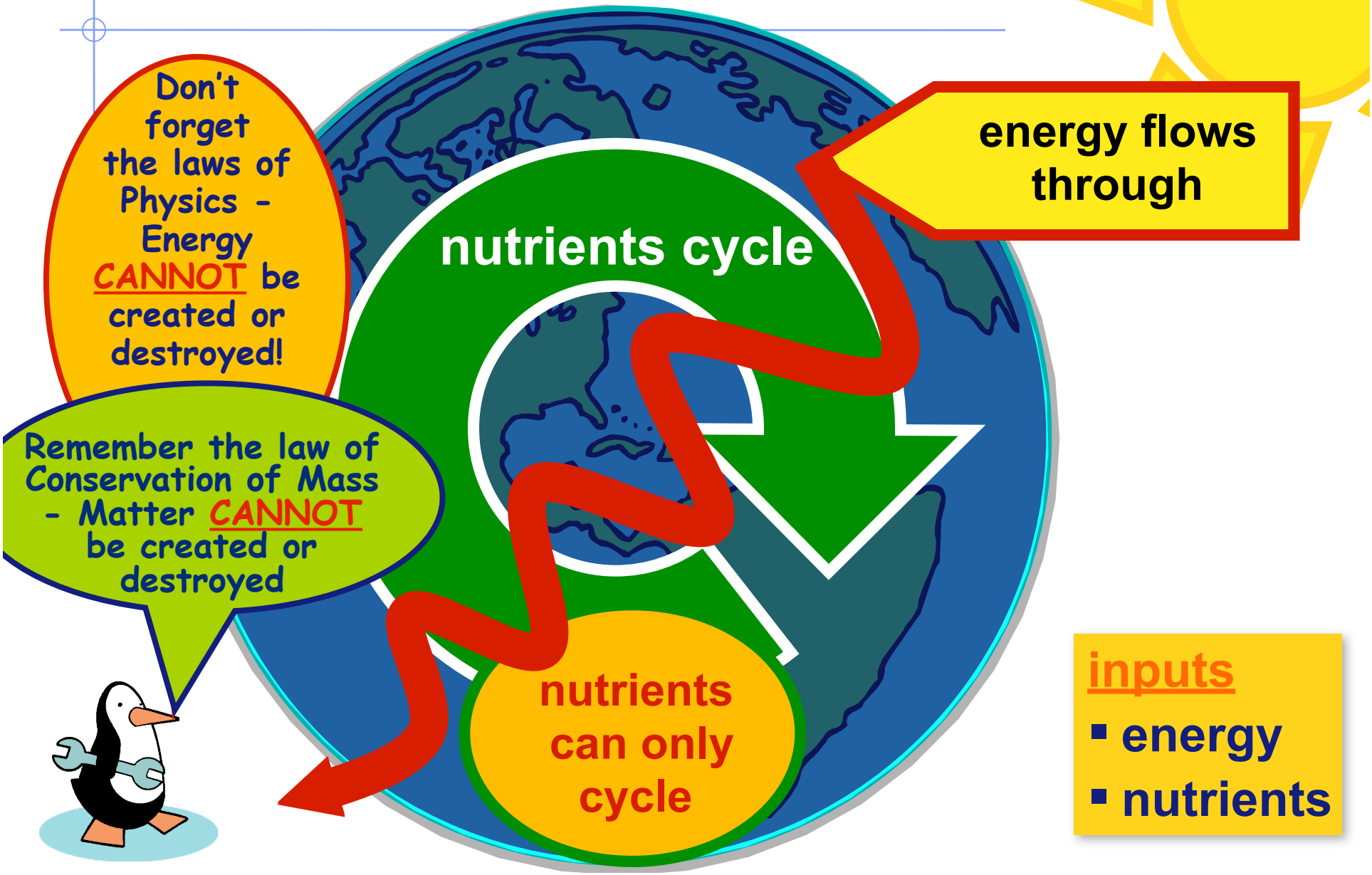
Ecosystem Inputs



inputs

- energy
- nutrients

Global Issues Related to Ecosystems

- **Climate Change**
- **Water & Carbon Cycle Disruptions**
- **Non-human organisms' Habitat Loss, Habitat Fragmentation, & Contamination**
- **Soil fertility** - too many nutrients added to soil can result in excess mineral run off *(minerals dissolved in water that enters lakes and oceans)* leading to eutrophication.
- **Soil erosion** - without soil, many organisms and producers would no longer grow, affecting biodiversity and the carbon and water cycles.
- **Irrigation** - over watering can cause increase mineral loss from the more superficial layers of soil, leaching the soil from valuable nutrients that then wash out into the deeper ground water.
- **forestry destruction** - has a negative impact not only on soil health, but the carbon and water cycles as well as biodiversity.

Generalized Nutrient cycling

Decomposition connects all trophic levels

consumers

producers

decomposers

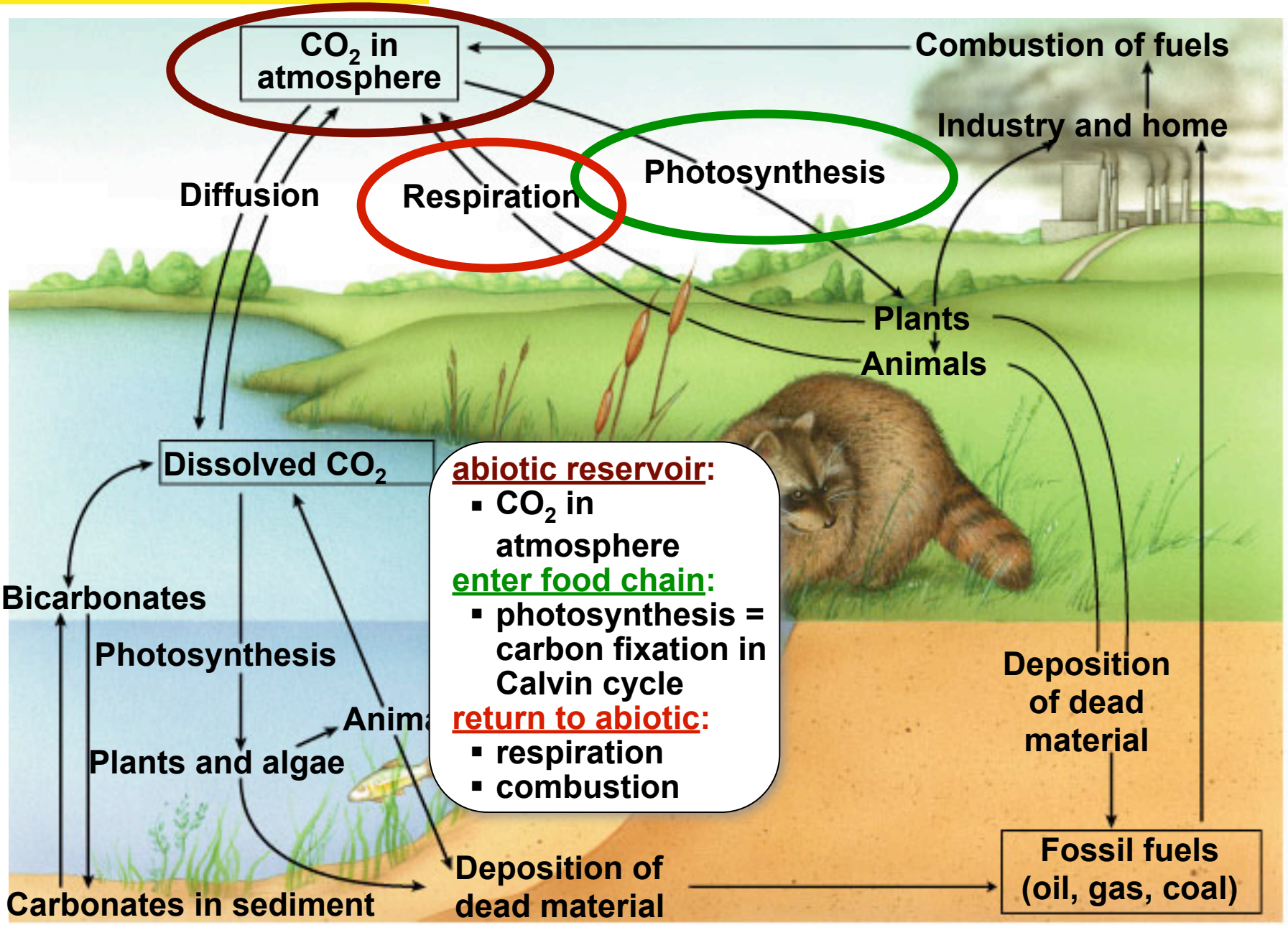
nutrients
ENTER FOOD CHAIN
= made available to producers

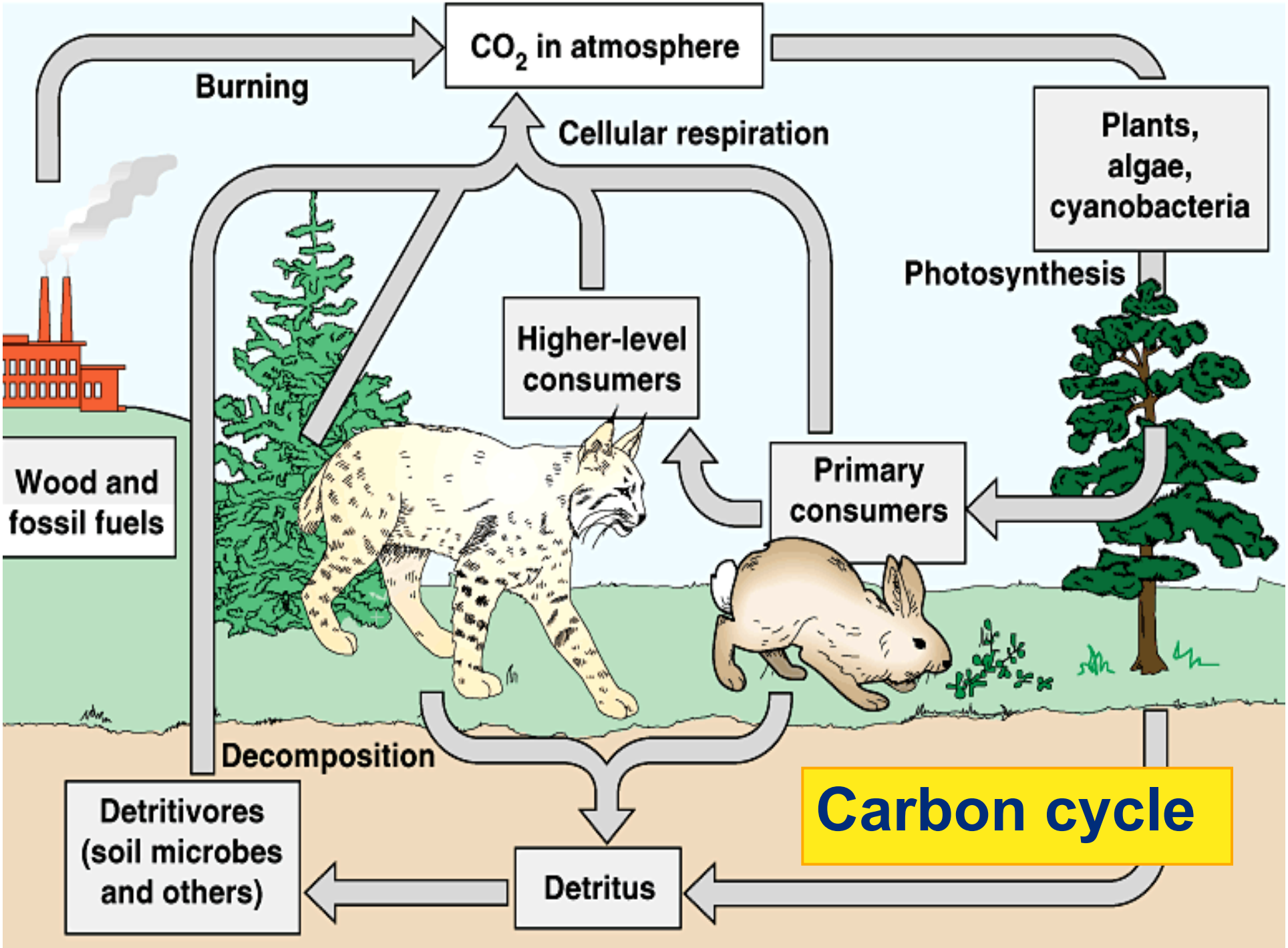
return to abiotic reservoir

abiotic reservoir

geologic processes

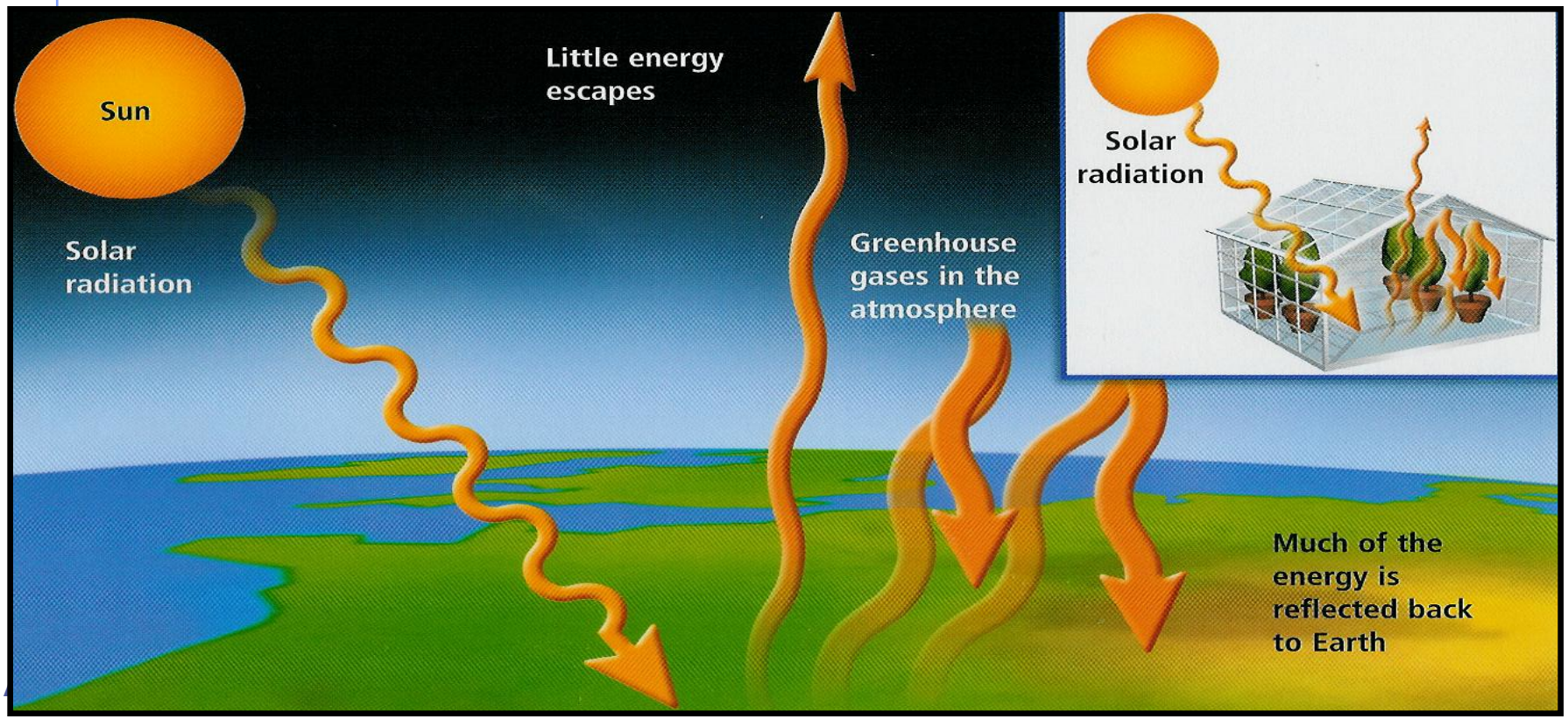
Carbon cycle

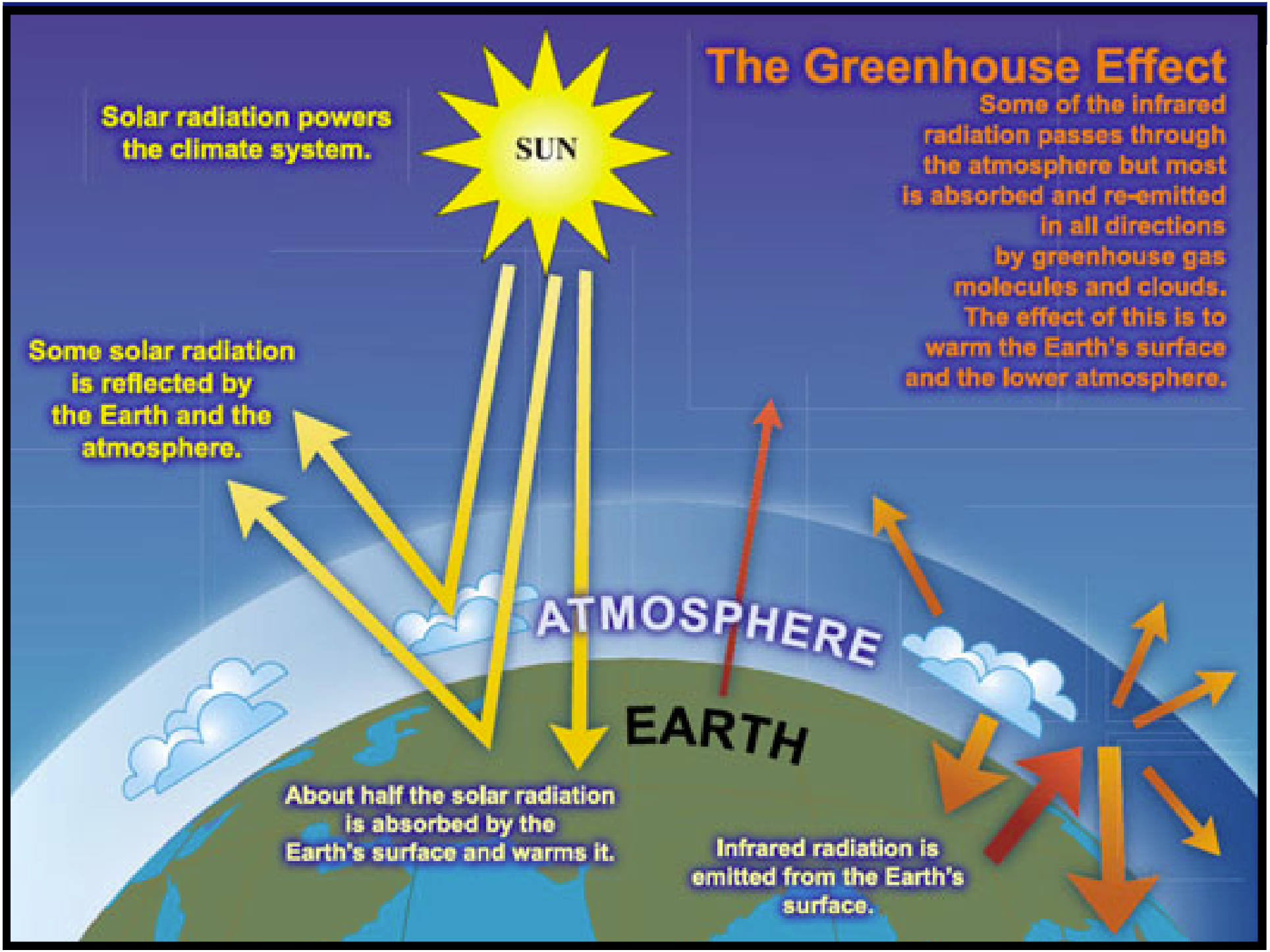



CO_2 in atmosphere
Burning
Cellular respiration
Plants, algae, cyanobacteria
Photosynthesis
Higher-level consumers
Primary consumers
Wood and fossil fuels
Decomposition
Detritivores (soil microbes and others)
Detritus
Carbon cycle

The Green House Effect

- The atmosphere is made up of several gases some of which trap solar heat helping keep Earth warm enough for life = <u>The Green House Effect</u>
  - Greenhouse gases include H_2O, CH_4, and CO_2

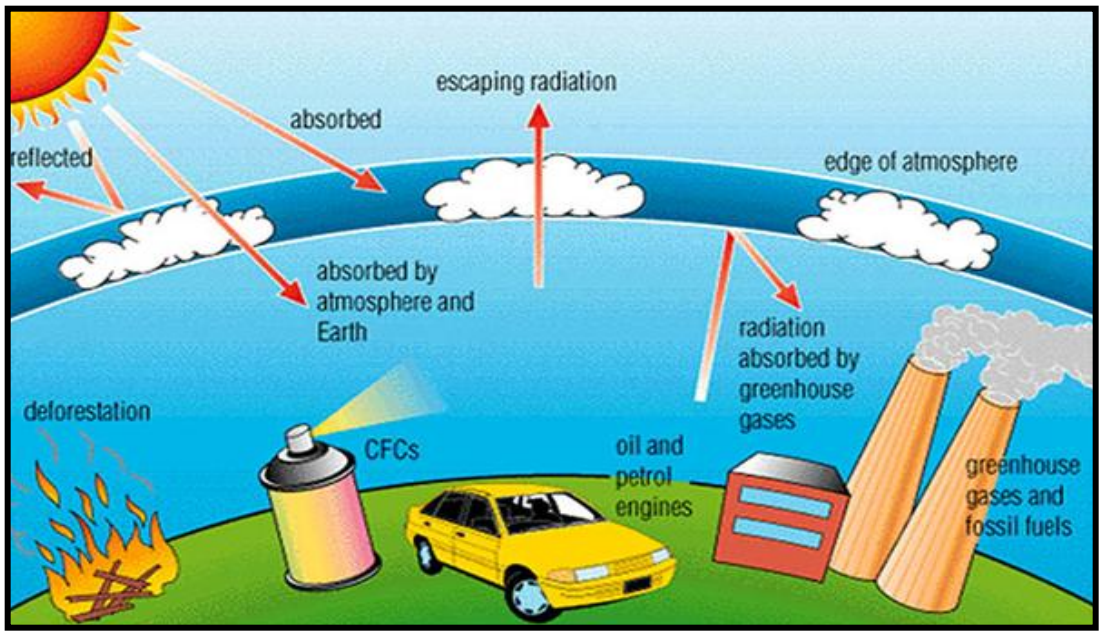



The Greenhouse Effect
Some of the infrared radiation passes through the atmosphere but most is absorbed and re-emitted in all directions by greenhouse gas molecules and clouds. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation powers the climate system.
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
ATMOSPHERE
EARTH
About half the solar radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

The problem of burning fossil fuels

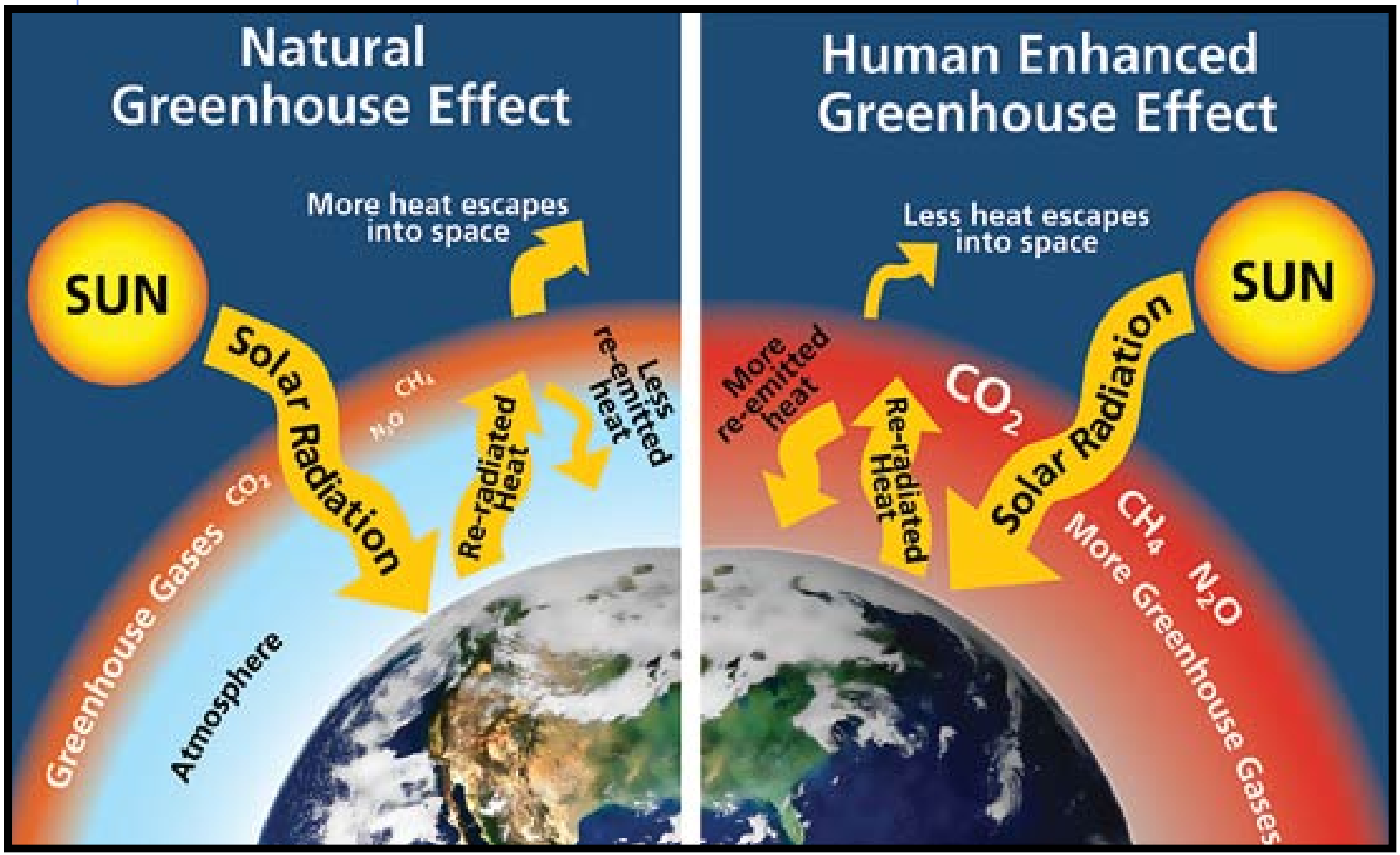
- **The Enhanced Greenhouse Effect = Global Warming**
  - **Human activities such as burning of fossil fuels, farming and land use changes are resulting in more CO_2 and Ch_4 (methane) in the atmosphere**
    - **This increase in greenhouse gases traps more of the re-radiated rays in the atmosphere, warming up the planet more.**

- **Scientists have determined that the global mean temp. has risen 0.8 C since 1880.**



Burning fossil fuels and deforestation

(leads higher CO2 levels in atmosphere - more CO2 added through combustion & less CO2 removed by photosynthesis)



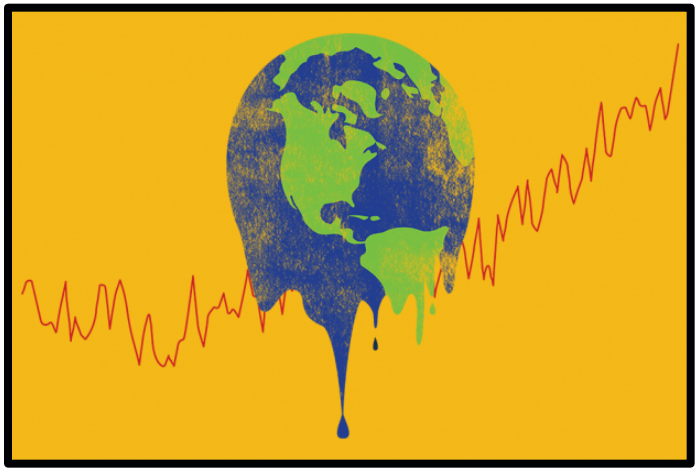
The Consequences of Atmospheric Warming

As humans continue to pour greenhouse gases like CO_2 into the atmosphere, more solar energy is trapped by our atmosphere causing increased global warming.

- **The world's seas have absorbed more than 90% of the solar heat absorbed by these atmospheric gases.**

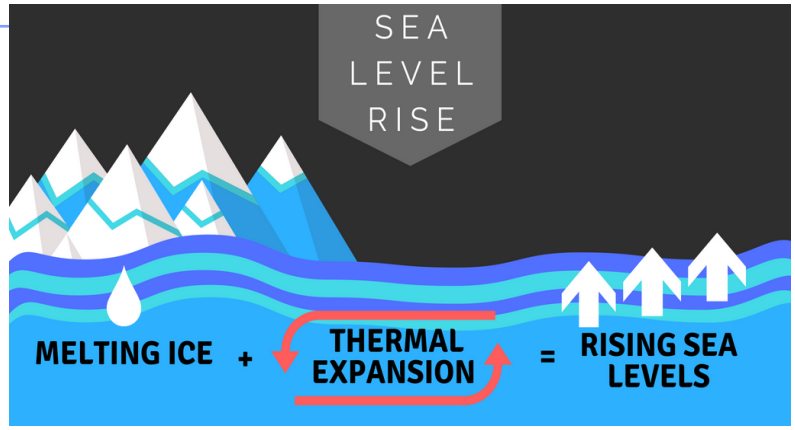
Scientists use the term CLIMATE CHANGE when describing the complex shifts affecting our planet's weather and climate systems, which include more than just global temperature rise.

- **Rising seas is one of those climate change effects.**
  - **Average sea levels have swelled over 8 inches (about 23 cm) since 1880, with about three of those inches gained in the last 25 years.**



The Consequences of Atmospheric Warming on Sea Level Rise

Every year, the sea rises another 0.13 inches (3.2 mm). Why?

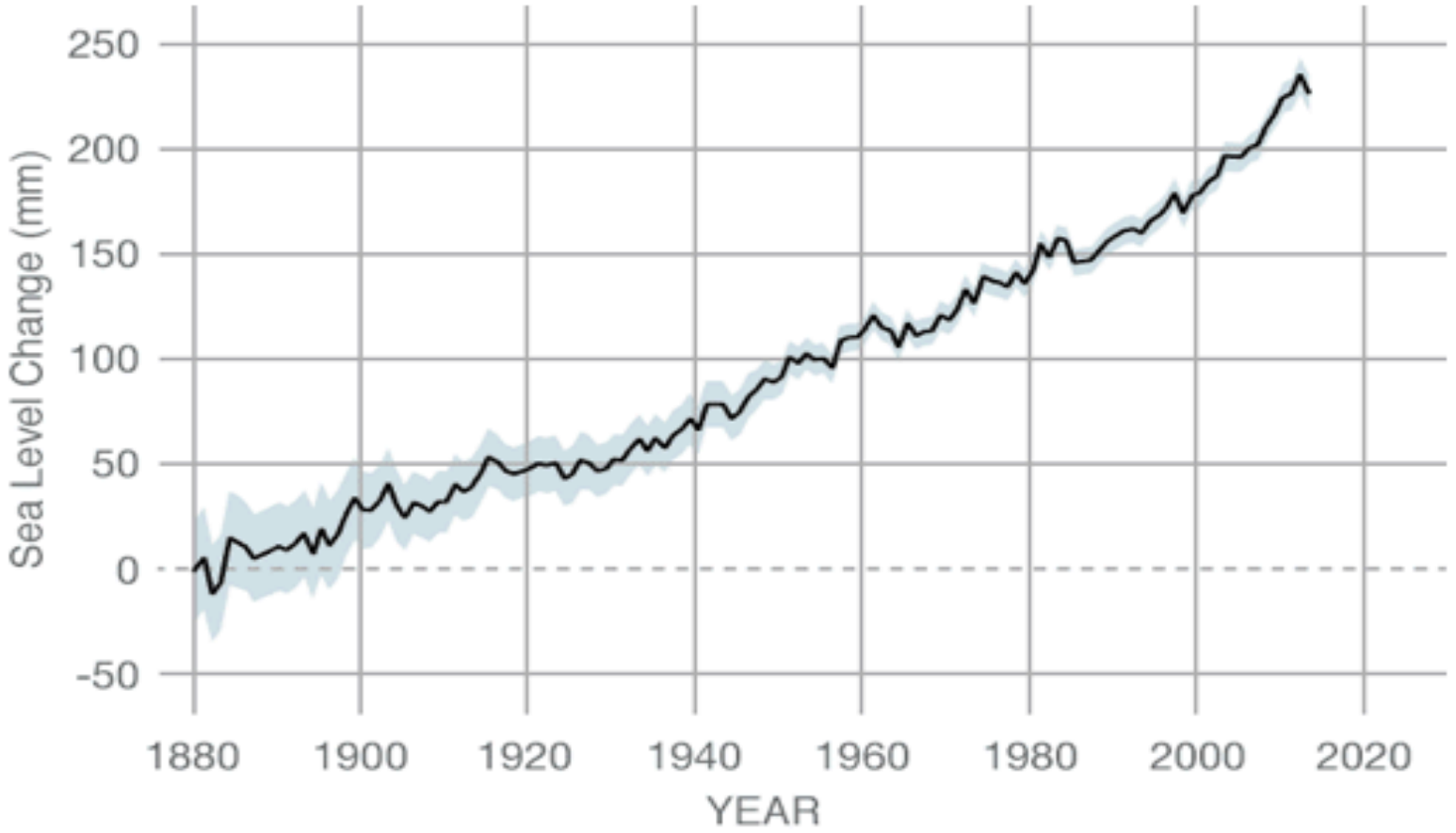


1. **Thermal expansion: When water heats up, it expands.**
   - ~50% of sea-level rise over the past 25 years is attributable to warmer oceans simply occupying more space.
2. **Melting glaciers: Persistently higher temperatures caused by global warming have led to greater-than-average summer melting as well as diminished snowfall due to later winters and earlier springs.**
   - An imbalance is created between runoff due to melting & ocean evaporation that returns water to the glacier via snowfall, causing sea level rise.
3. **Loss of Greenland and Antarctica's ice sheets: Increased heat is causing the massive ice sheets that cover Greenland and Antarctica to melt more quickly.**
   - Scientists also believe that meltwater from above and seawater from below is seeping beneath ice sheets, effectively lubricating ice streams and causing them to move more quickly into the sea.

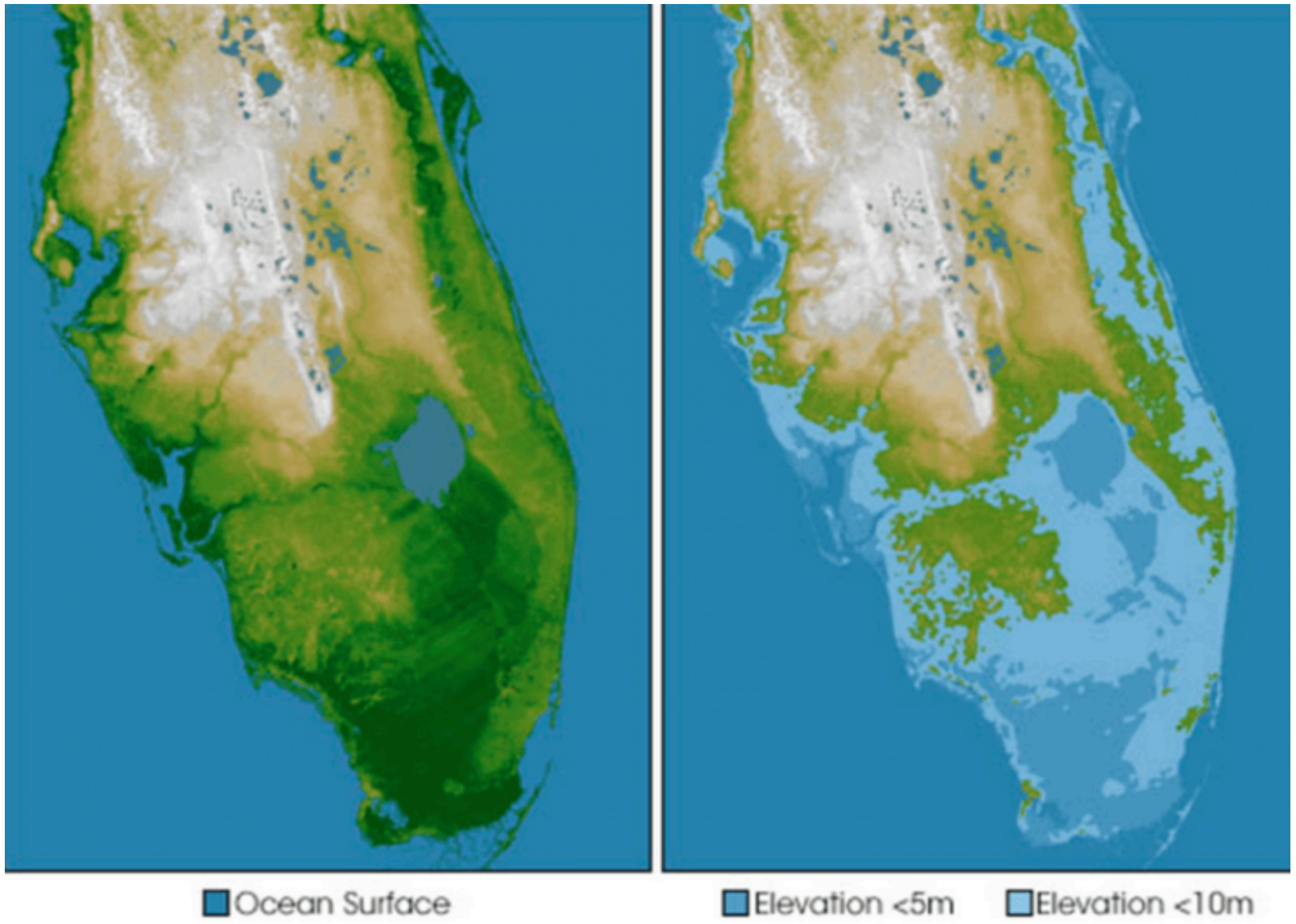
The Consequences of Atmospheric Warming on Sea Level Rise

GROUND DATA: 1870-2013

Data source: Coastal tide gauge records.
Credit: CSIRO



The Consequences of Atmospheric Warming on Sea Level Rise



The Consequences of Atmospheric Warming on Sea Level Rise

Sea level increase can cause:

- Destructive erosion
- Wetland flooding

Disruptive & expensive nuisance flooding is 300-900% more frequent within U.S. coastal communities than it was just 50 years ago.

- In the U.S., ~40% live in relatively high-population-density coastal areas & globally, 8 of the 10 largest cities are near a coast.

- Aquifer and agricultural soil contamination with salt water
- Lost habitat for fish, birds, & plants.
- More dangerous hurricanes and typhoons that move more slowly and drop more rain, contributing to more powerful storm surges that can have devastating effects on habitats further inland and cause deaths.

- One study found that between 1963-2012, ~50% of all deaths from Atlantic hurricanes were caused by storm surges.
  - Storm surge = temporary abnormal rise of water generated by a storm, over and above the predicted astronomical tides.
- Flooding in coastal areas is forcing people to migrate to higher ground

Millions are vulnerable from flood risk & other climate change effects.

- Infrastructure damage threatens country's economies
- Even basic services such as Internet access is threatened, much of the underlying communications infrastructure under ground

Global Warming Effects

World Wide

The temperature could rise between 2.4 and 4.5 degrees Fahrenheit.

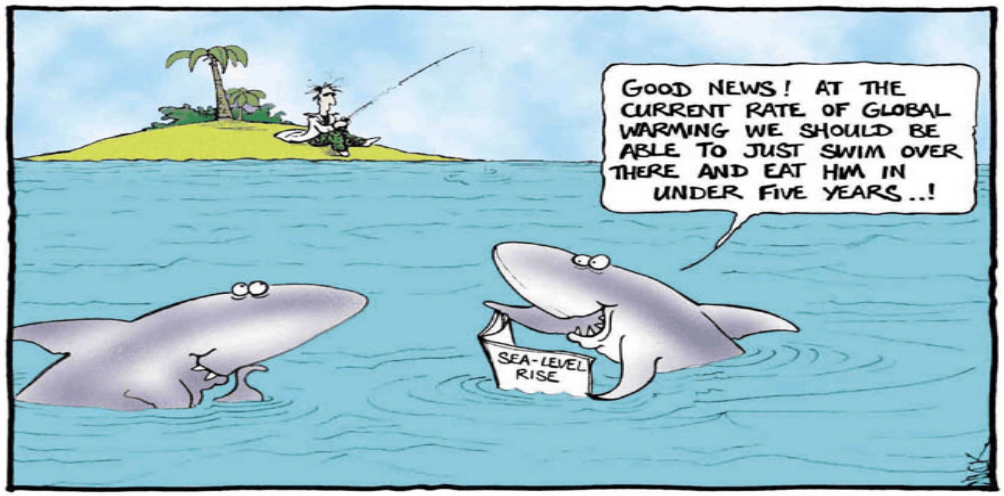
- Leading to the extinction of about 20 to 30 percent of the world's species.

Water temperatures will continuously rise.

- Coral Reefs will bleaching out and die.

Permafrost in mountainous regions and at high latitudes is warming.

- Increases the danger of land slides.



Regionally – New York

Glacial lakes are increasing in both size and number.

- Deadly Floods

River currents are affected by melting glaciers and ice.

- Dangerously speeding up during the spring.

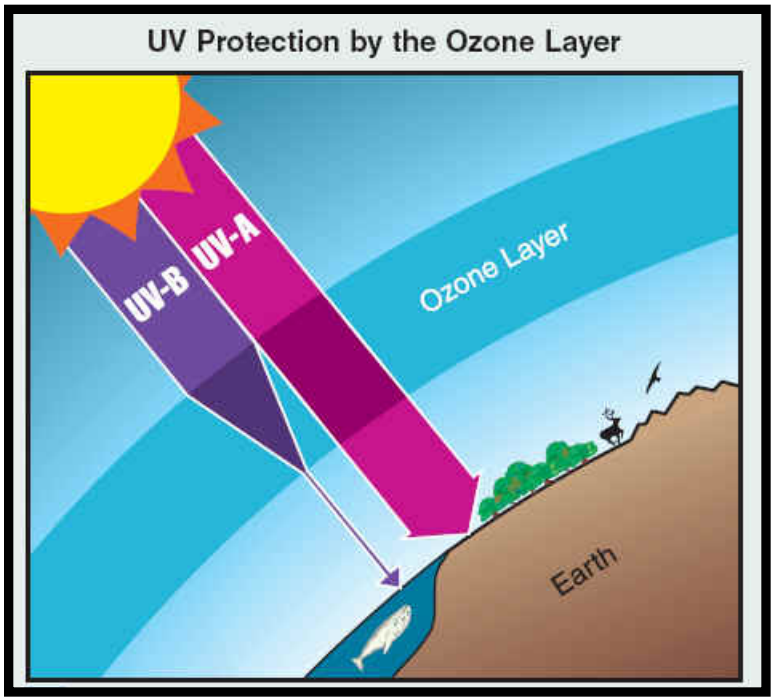
Springtime is starting earlier.

- Plants bloom earlier
- Changes the migrations of birds

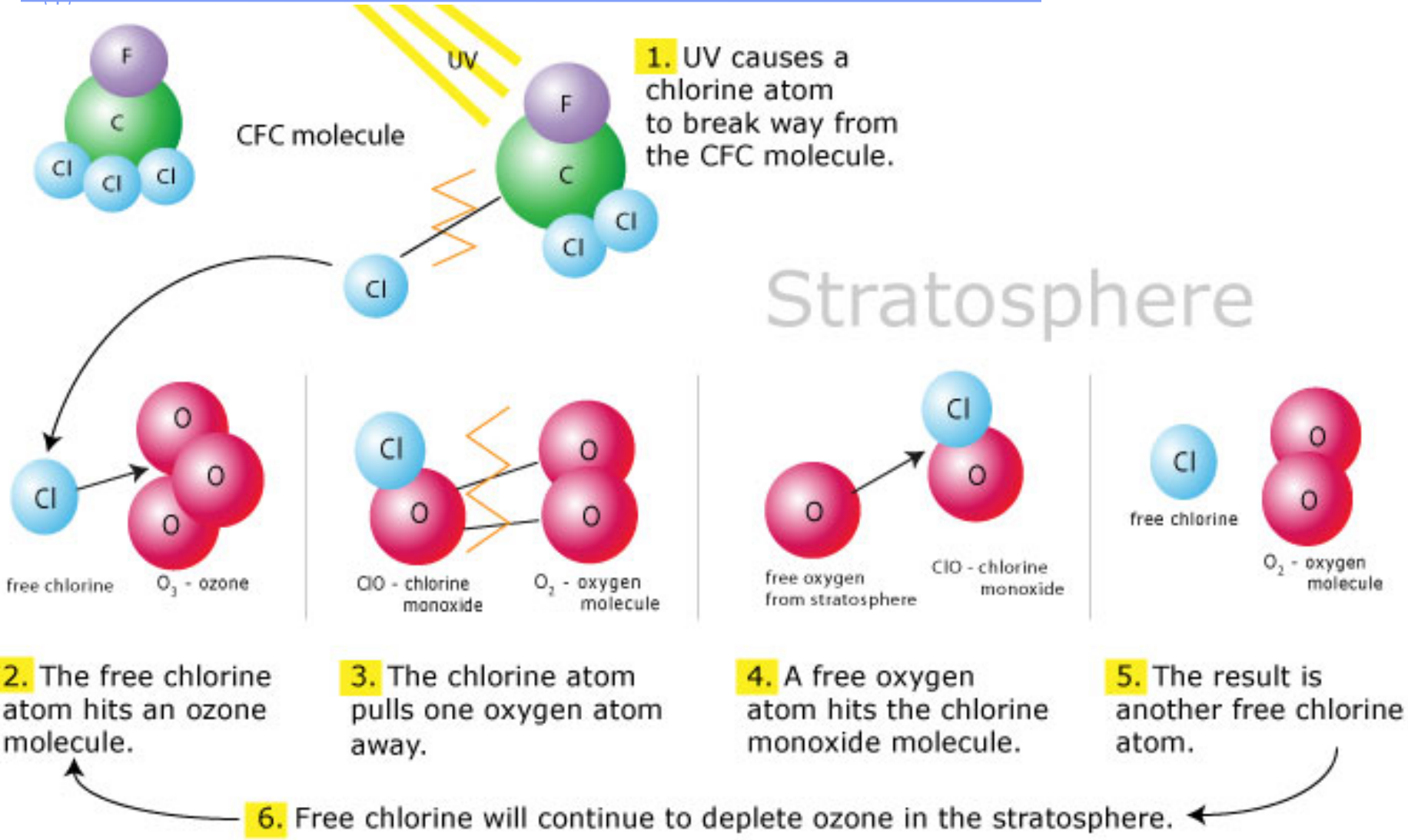
P.S. There's another problem of human pollutants…

Ozone Layer: A form of oxygen gas (O_3) that makes up a layer of the stratosphere, where it filters out UV radiation from the sun.

- The production and emission of Chlorofluorocarbons (CFC's) is the leading cause of depletion.
  - CFC's can come from cooling systems, fire extinguishers, styrofoam containers, home insulation, plastic foam, and throwaway food containers.



The “unending” chemical reaction….

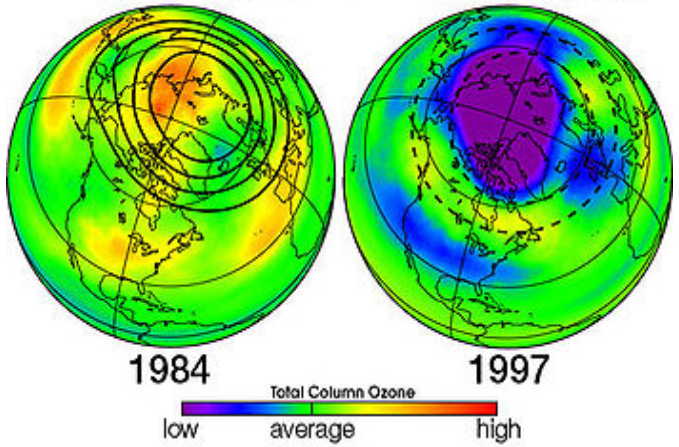


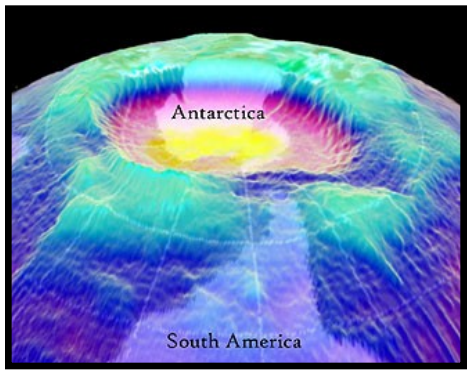
Ozone Depletion

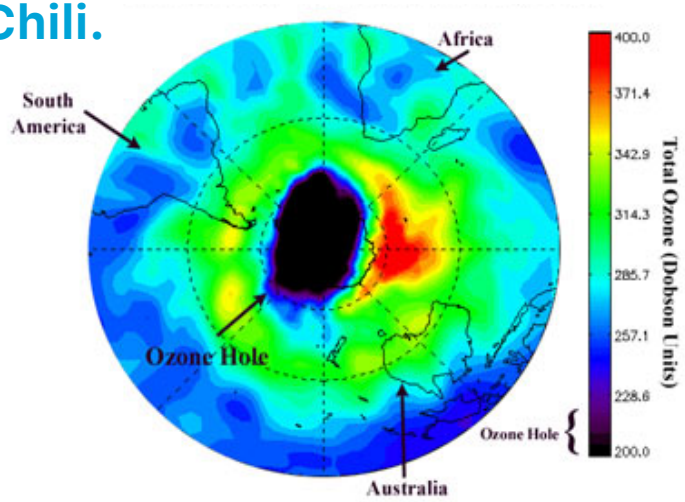
Stratospheric ozone hole discovered in 1975 by Sherwood Roland and Mario Molina.

In 2000, it covered an area larger than the U.S., Canada, and Mexico combined, which is approximately 11.4 million square miles.

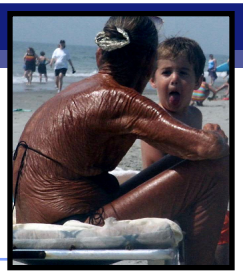
The hole intensifies in September and, in 2000, it extended over a city of about 120,000 people in southern Chili.



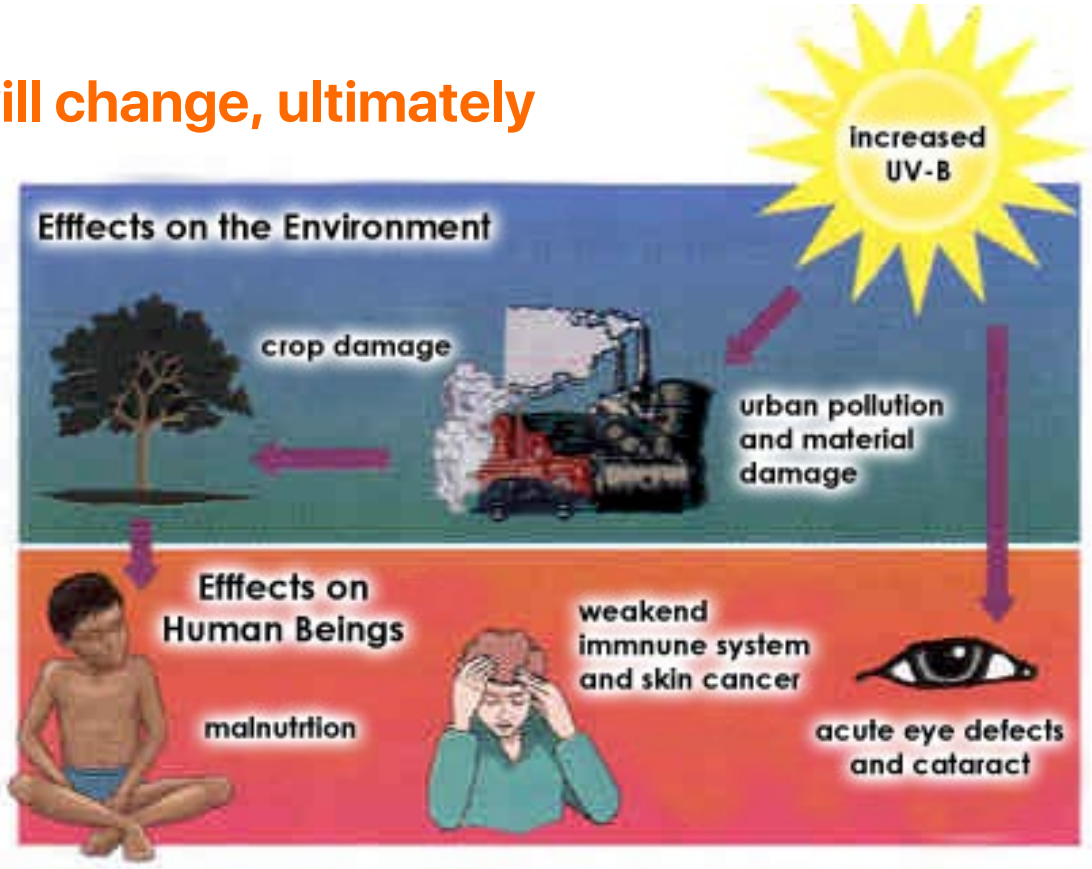




Ozone Depletion



- Life on Earth is possible because the ozone layer is thick enough to shield destructive UV (energy) rays.
  - When 1% of the ozone layer is depleted, there can be up to 6% of an increase in the incidence of skin cancer caused by UV-B rays.
  - Life cycles in plants will change, ultimately disrupting the food chain, which can lead to severe effects on animals.
  - The ice caps in Antarctica will melt faster, and could one day destroy coastal regions and lead to massive flooding.



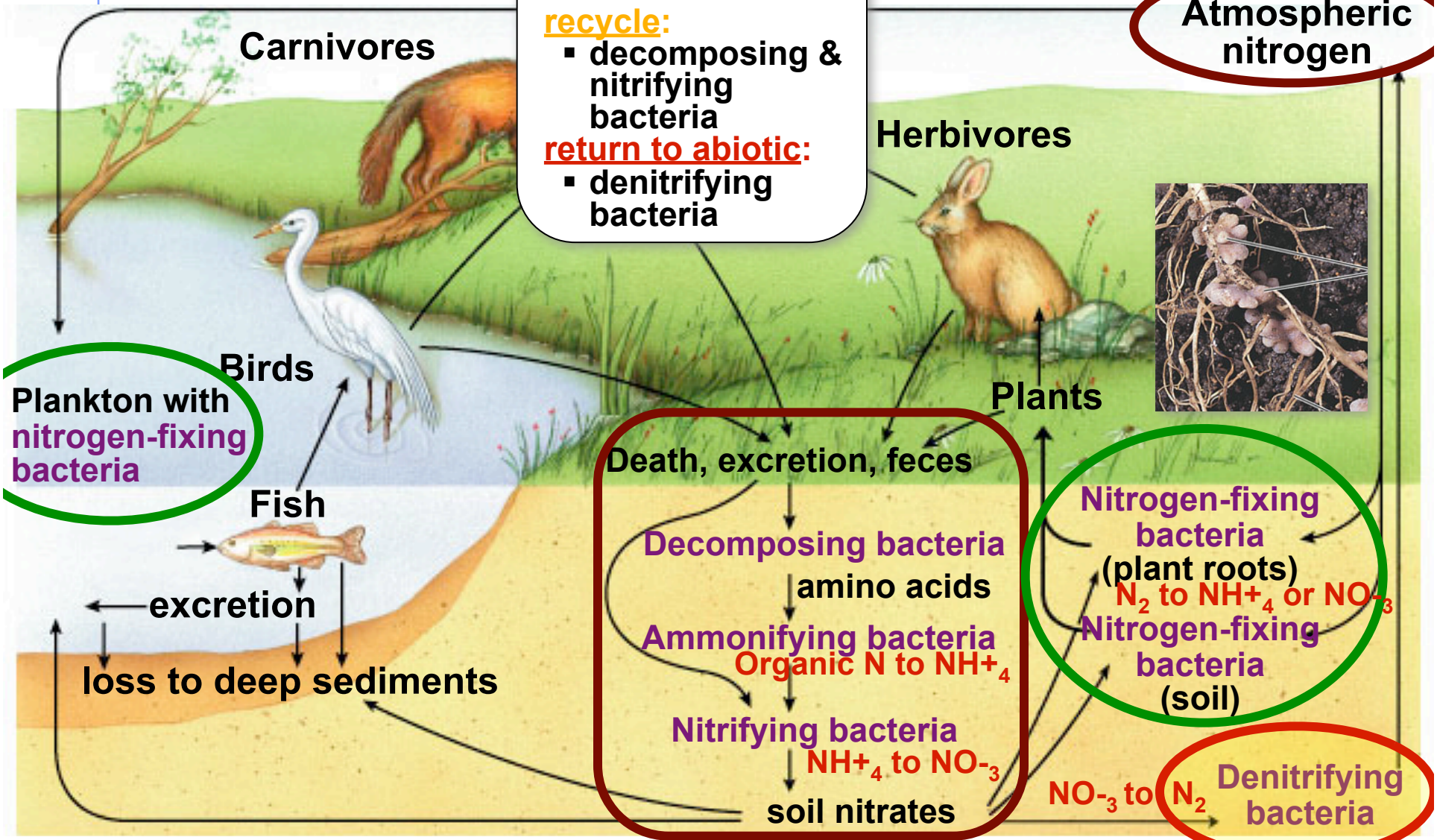
Nitrogen cycle

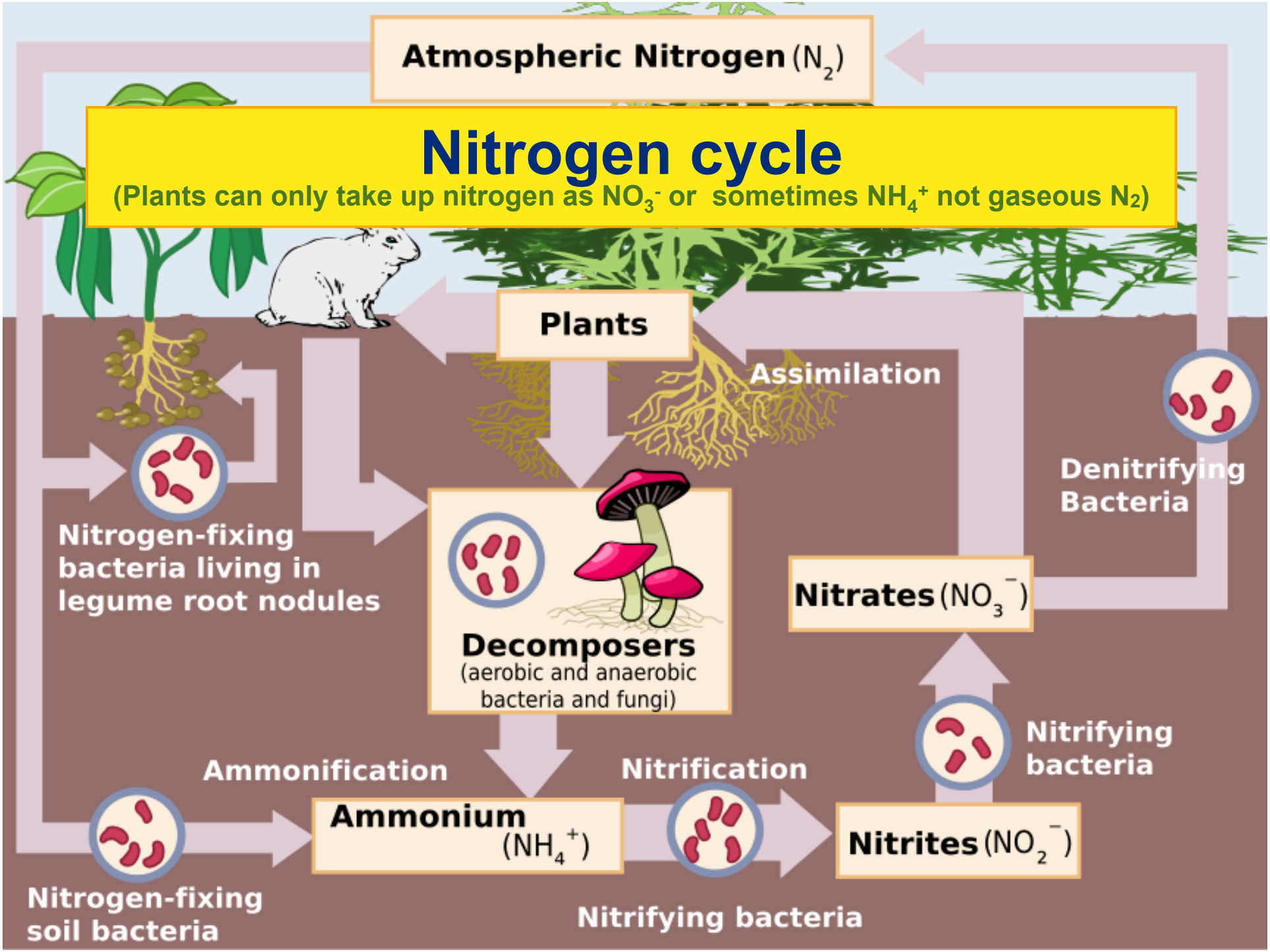
abiotic reservoir:
- N in atmosphere

enter food chain:
- nitrogen fixation by soil & aquatic bacteria

recycle:
- decomposing & nitrifying bacteria

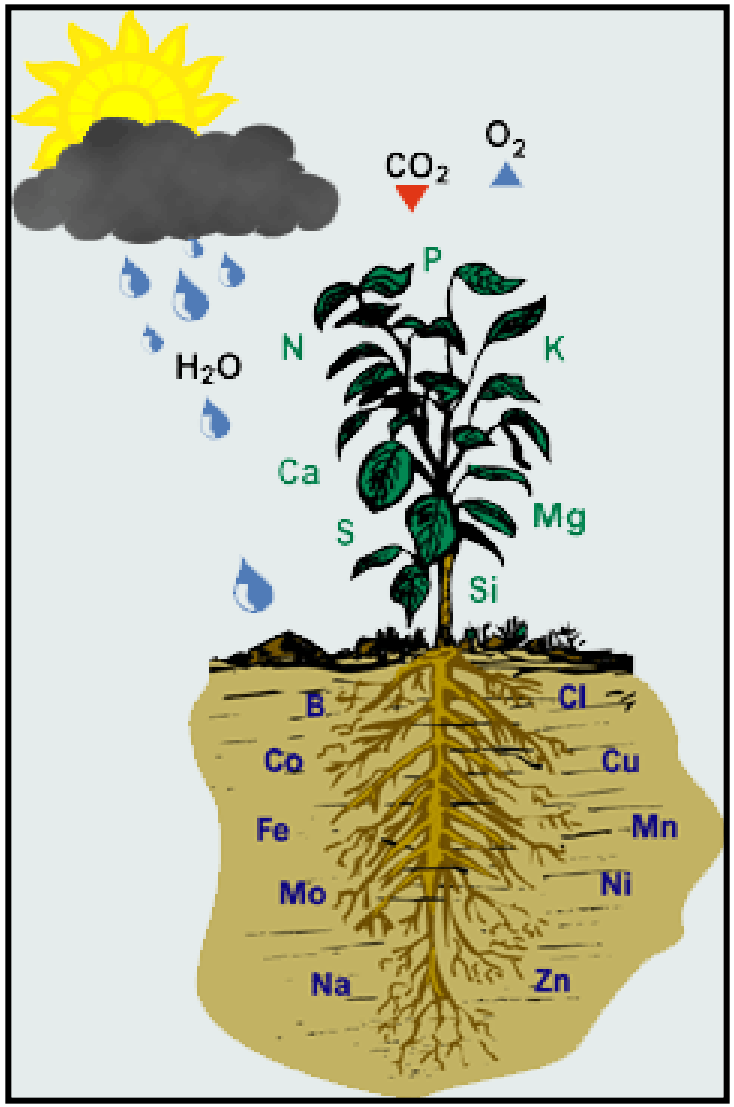
return to abiotic:
- denitrifying bacteria




Atmospheric Nitrogen (N_2)
Nitrogen cycle
(Plants can only take up nitrogen as NO_3^- or sometimes NH_4^+ not gaseous N_2)
Plants
Assimilation
Denitrifying Bacteria
Nitrogen-fixing bacteria living in legume root nodules
Decomposers
(aerobic and anaerobic bacteria and fungi)
Nitrates (NO_3^-)
Nitrifying bacteria
Ammonification
Nitrification
Ammonium (NH_4^+)
Nitrites (NO_2^-)
Nitrogen-fixing soil bacteria
Nitrifying bacteria

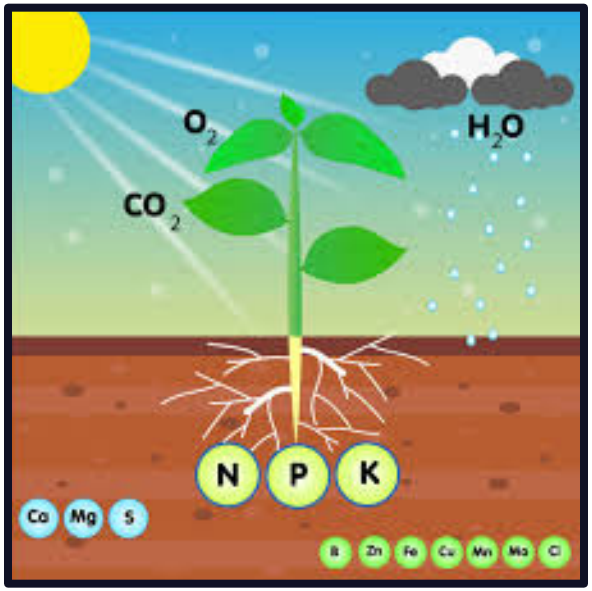
Nutritional needs of plants

- **Photoautotrophic does not mean autonomous**
  - plants need…
    - sun as an energy source
    - inorganic compounds and ions for necessary cell activities and as raw materials for building macromolecules and other chemical products
      - water (H_2O)
      - CO_2
      - minerals *(solid inorganic substances in the soil)*



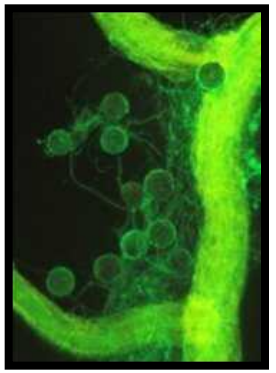
Macro- & Micronutrients of Plants

- **Essential elements** = elements required for a plant to complete its life cycle and produce another generation
  - Plants need 17 essential elements
- Nine essential elements are **macronutrients**
  - Plants require them in relatively large amounts
    - Six are part of organic compounds forming plants structure:
      C, O, H, N, P, S
    - The remaining three are:
      K, Ca, Mg (in chlorphyl)
- Eight essential elements are **micronutrients**
  - Required in tiny quantities
    - Cl, Fe (Iron), Manganese, boron, zinc, copper, nickel, molybdenum
- **Nitrogen contributes most to terrestrial plant growth and crop yields!!!**
  - Nitrogen is a component of proteins, nucleic acids, chlorophyll etc..



Remember roots live in symbiosis with fungi

- Some plants are "mycorrhizal-obligate," meaning that they can't survive to maturity without their fungal associate.

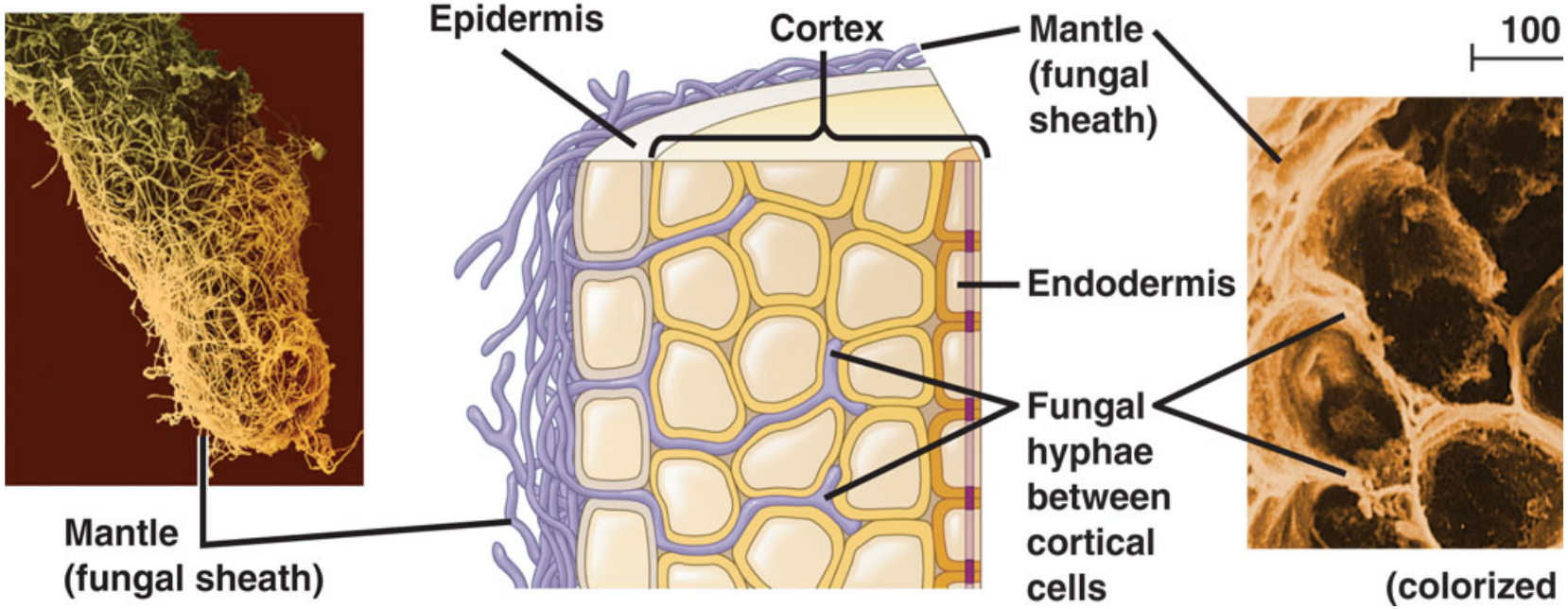


- Mycorrhizae ("fungus" "root") assist the host plant with the uptake of vital nutrients
  - Mainly phosphorus and nitrogen
  - Also absorbs water
  - Mycorrhizae increase the surface area associated with the plant root, which allows the plant to reach nutrients and water that might not be available otherwise.

1. Makes the plant stronger, especially during drought periods by collecting distant water for the plant.
2. Makes plant community more resilient to disturbance.
3. Stimulates plant to grow by secreting growth factors.
4. Some mycorrhizae may even protect their host plant against unwanted pathogens by secreting antibiotics.

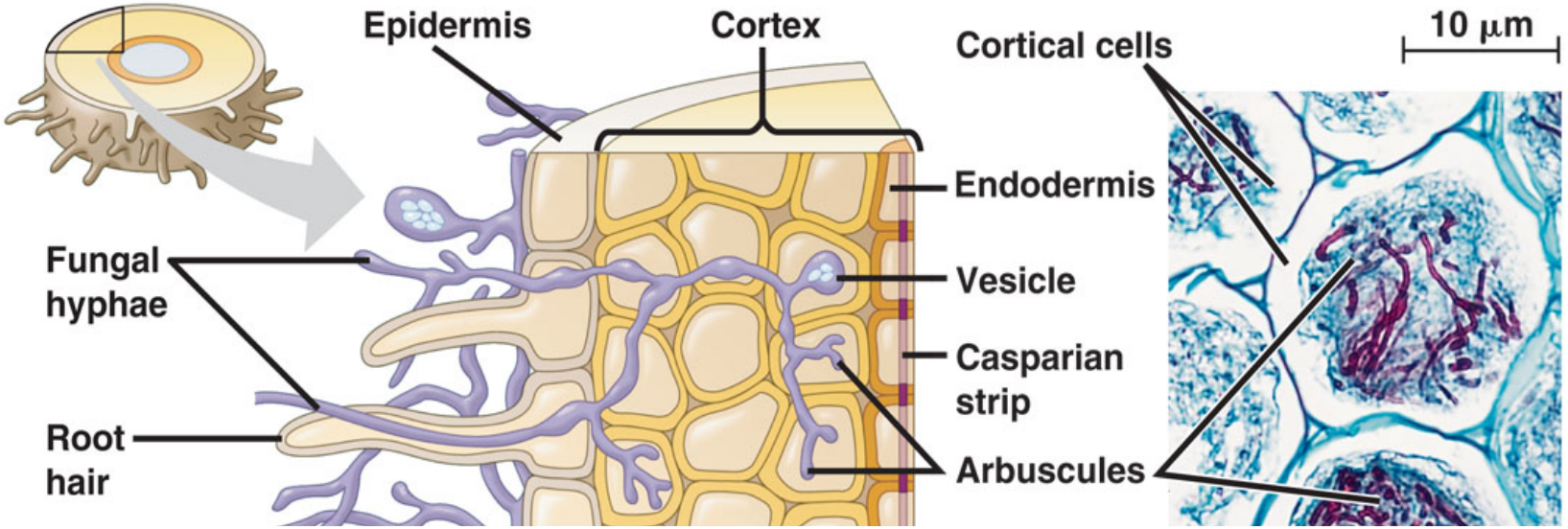
Two types of symbiotic relationship between fungi & plant:
Ectomycorrhizae versus Endomycorrhizae

- **Ectomycorrhizae**
  - Mycelium (mass branch of fungal hyphae) forms dense sheath or mantle over the surface of root
    - Fungal hyphae extend from mantle into soil
      - Increased water and mineral absorption
    - Hyphae also grow into root cortex
      - Hyphae do NOT penetrate root cells
      - Network formed in apoplast (extracellular space) of root cortex cells
        - Facilitates nutrient exchange



Two types of symbiotic relationship between fungi & plant:
Ectomycorrhizae versus Endomycorrhizae

- **Endomycorrhizae (a.k.a. Arbuscular Mycorrhizae)**
  - Most common mycorrhizal association (85% of all plant species)
  - NO dense mantle covering root
  - Microscopic soil hyphae grow towards root
  - Hyphae penetrate between epidermal cells and enter root cortex
  - Hyphae digest small patches of cortical cell wall
    - Invaginate the root cell's plasma membrane without piercing it
  - Inside cell hyphae branches extensively forming arbucles ("little trees")
    - Important sites of nutrient transfer
      - Oval vesicles may form serving as food storage sites for fungus

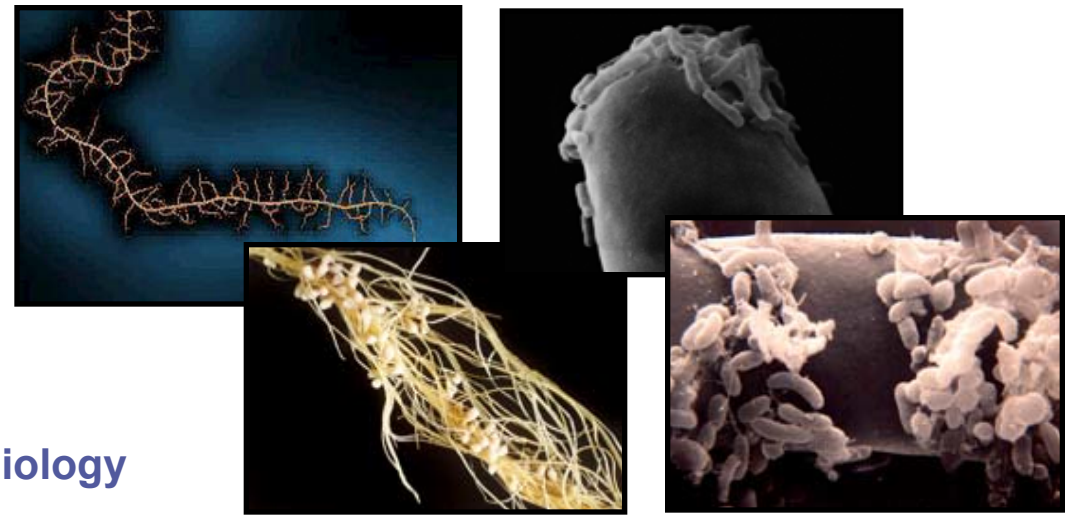


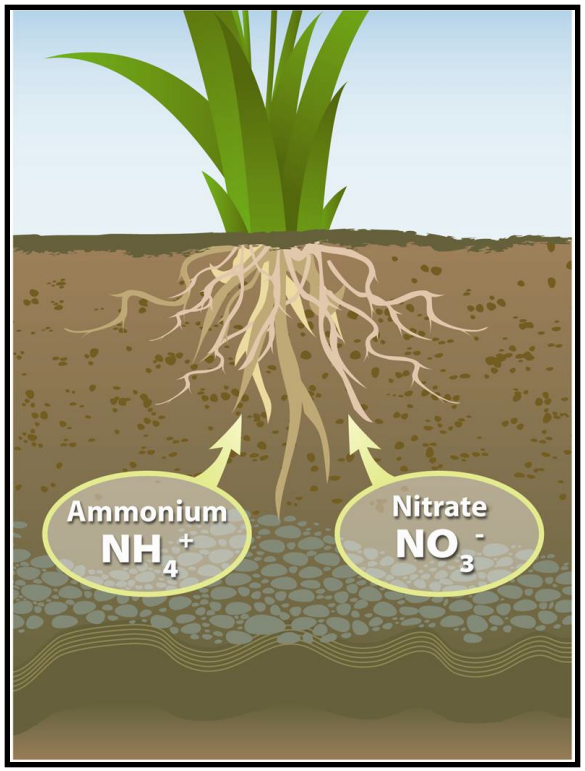
AP

Plants associate with fungi and soil bacteria called Rhizobacteria

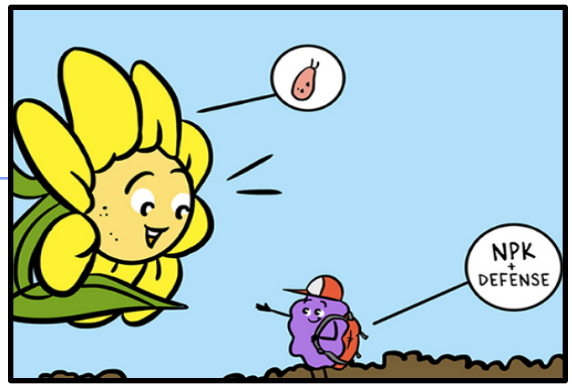
1. Some beneficial bacteria are found in rhizosphere
   - The soil layer that is bound to the plant's roots
2. Other bacteria are decomposers
   - Derive nutrition from decaying organic material (humus) in topsoil
3. Another class are the nitrogen-providing bacteria
   - Grow inside roots

- Plants can absorb NH_4^+
- Plants acquire nitrogen mainly in the form of nitrate NO_3^-





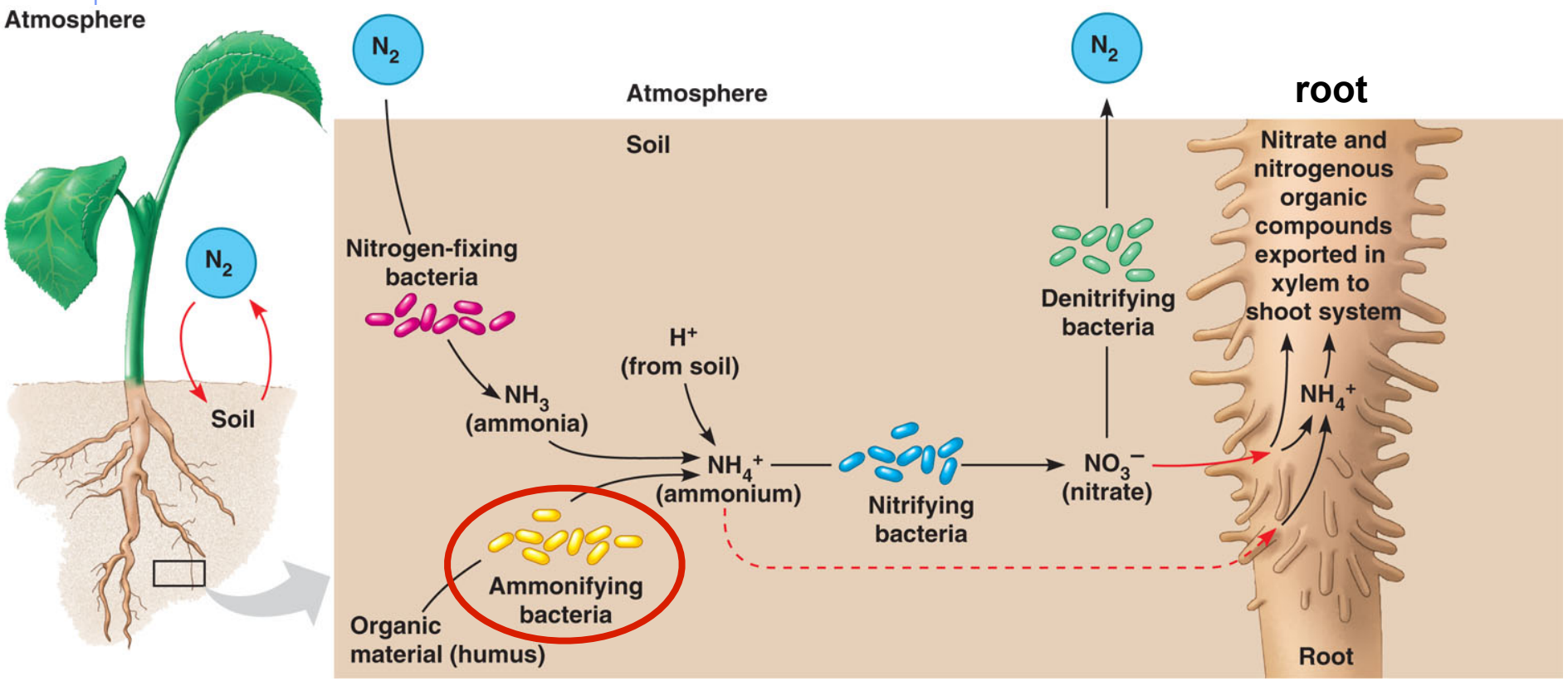
Plants & Bacteria



- **Mutualistic Relationship**
  - Plant Roots
    - Secrete nutrients like sugar, amino acids, organic acids
  - Plant-growth promoting rhizobacteria
    - Produce chemicals that stimulate plant growth
    - Produce antibiotics that protect roots from disease
    - Absorb toxic metals or make nutrients more available to roots
  - Other bacteria help make nitrogen more available
- **Nitrogen is the nutrient that MOST limits plant growth**
  - Component of nucleic acids and proteins
- **NH_4^+ and NO_3^- are not derived from weathering of rocks like other minerals**
  - Most sources of plant nitrogen come from bacterial activity

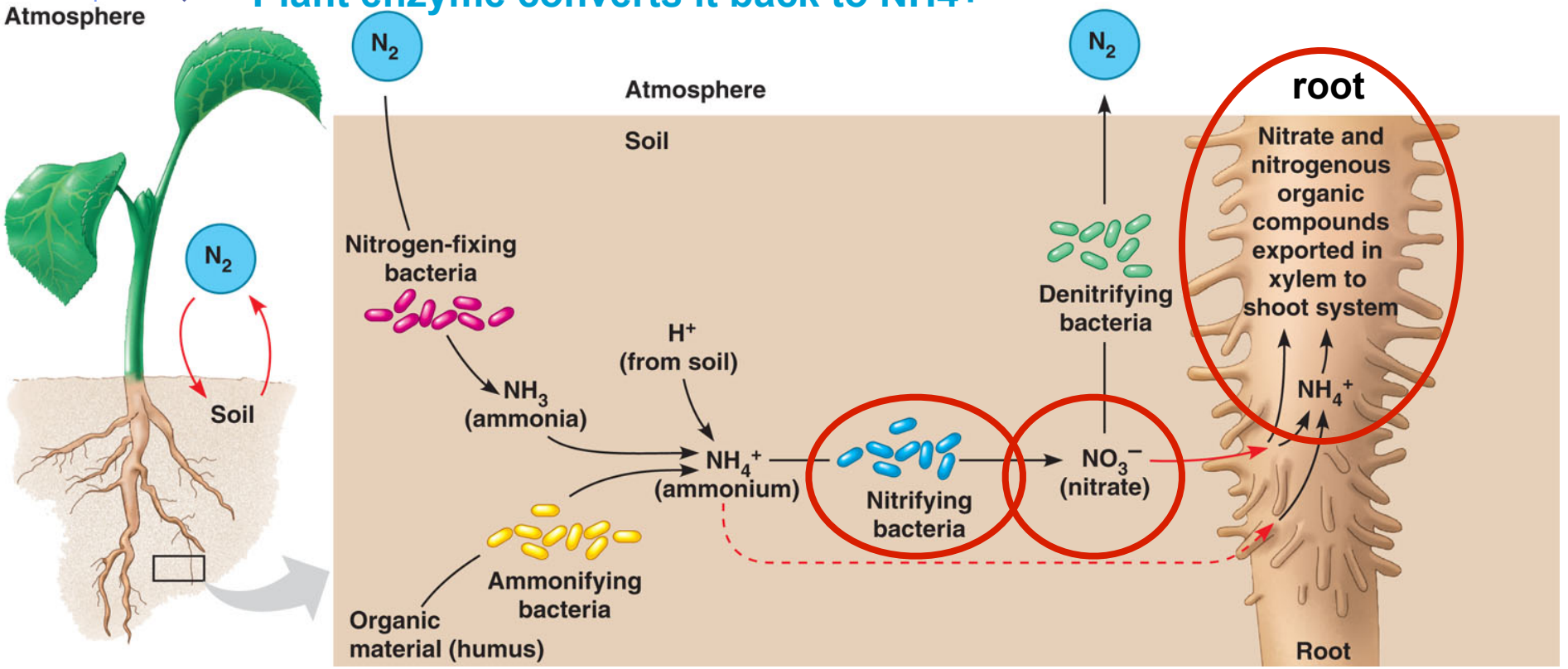
Bacteria and the Nitrogen Cycle

- **Ammonifying Bacteria**
  - Decomposers living in humus-rich soil
    - Release ammonia (NH_3) by breaking down proteins and organic compounds in humus
      - NH_3 gains H+ from the soil and becomes NH_4^+



Bacteria and the Nitrogen Cycle

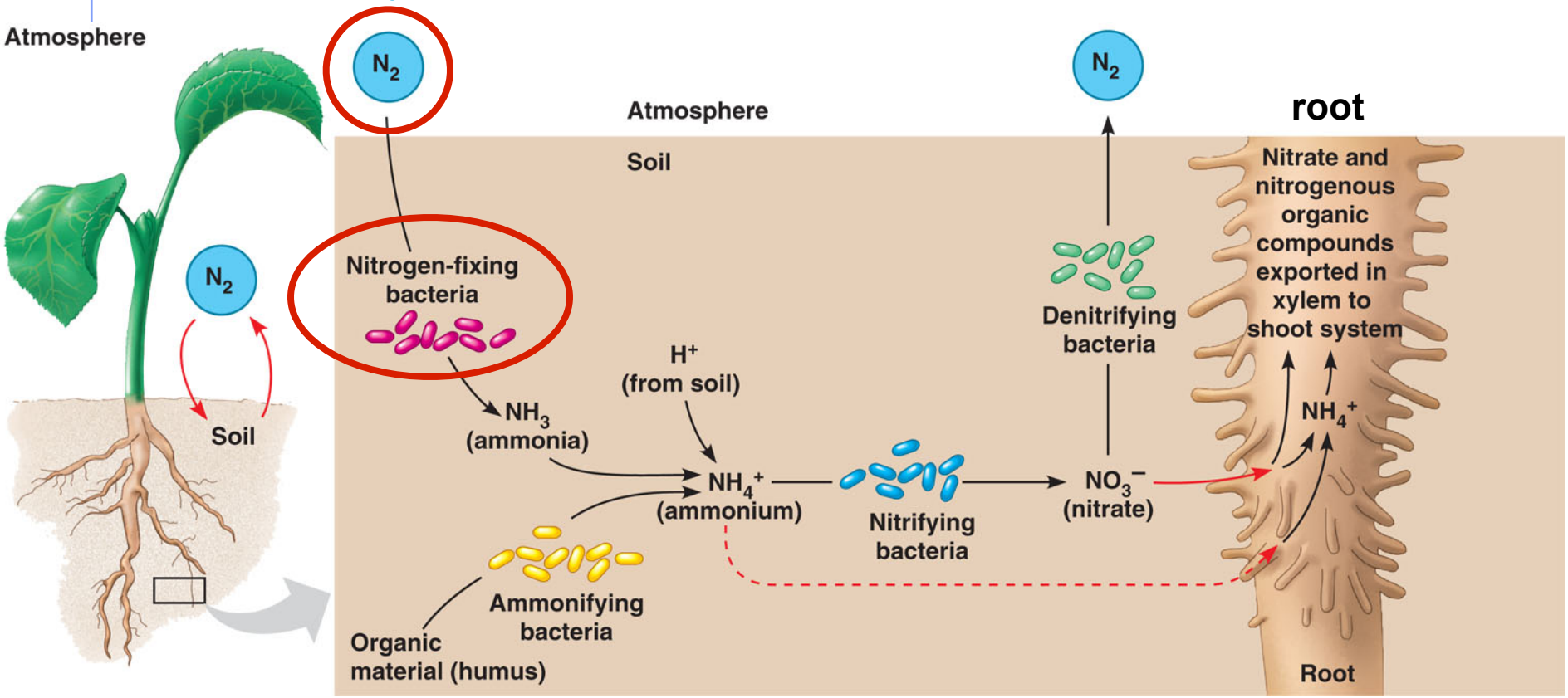
- Soil NO_3^- formation involves two steps mediated by nitrifying bacteria:
  1. Nitrification: Oxidation of NH3 to nitrite NO2-
  2. Oxidation of nitrite to nitrate NO3-
     - Roots absorb NO_3^-
- Plants export nitrogen from roots to shoots via xylem as NO3-
- Plant enzyme converts it back to NH4+



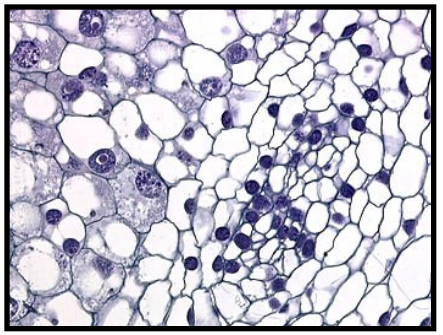
Bacteria and the Nitrogen Cycle

Plants cannot use free gaseous nitrogen N_2 because triple bond is hard to break

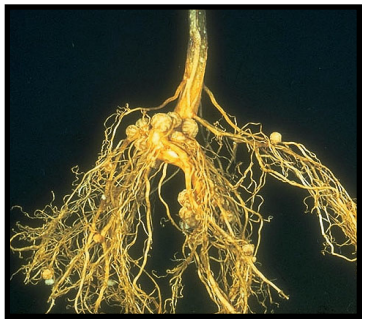
- **Nitrogen-fixing bacteria**
  - **Reduces gaseous nitrogen (N_2) into NH_3**
    - **NH_3 gains H+ from the soil and becomes NH_4^+**



Bacteria and the Nitrogen Cycle



- **Nitrogen fixation**
  - Reduces gaseous nitrogen (N_2) into NH_3



- **Prokaryotes that can fix nitrogen can exist as free living organisms or evolve a mutualistic relationship directly with certain plants**
  - **<u>Rhizobium bacteria</u> form an intimate association <u>within</u> the roots of legume plants**
    - **Peas, soybeans, alfalfa, clover**

Nitrogen-fixing nodules on leguminous-plant roots

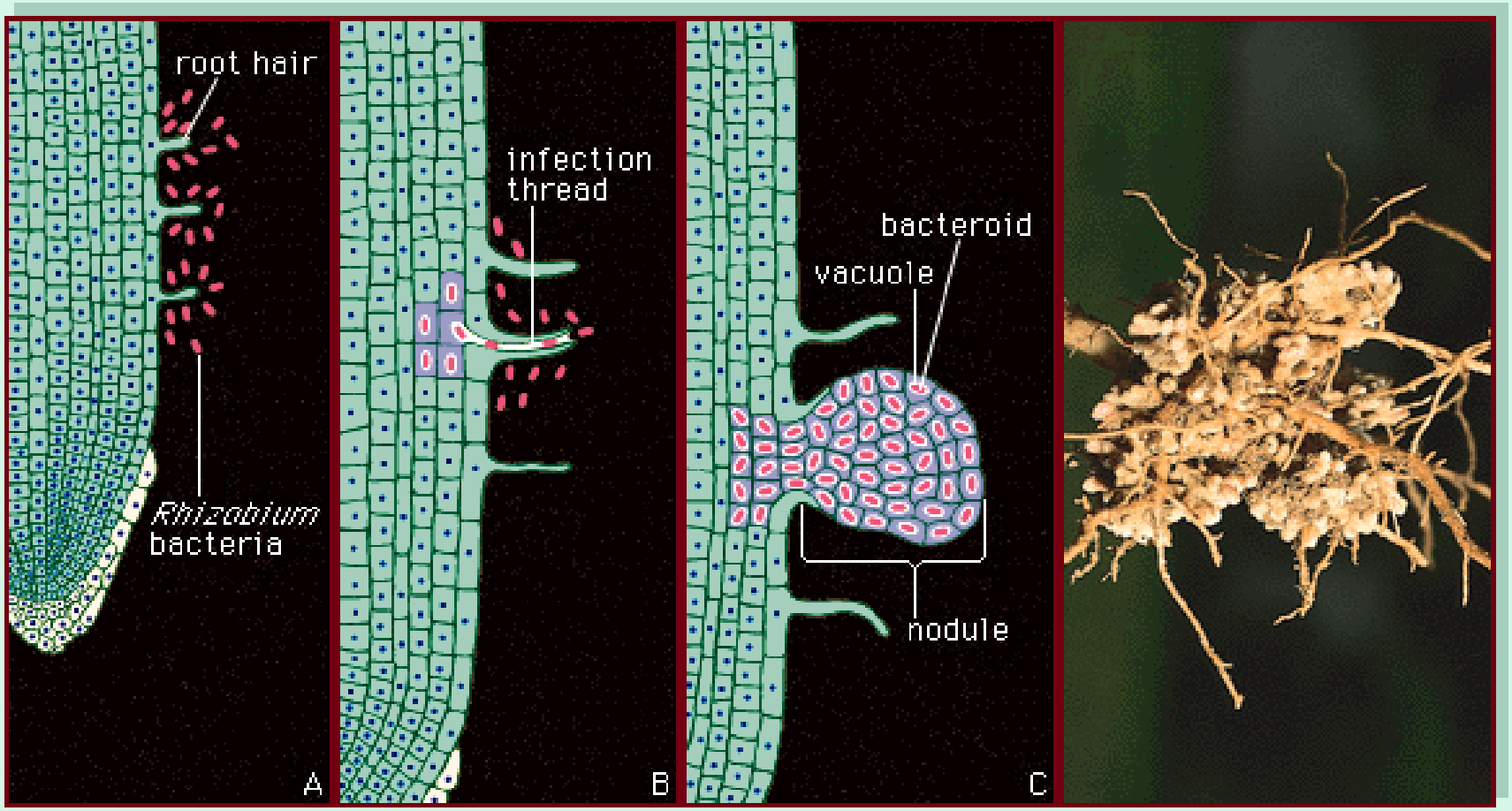
AP

Bacteria and the Nitrogen Cycle

- **Rhizobium bacterial associates with root cortex**
  - **Together mutualistic relationship established**
    - **Free-living Rhizobium bacteria cannot fix N_2**
    - **Legumes roots cannot fix N_2 without the bacteria**
  - **Rhizobium requires 8 ATP molecules to reduce N_2 to NH3+**
    - **To make ATP, it needs a rich supply of carbohydrate sugars**
      - **Gets carbs from vascular tissue (phloem) of plants**
- **Rhizobium bacterial associations alter root structure**
  - **Swelling in legume's roots form called nodules**
    - **Composed of plant cells infected with rhizobium ("root" "living") bacteria**

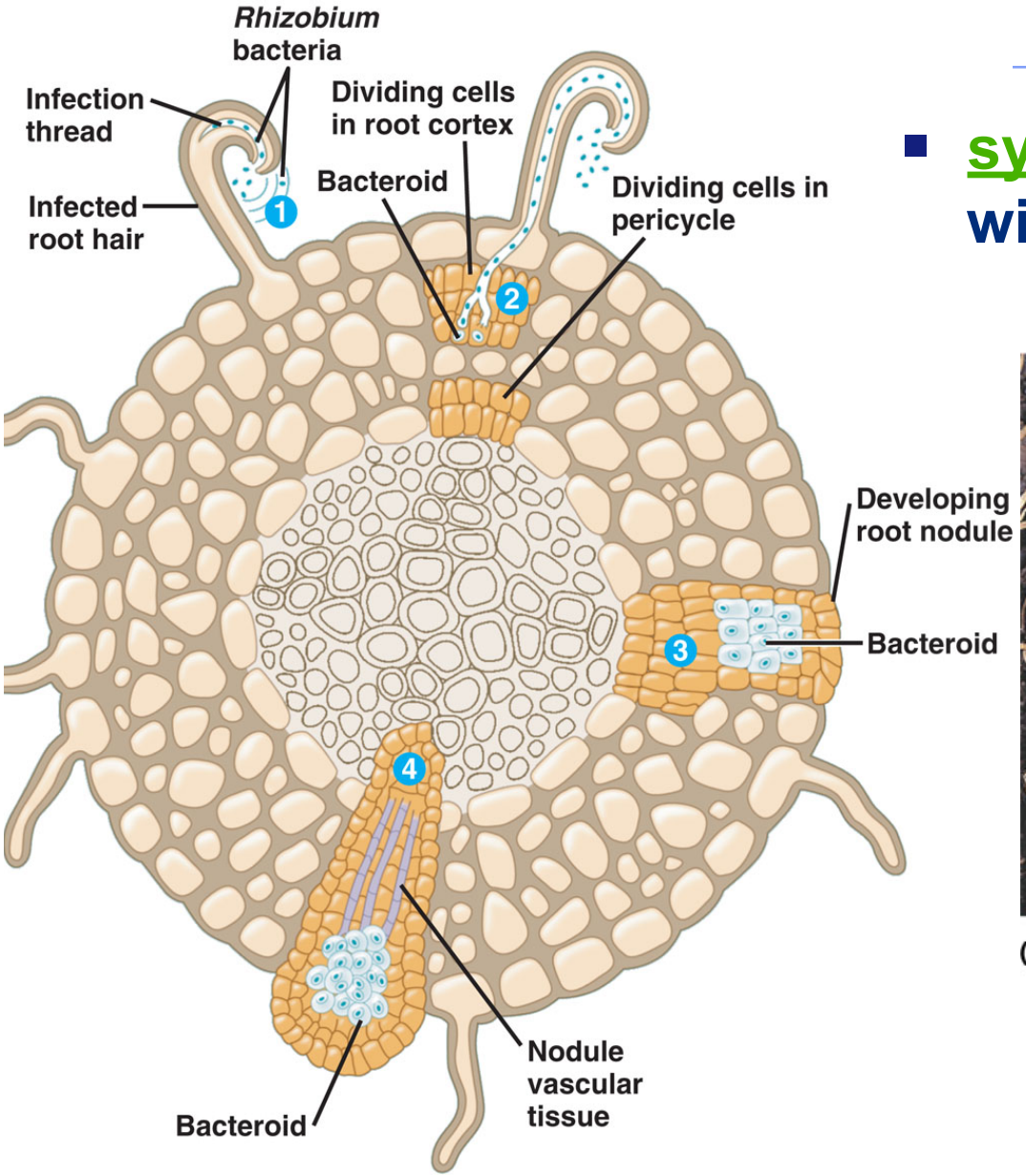
Root Nodules

- **Inside the nodule, bacteria take on a form called bacteroids**
  - **They are contained in vesicles formed in root cells**



AP

Soybean root nodules formation: N-fixation by *Rhizobium* bacteria

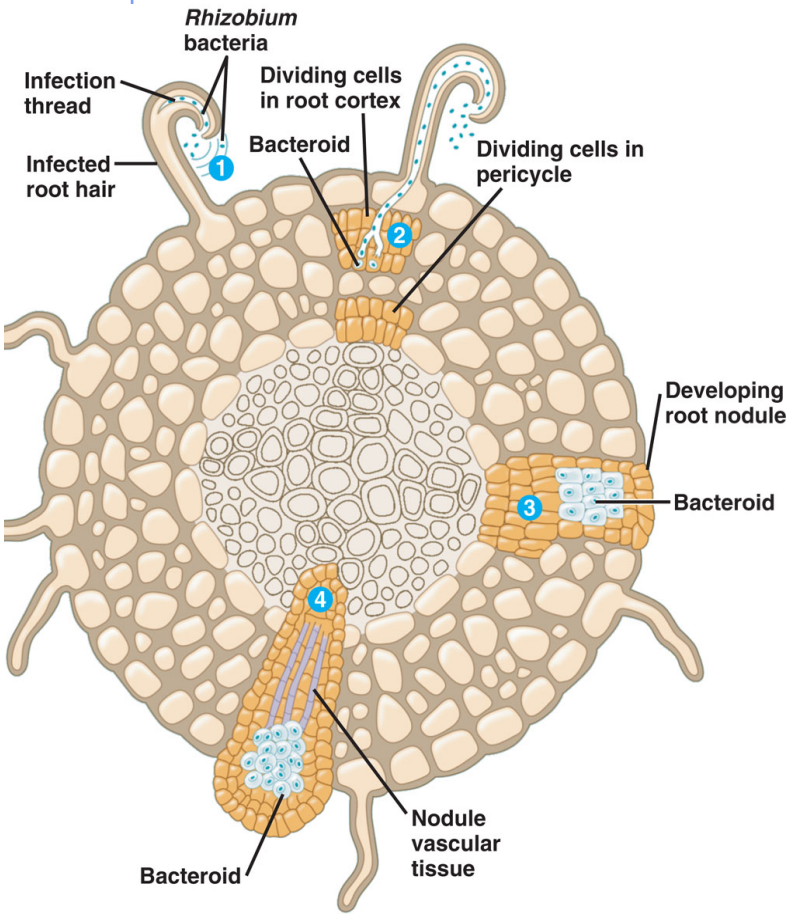


- symbiotic relationship with bean family (legumes)

(a) **Pea plant root.** The bumps on this pea plant root are nodules containing *Rhizobium* bacteria. The bacteria fix nitrogen and obtain photosynthetic products supplied by the plant.

(b) **Bacteroids in a soybean root nodule.** In this TEM, a cell from a root nodule of soybean is filled with bacteroids in vesicles. The cells on the left are uninfected.

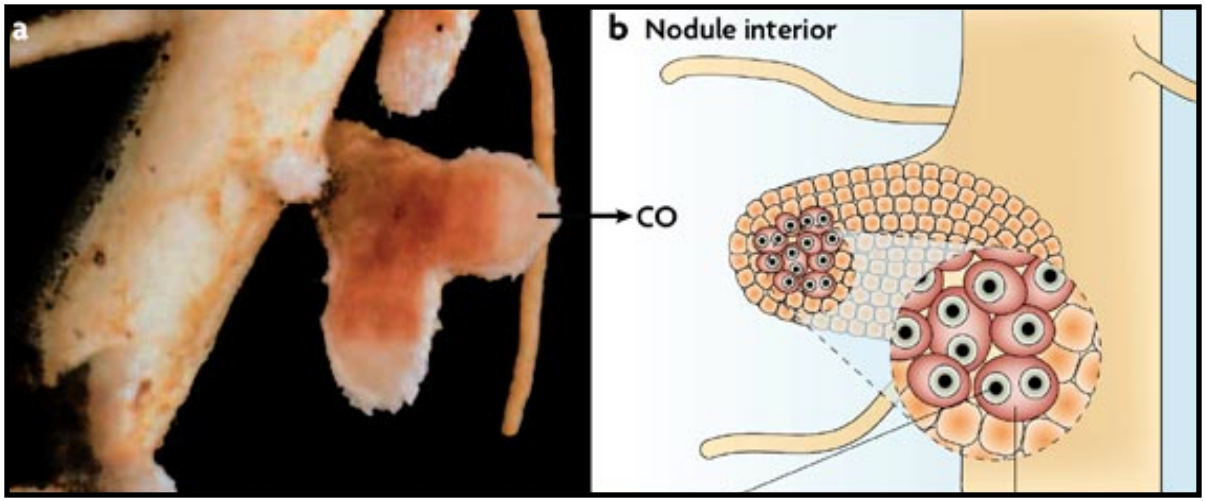
Soybean root nodules formation



1. Roots emit chemical signals that attract Rhizobium bacteria.
2. Bacteria emit signal that stimulates root hair cells to elongate and form an infection thread.
   - An invagination of plasma membrane
3. Bacteria move into cortex (the outer layer) of the plant root via the infection thread
4. Plant cortex and pericle cells begin dividing
5. Vesicles containing bacteria bud into cortical cells forming bacteroids.
6. The masses of infected plant cortex and pericycle cells eventually fuse forming root nodules
   - Nodules develop vascular tissue (phloem) that supply the nitrogen-fixing bacteroids with nutrients and carry nitrogenous compounds from the bacteroids into the vascular tissue of plants to be distributed throughout the plant body

Root Nodules

- **Nitrogen fixation requires anaerobic environment**
  - So, for the bacteria, living inside non-photosynthesizing root cells is ideal *(since O2 is a byproduct of photosynthesis)*
  - Lignified external root nodules (plant tissue with hardened cell walls) also limit gas exchange
  - Leghemoglobin also is an iron containing protein that binds reversibly to oxygen aiding the creation of anaerobic environment in nodules, but helping bring oxygen into plant cell for respiration and ATP production
  - Plant uses NH3, ammonium, made by bacterioids through nitrogen fixation to make amino acids and nucleotides, transporting them up the xylem to other plant cells



Give it a try… "Energy in Ecosystems"

80% of our atmosphere is nitrogen gas, yet every year farmers spray ammonia manufactured from natural gas on their fields as a fertilizer. This is because the only way to convert nitrogen from a gas into an available form is done by

A. decomposers.
B. nitrifying bacteria.
C. denitrifying bacteria.
D. nitrogen-fixing bacteria.
E. rain.

Nitrogen fixation is a process by which nitrogen (N_2) in the atmosphere is converted into ammonia (NH_3). Access to N is essential because N is needed for biosynthesizes macromolecules like nucleotides of DNA/RNA and amino acids of proteins