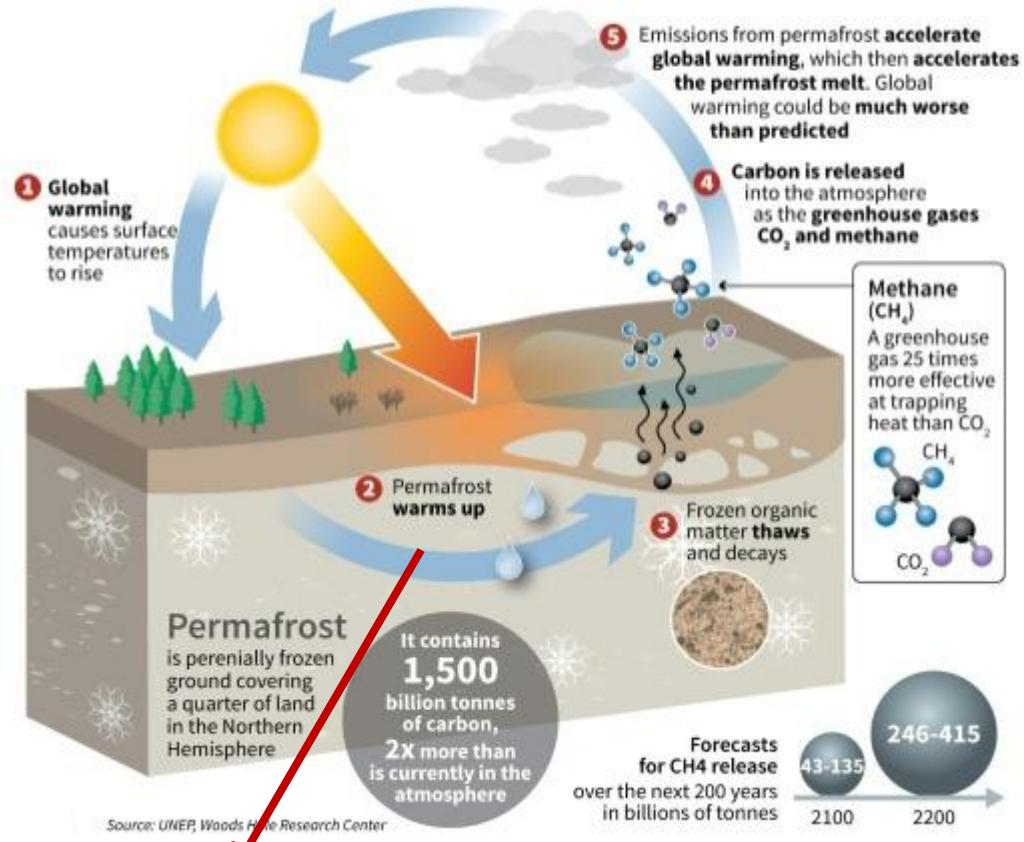
Permafrost is soil that has been frozen for at least two consecutive years.

It is found in large parts of the Arctic & in the Himalayas – encompassing about 25% of the northern hemisphere land area.

There's more than twice as much carbon stored in permafrost as there is in the whole atmosphere.

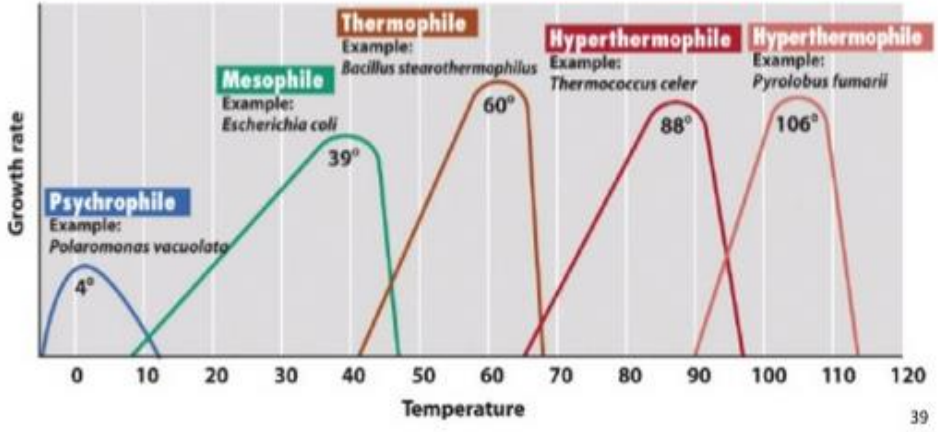


The Permafrost timebomb



Microbial diversity in permafrost

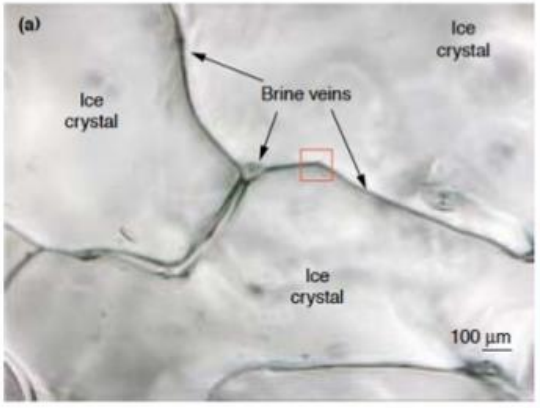
- Bacteria
  - Proteobacteria, Actinobacteria, Firmicutes, Bacteroidetes
  - Similar diversity as other non-frozen soils
- Eukarya
  - Mostly fungi
- Archaea
  - There is a wide diversity of psychrophilic archaea
  - Methanogens & methanotrophs

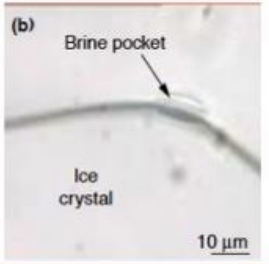


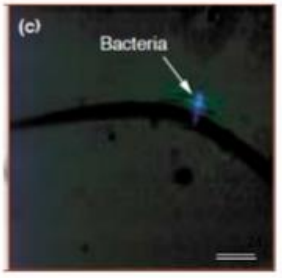
39

Archaea: functional diversity

- **Methanogens**— archaeans that produce methane gas as a waste product of their "digestion," or process of making energy.
- **Halophiles**— those archaeans that live in salty environments.
- **Thermophiles**— the archaeans that live at extremely hot temperatures.
- **Psychrophiles**— those that live at unusually cold temperatures.







Deming, Current Opinion in Microbiology 2002, 5:301–309

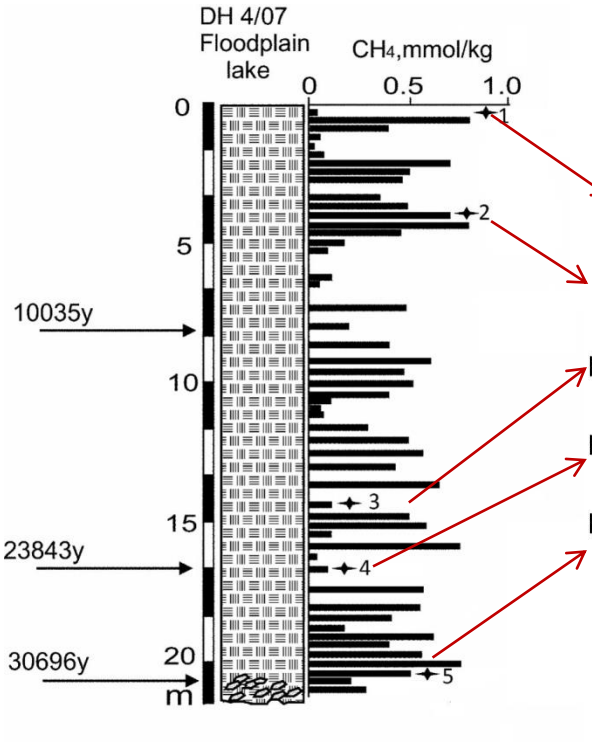
- Psychrophilic microorganisms proliferate at 0–10°C, metabolize in snow and ice at –20°C, are predicted to metabolize at –40°C and can survive at –45°C.
- Temperatures – Psychrophiles grow optimally below 15°C. 80% of Earth's biosphere is < 15°C.

Methanogenic Achaea in permafrost

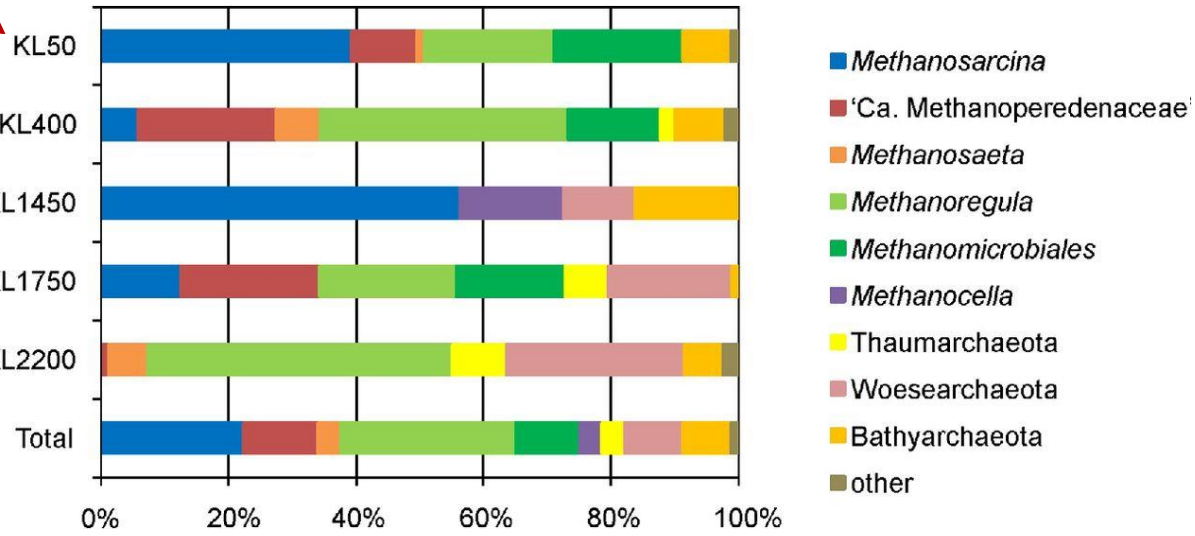
Archaeal communities of Arctic methane-containing permafrost FREE

Victoria Shcherbakova ✉, Yoshitaka Yoshimura, Yana Ryzhmanova, Yukihiro Taguchi, Takahiro Segawa, Victoria Oshurkova, Elizaveta Rivkina

FEMS Microbiology Ecology, Volume 92, Issue 10, 1 October 2016, fiw135, https://doi.org/10.1093/femsec/fiw135



Distribution of archaeal lineages based on 16S rRNA gene sequences within permafrost samples.



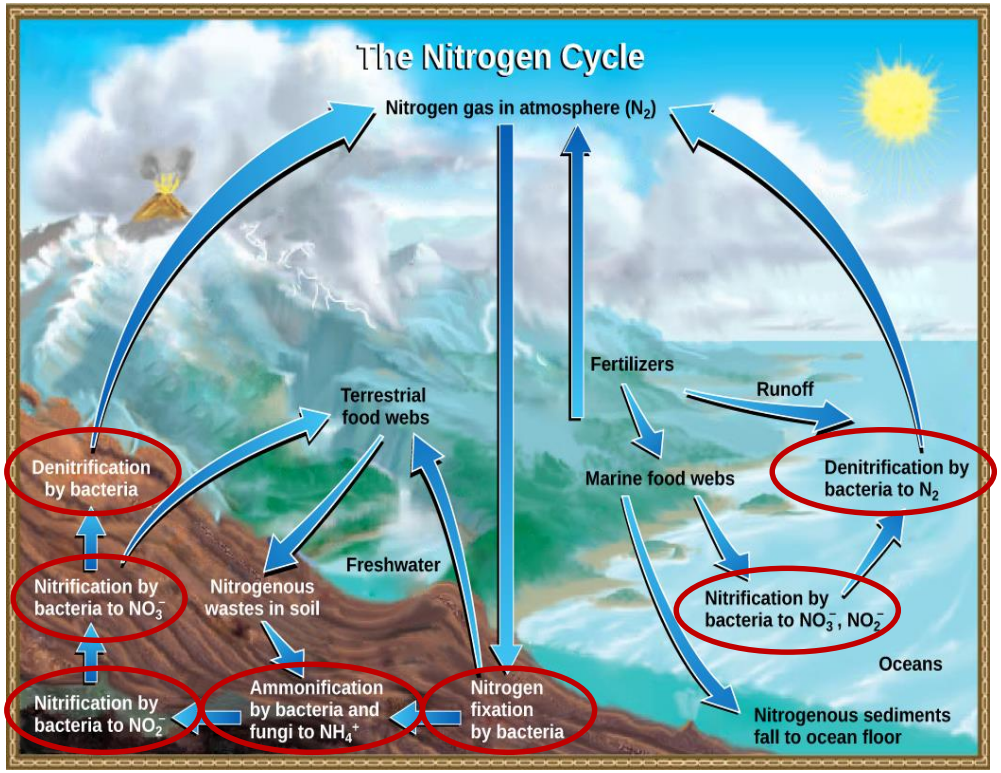
Anthrax Virus

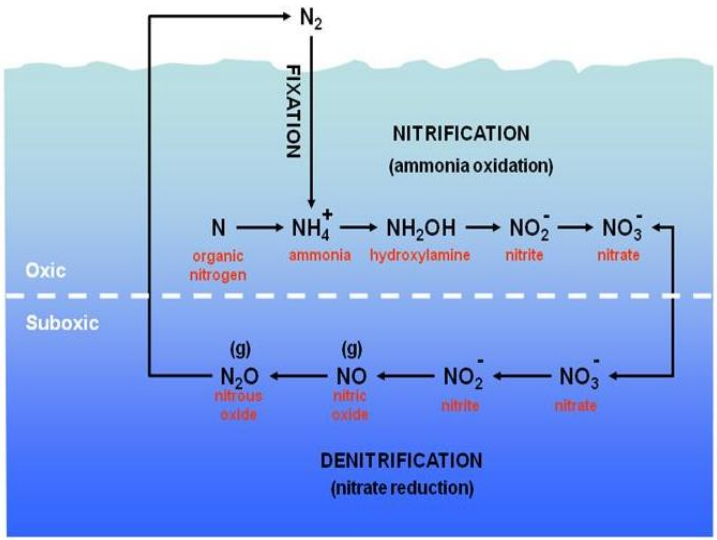
Climate Change - Degradation of Permafrost – Anthrax cattle burial grounds

- Anthrax among people or cattle have been reported in 29,000 settlements of the Russian North, including 270 Yakutia settlements (1906-2004 years), located near the burial grounds of cattle died from Anthrax
- The results of paleo-microbiological tests showed that viable viruses of anthrax might survive in tissues of corpses under permafrost conditions (Belanov et al., 1997).

Frozen in ice for millennia, this Siberian mummy is the best-preserved ancient horse ever found.

The Nitrogen Cycle

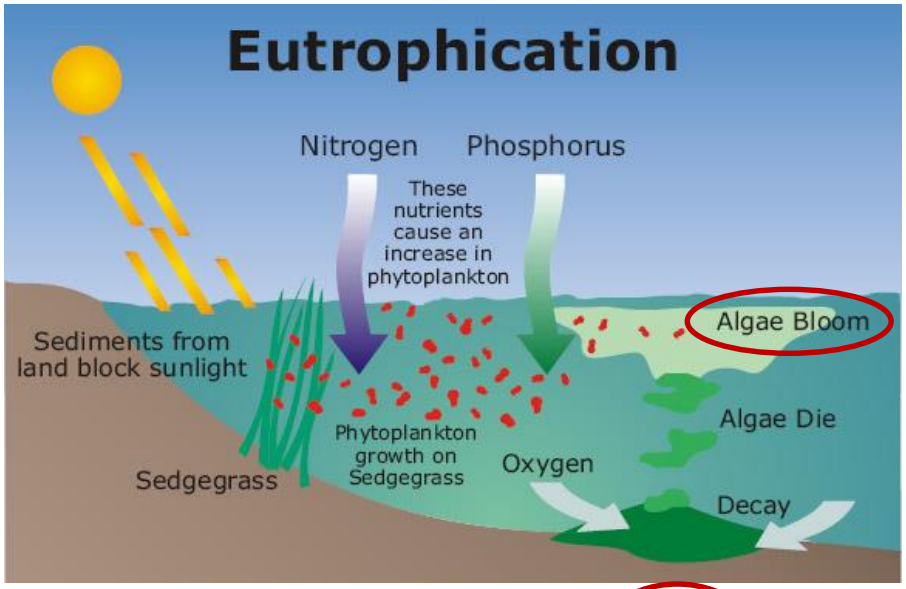




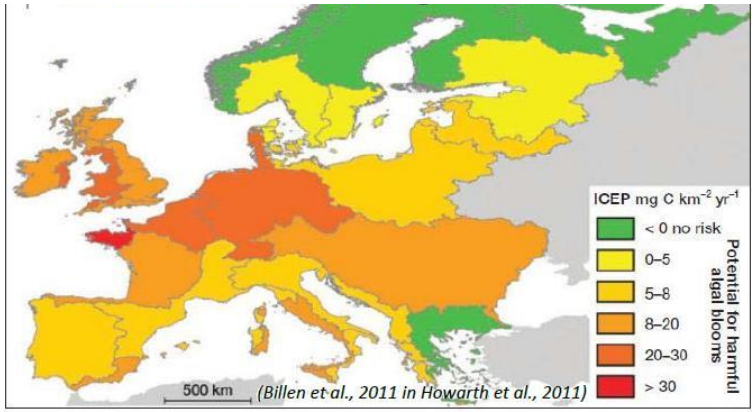
Nitrogen enters the living world from the atmosphere via nitrogen-fixing bacteria. This nitrogen and nitrogenous waste from animals is then processed back into gaseous nitrogen by marine and soil bacteria, which also supply terrestrial food webs with the organic nitrogen they need.

Eutrophication effect

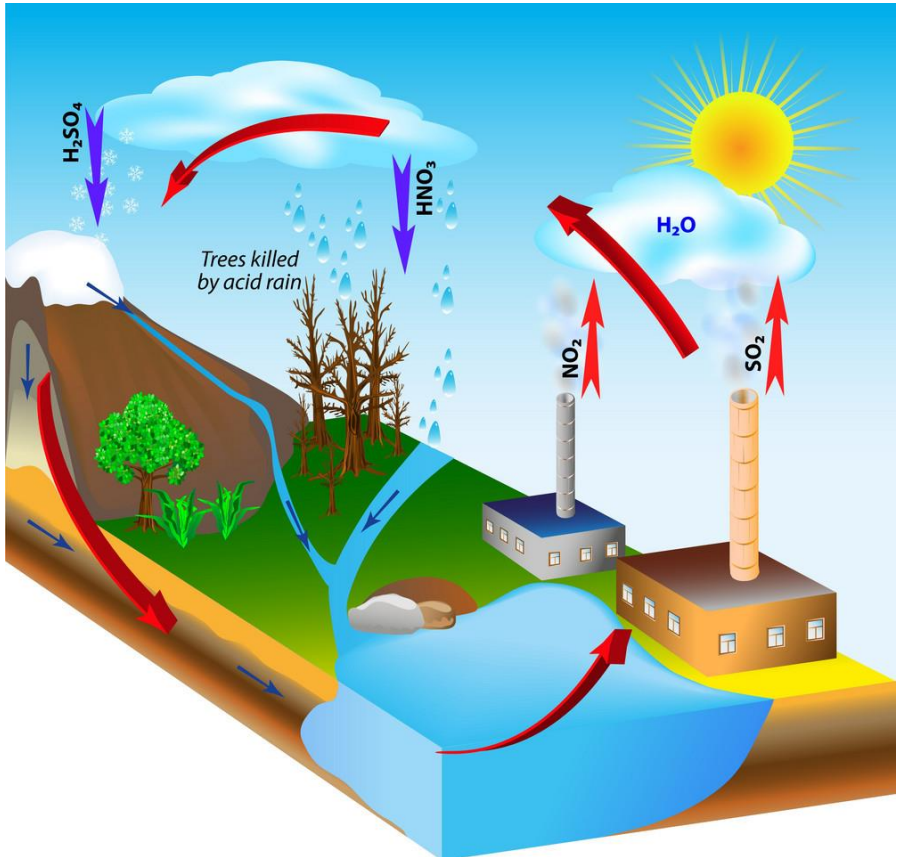
Eutrophication is an enrichment of water by nutrient salts that causes structural changes to the ecosystem such as: increased production of algae and aquatic plants, depletion of fish species, general deterioration of water quality and other effects that reduce and preclude use



Eutrophication affects 54% of Asian lakes, 53% of those in Europe, 48% of those in North America, 41% of those in South America and 28% of those in Africa

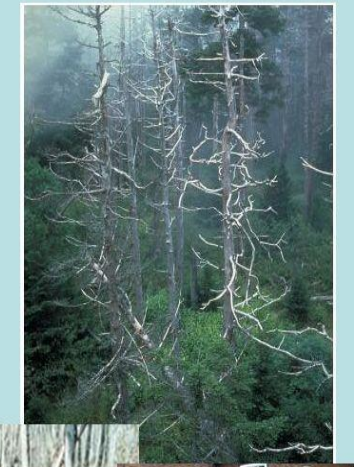


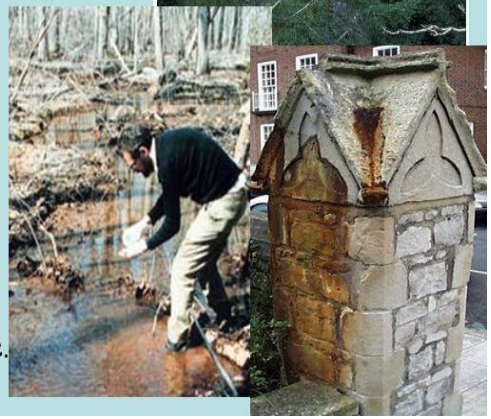
Acid Rain



Effects of Acid Rain

- Acid rain can increase the acidity of lakes, dams and streams and cause the death of aquatic life.
- Acid rain can increase the acidity of soil, water and shallow groundwater.
- Acid rain can dammage forests.
- Acid rain erodes buildings and monuments.
- Acid particles in the air are suspected of contributing to respiratory problems in people.





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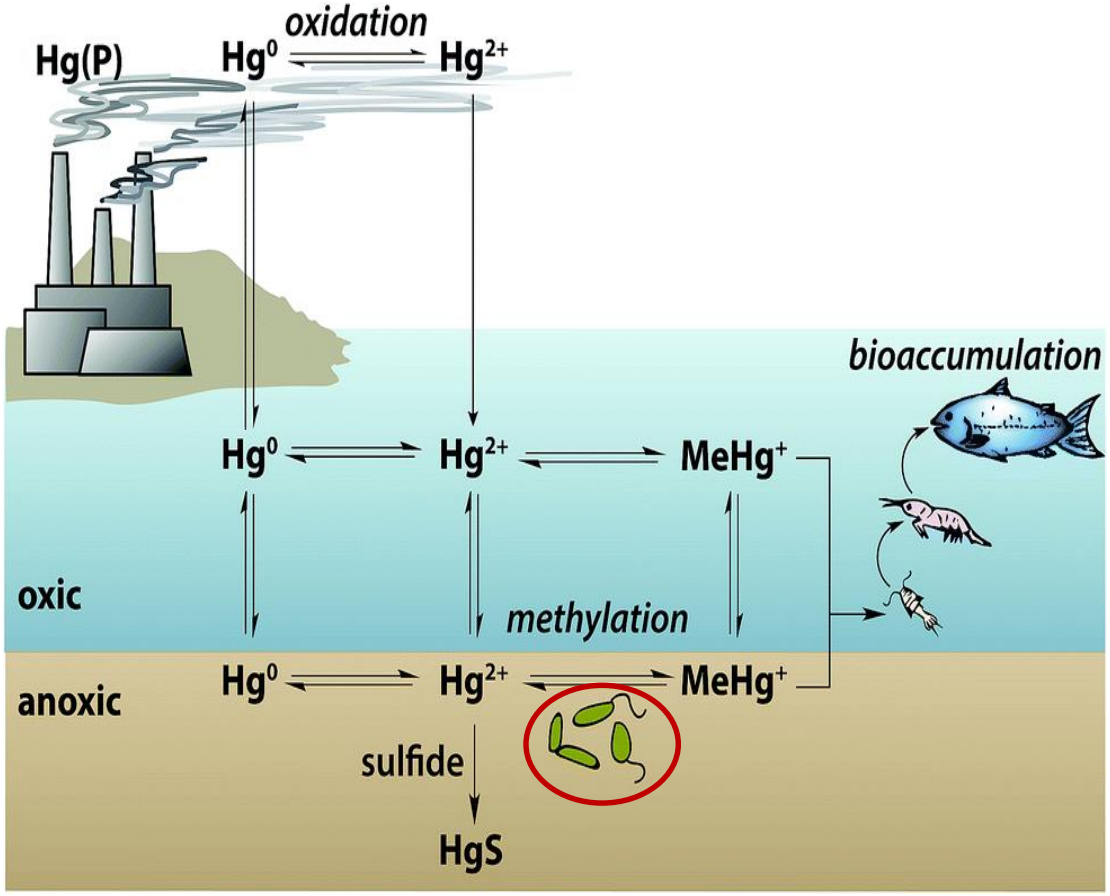
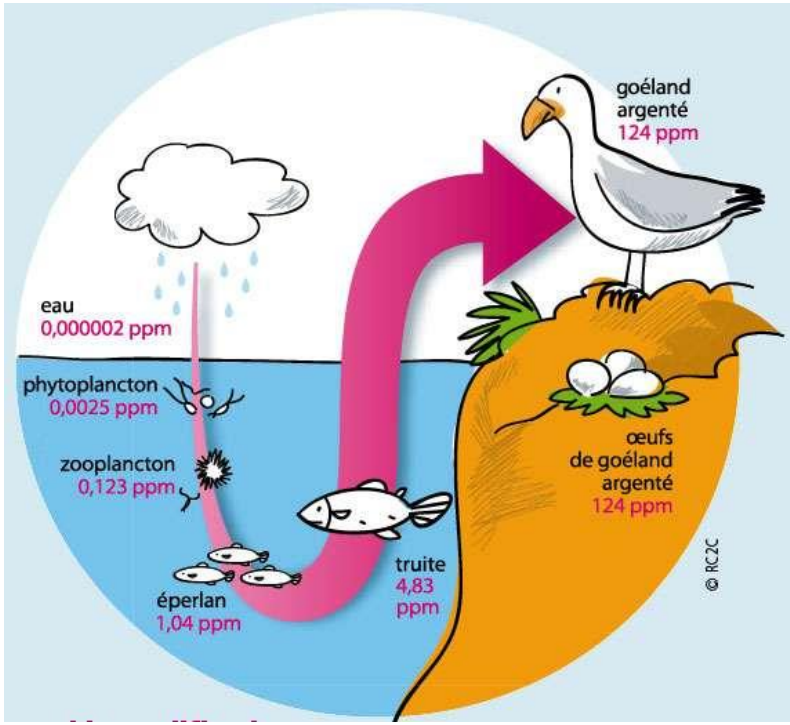
Microorganism can amplify pollution : Minamata case

Mercury Biogeochemical cycle





Microorganism can attenuate pollution: Oil spill Case

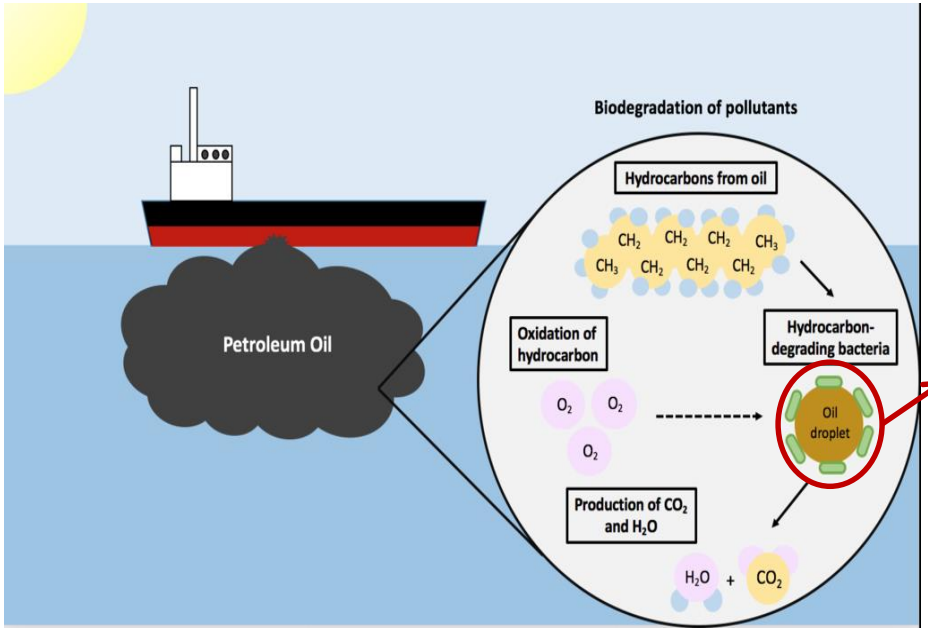
Natural attenuation occurs:

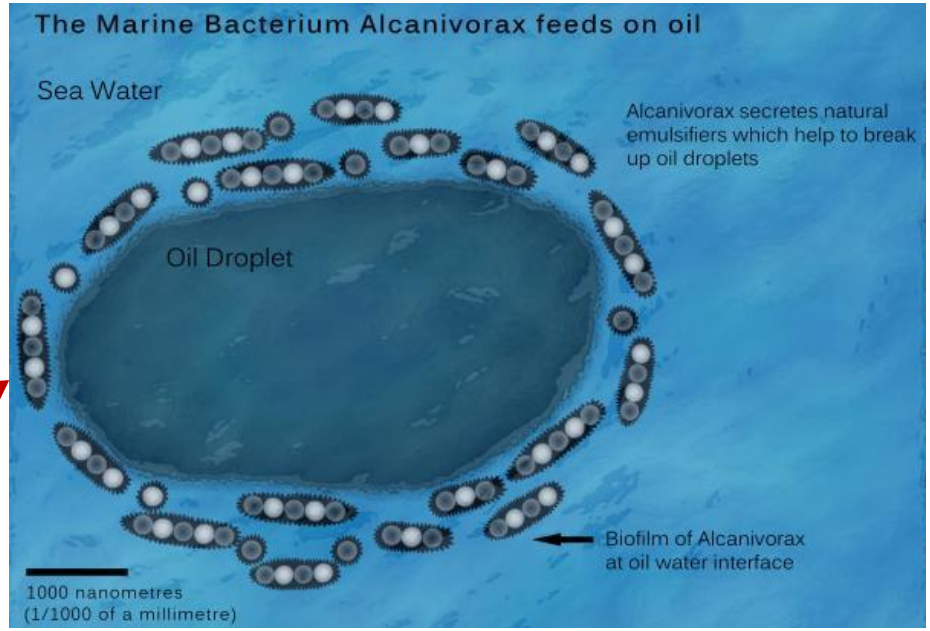
Processes involved: sorption, volatilization, chemical reactions, dispersion and **biodegradation**

Oil biodegradation

After an accidental oil spill into open water, the numbers of oil eating microbes increase. Oxygen concentration is high in sea water close to the surface, so microbes break down oil at relatively rapid rates using aerobic respiration.

Oil eating bacteria include Alcanivorax borkumensis, which breaks down straight-chain and branched-chain hydrocarbons 1. As the oil is fragmented into droplets by wave action, Alcanivorax cluster on the surface of droplets forming a biofilm, and secrete biosurfactant which helps with ingesting the oil.





What is a natural ecosystem? What are some examples?

❖Aerobic and anaerobic biodegradation

- •Aerobic
  - •Oxygen is reduced to water and the organic molecules (e.g. petroleum, sugar) are oxidized
- •Anaerobic
  - •An inorganic compound is reduced and the organic molecules are oxidized (e.g. nitrate is reduced and sugar is oxidized)
- •NOTE: Many microbes can do both aerobic and anaerobic respiration; the process which produces the most ATP is used first!