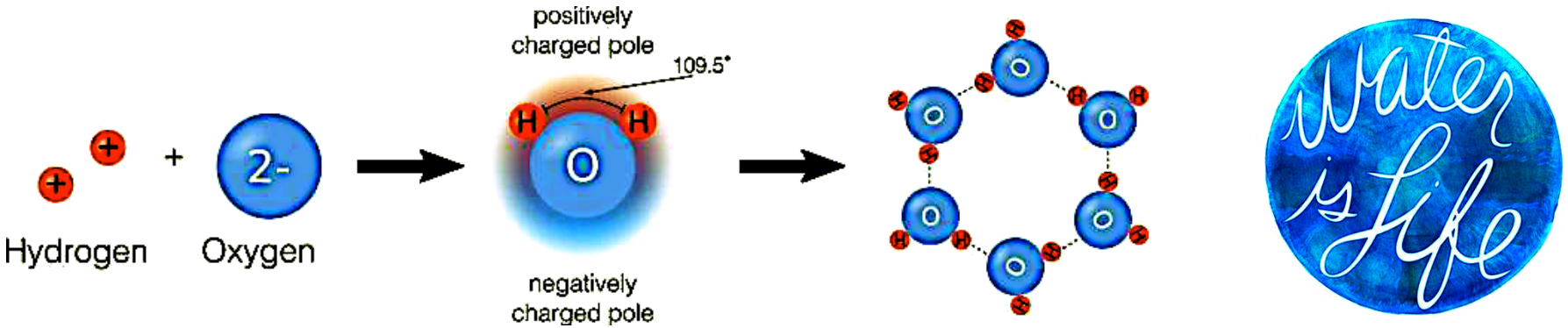
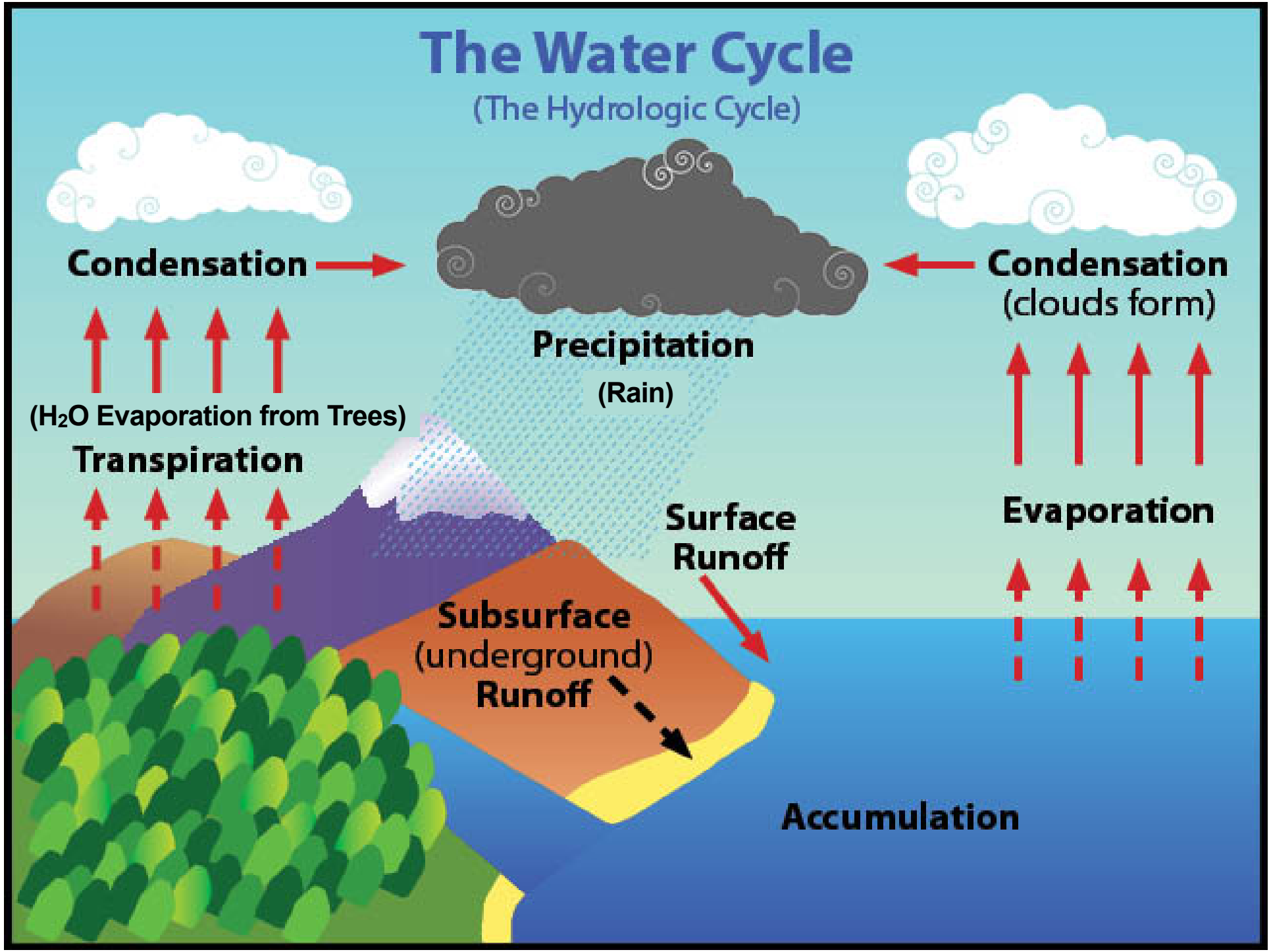
Water Is Essential to Life

- **Water makes up 60-80% of human body weight.**
  - **A loss of just 4% of total body water leads to dehydration, and a loss of 15% can be fatal.**
  - **Likewise, a person could survive a month without food but wouldn't survive 3 days without water.**
    - **Many of water's roles in supporting life are due to its molecular structure and special properties due to hydrogen bonding. Ex:**
      - **Moderating temperatures of organisms and bodies of water**
      - **"Universal" solvent for so many charged and polar solutes**
      - **Reactant in chemical reactions that break down macromolecules**
      - **Solid water, ice, floats insulating deeper lakes from freezing solid, helping aquatic organisms survive winter months**
      - **Cohesion and adhesion allows for water movement up plants**




The Water Cycle
(The Hydrologic Cycle)
Condensation
Condensation
(clouds form)
Precipitation
(Rain)
(H2O Evaporation from Trees)
Transpiration
Evaporation
Surface
Runoff
Subsurface
(underground)
Runoff
Accumulation

Run Off - water pulled by gravity across the land's surface

Runoff is precipitation that did not get absorbed (infiltrate) into the soil or did not evaporate, and therefore, made its way from the ground surface into larger bodies of water where water collects.

Runoff causes erosion and also carries minerals, chemicals, & other substances along the ground's surface to the rivers and oceans

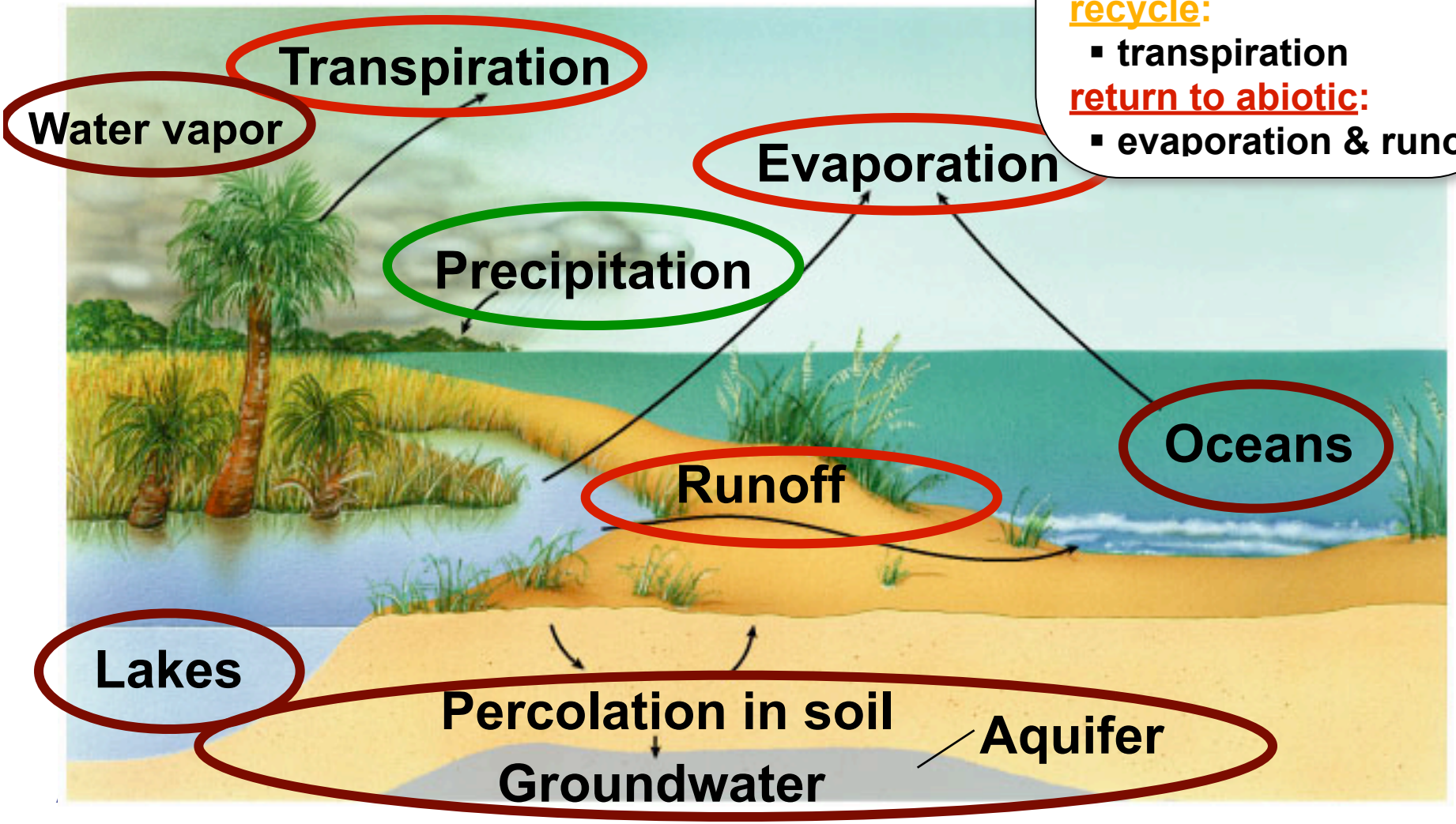
Water cycle

abiotic reservoir:
- surface & atmospheric water

enter food chain:
- precipitation & plant uptake

recycle:
- transpiration

return to abiotic:
- evaporation & runoff



Percolation & Groundwater

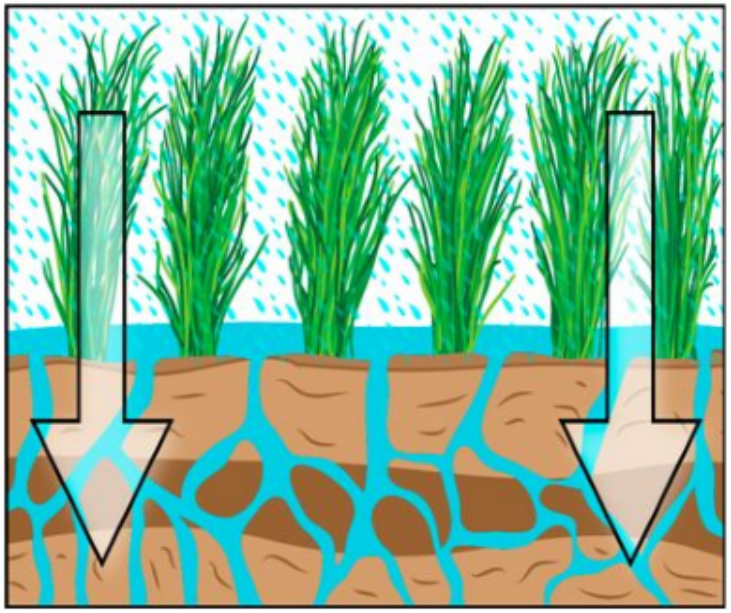
Groundwater is water that has filled the spaces between sediments and cracks in rock and thus exists underground in saturated zones beneath the land surface

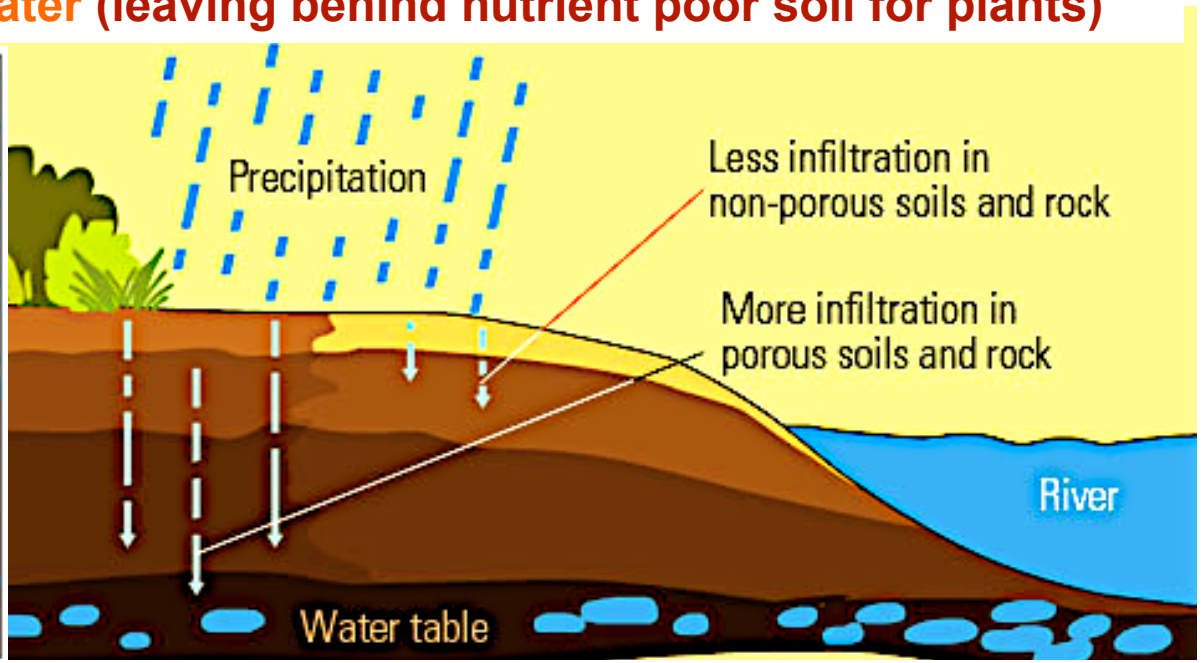
The upper surface of the saturated zone underground is called the water table.

Percolation is the downward movement of water through soil layers due to gravity and capillary forces.

Percolation is an important process required to replenish aquifers that hold groundwater. It is also a component of the water cycle.

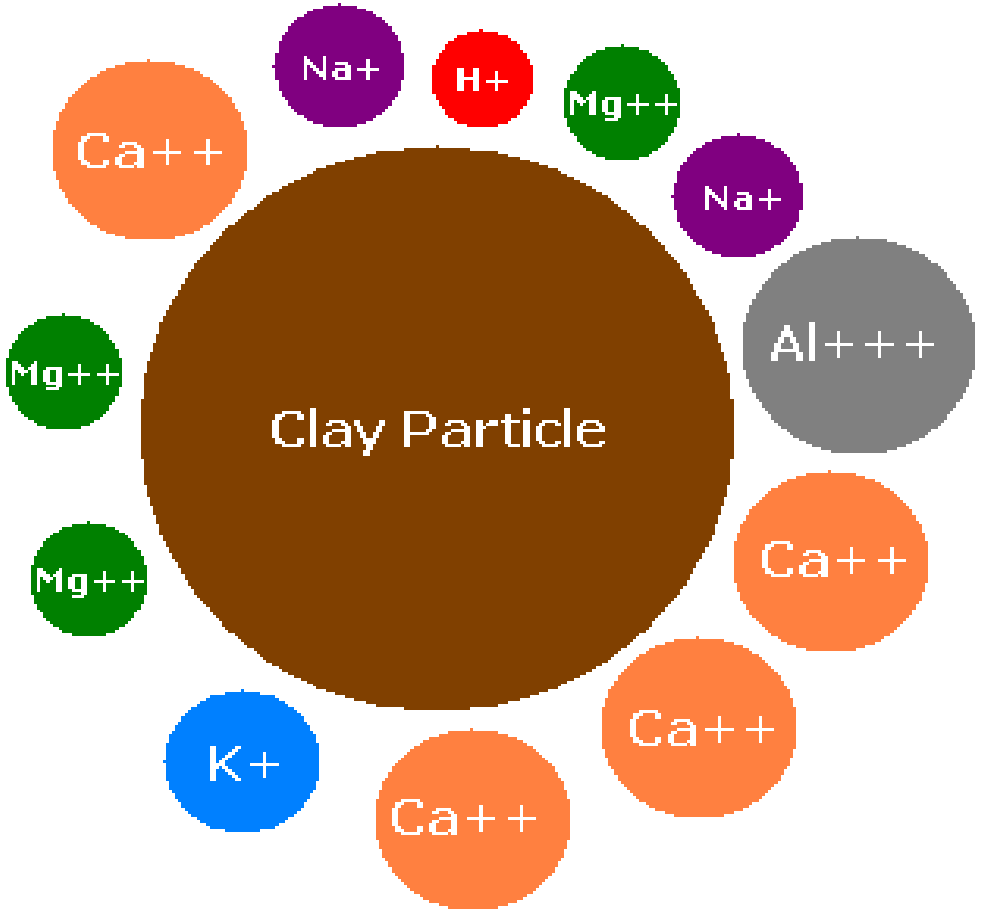
If too much water infiltrates the soil and begins percolating through the soil layers it can carry too many dissolved ions/minerals out of the soil and into the ground water (leaving behind nutrient poor soil for plants)





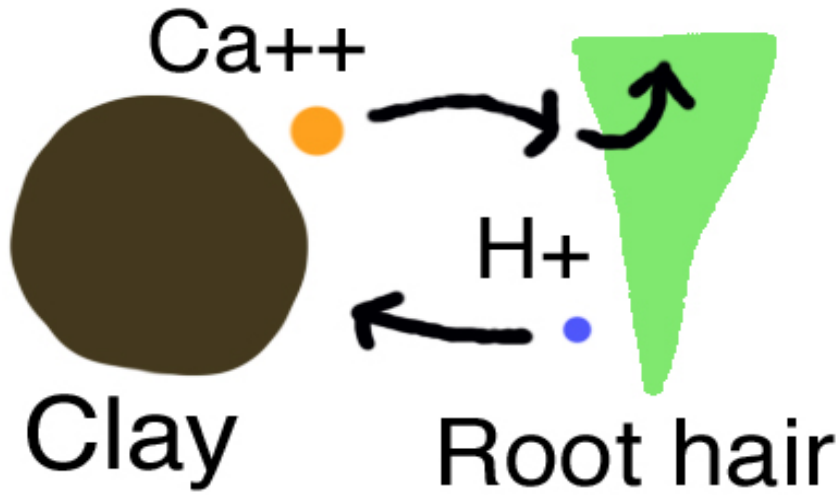
Ions in the soil

- **Most soil particles are negatively charged**
  - **Positive ions (cations) adhere to negative soil particles and are not easily lost by leaching**
    - **= The percolating of water through soil, which causes water to carry off dissolved ions into the deeper ground water and out of the soil plant roots have access to.**



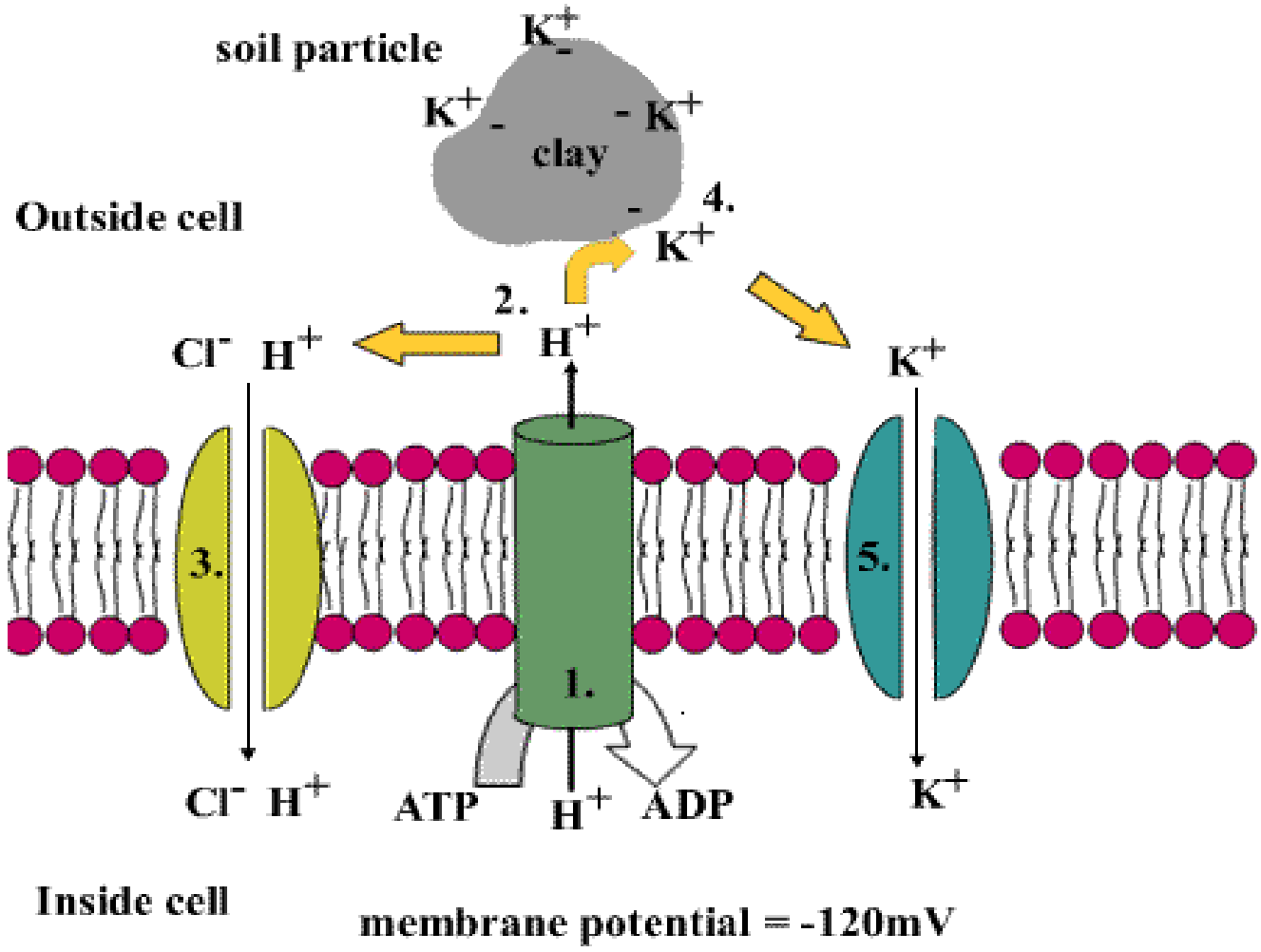
Ion Uptake

- Roots employ cation exchange to take in positive ions
  - Mineral cations are displaced form soil particles by other H+ pumped out of roots
    - Cations then enter soil solution and are absorbed by root hairs with the help of ion channels or carrier proteins
- Negative ions (anions) are not bound to negative soil particles and are taken up by secondary active transport also using the pumping out of H+ ions
  - These are easily leached from soil during heavy rains or irrigation
    - Nitrate NO_3^-
    - Phosphate $H_2PO_4^-$
    - Sulfate SO_4^{2-}



H+ participating in Cation Exchange to so K+ can diffuse in.

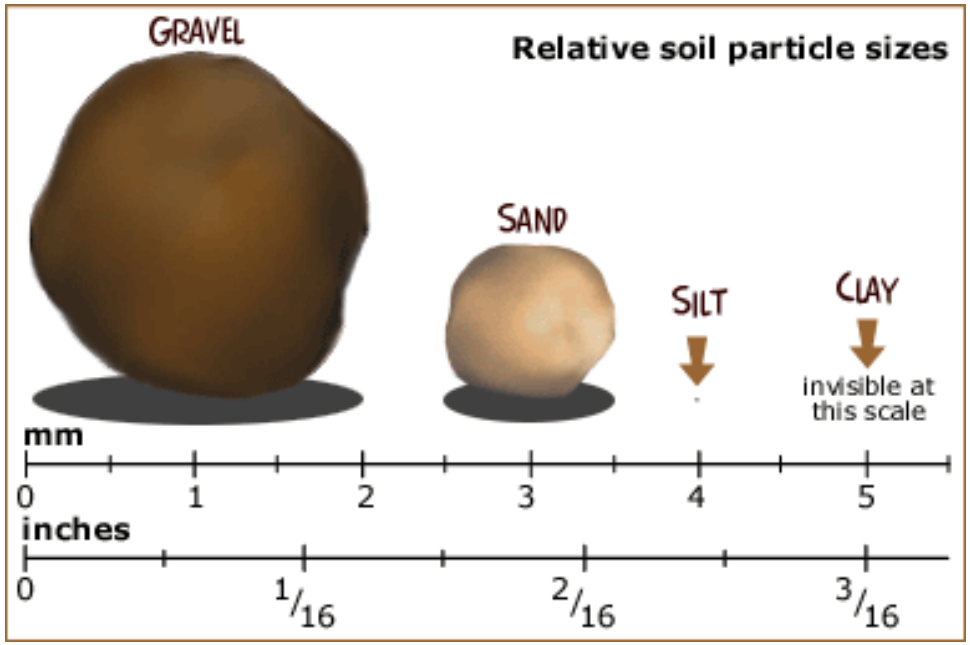
H+ participating in Secondary Active Transport to pump in Cl-



Proton Pump Uses in Root Hair Cell Plasma Membranes

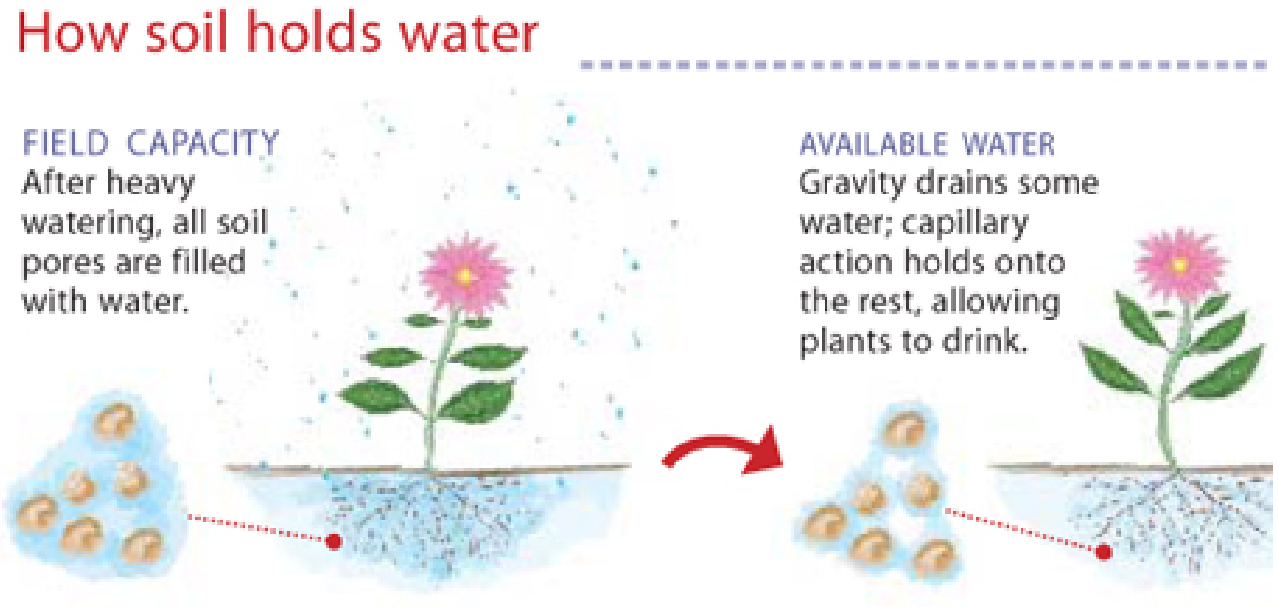
Soils are essential for plant health

- **Plants are dependent on soil quality**
  - Texture & structure of soil affect rate of water and mineral leaching (loss) from soil
    - Soil texture depends on relative sizes of soil particles
      - Soil particles can range from course to silt
        - Particles arise from weathering of rock, and...
        - water freezing in the crevices of rocks causes mechanical fracturing, and...
        - weak acids in the soil break rocks down chemically.



Top Soil & Organic Material

- Top soil contains organic material
  - Major organic component = Humus
    - 1 tsp. of topsoil has ~5 billion bacteria living with fungi, algae, protists, insects, earthworms, nematodes etc…
- Plants are nourished by the soil solution
  - The water & dissolves minerals in the pores between soil particles
    - Water is attracted to negatively charged surface of clay and other soil particles
- Pores also contain air pockets
  - Roots exchange take in O_2 for cellular respiration and release CO_2 waste



Types of Soils

- **Loams** are the most fertile top soils
  - Equal amounts of sand, silt, & clay
    - Smaller soil particles provide a lot of surface area for adhesion and retention of minerals and water
    - Spaces between larger soil particles allows for sufficient diffusion of oxygen to roots
- **Sandy soil** does not hold much water - the soil particles are large causing large spaces to exist in between particles, resulting in too little capillary action and not enough water sticking to the particles by adhesion
- Soil that does not drain properly though (like clays with very fine, small soil particles and lots of capillary action or soils that are overwatered) cause air (with oxygen gas) to be replaced by water, suffocating/drowning roots.
  - All plant cells need O_2 gas for cellular respiration during the night while all non-photosynthetic cells this gas during daylight hours too so they can extract energy from the sugars they receive from photosynthetic cells or cells that store sugars.

Deforestation:

Cutting down / removal forests

Harmful:

Changes a forest to create an area used for grazing, logging, or urban construction purposes

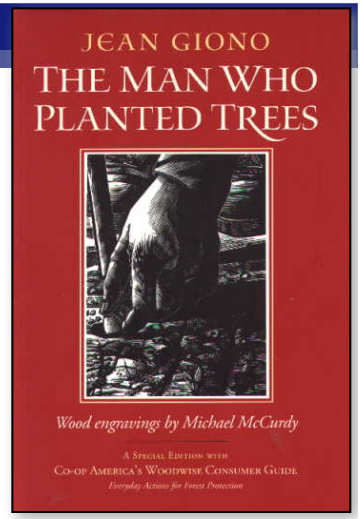
*** Reduces biodiversity**

*** Can be man-done or can occur naturally**

Deforestation Results

1. Prevents nutrients in trees from being returned to the soil
2. Interrupts the carbon cycle *(normally prevents excessive build up of carbon dioxide and adds oxygen to the air - with more CO_2 comes more global warming)*
3. Interrupts the water cycle by causing less rain to be produced through transpiration *(leading to droughts downwind)*
4. Increases the chances of minerals washing out of the soil into ground water (leaching)
5. Destroys habitat other organisms use to live off of
   - Rainforests cover only a small part of the earth's surface - about 6%, yet they are home to over half the species of plants & animals in the world.

Breaking the water cycle



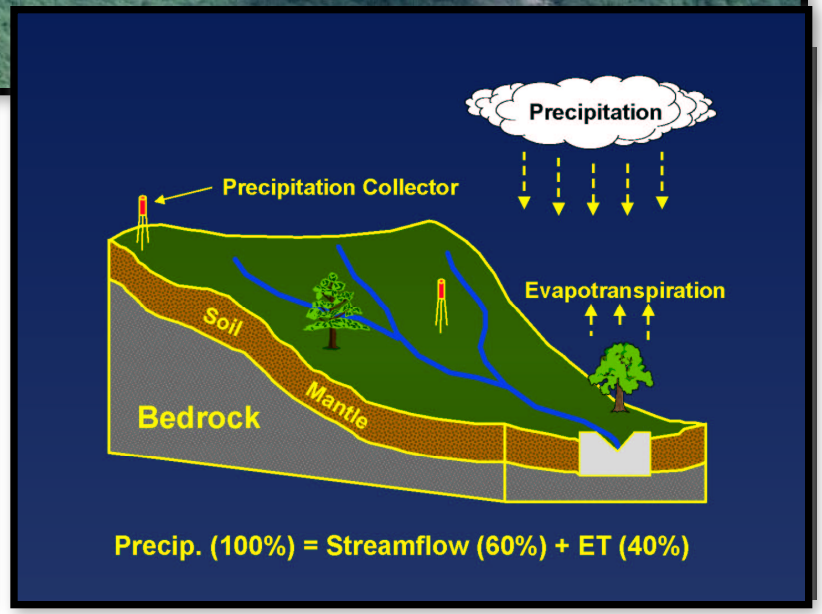
- **Deforestation breaks the water cycle** ***(as well as the carbon cycle leading to higher CO_2 in the air)***
  - **groundwater is not transpired to the atmosphere, so precipitation (rain) is not created**
  - **Minerals and ions are washed out *(leached)* of the soil without being replaced by decomposition making the soil nutrient poor**

forest → desert

desertification

Studying Ecosystems

Hubbard Brook Experimental Forest

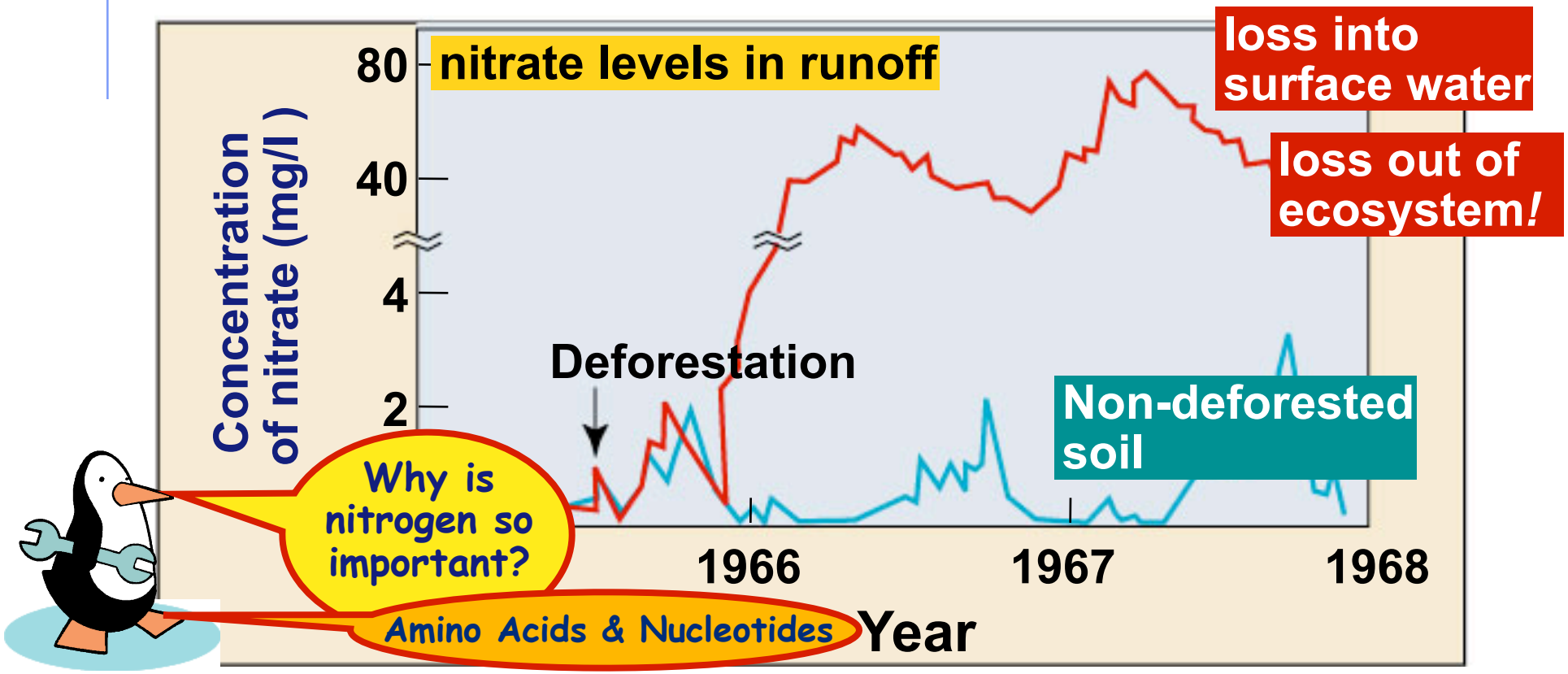


Effects of Deforestation in Hubbard Brook

40% increase in runoff

- loss of water

- 60x loss in nitrogen
- 10x loss in calcium



Soil health is a global issue!!!

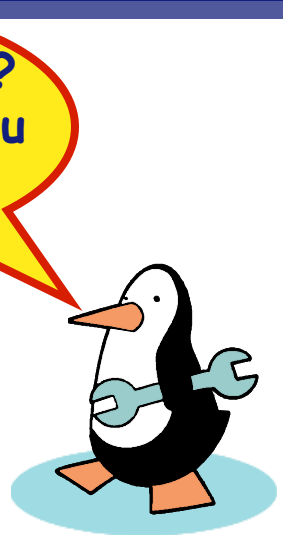
Not taking care of soil health has far-reaching, damaging consequences

- Ex: 1920's Dust Bowl

- lack of soil conservation
  - Growing the same crop year after year (wheat)

    depletes certain minerals
  - Over-grazing by cattle exposes soil to air
  - Bare ground gets exposed to wind erosion in winter
  - Drought lead to fertile soil (rich in minerals) being blown away
  - Over-irrigation causes ions to get carried off into deeper ground water, out of the upper soil layers *(leaching)*
  - Irrigation with groundwater though, *(which contains ions too)* can lead to salinization, soil too salty for plant growth

Increasing soil fertility

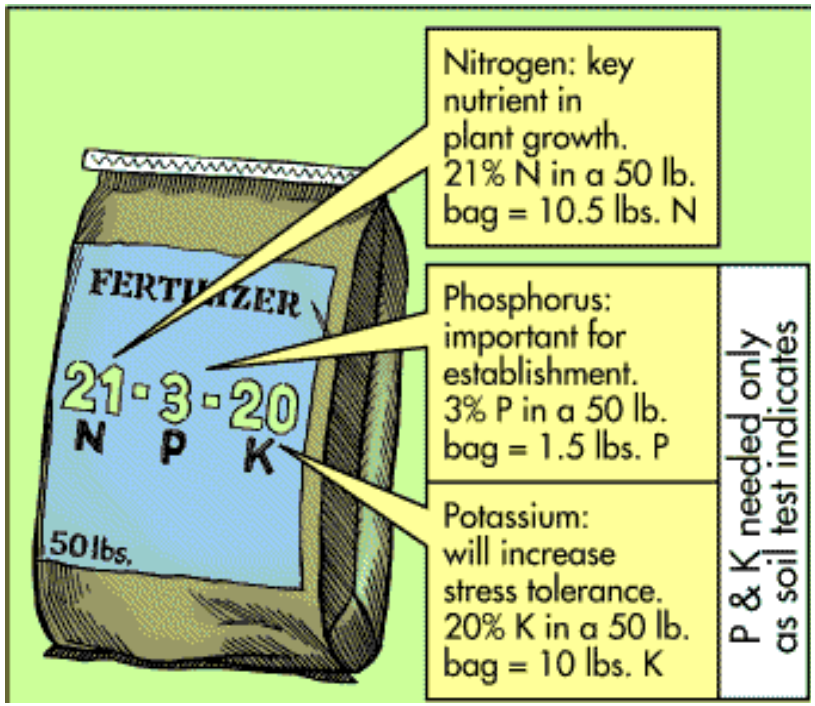


- Grow "cover crops"
  - growing a field of plants in between regular agricultural growth just to plow them under
    - usually a legume crop
    - taking care of soil's health
      - puts nitrogen back in soil by allowing the cover crop to decomposed on site, which results in minerals being returned to the soil that may be removed by the other crops grown in the field

AP

Agriculture & Fertilizers

- In natural ecosystem, minerals are recycled by decomposing organic material and excretion of animal wastes
  - Agriculture is unnatural and deposits minerals far from original source
- Nutrient depletion is a major cause of global soil degradation
  - Reverse nutrient depletion by fertilization
    - Adding minerals nutrients to soil
      - Usually enriched N, P, of K
- Organic fertilizers like fishmeal, manure and compost must be decomposed into inorganic nutrients first

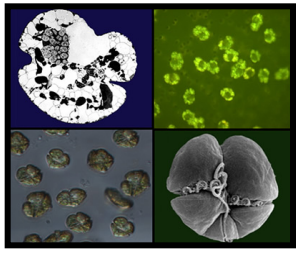


Fertilizers

- "Organic" fertilizers
  - manure, compost, fishmeal
- "Chemical" fertilizers
  - commercially manufactured
  - N-P-K (ex. 15-10-5)
    - 15% nitrogen
    - 10% phosphorus
    - 5% potassium

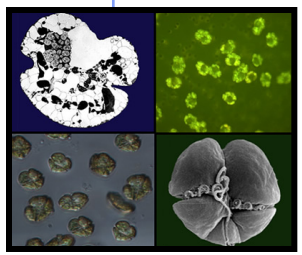
Agriculture & Mineral Run-Off

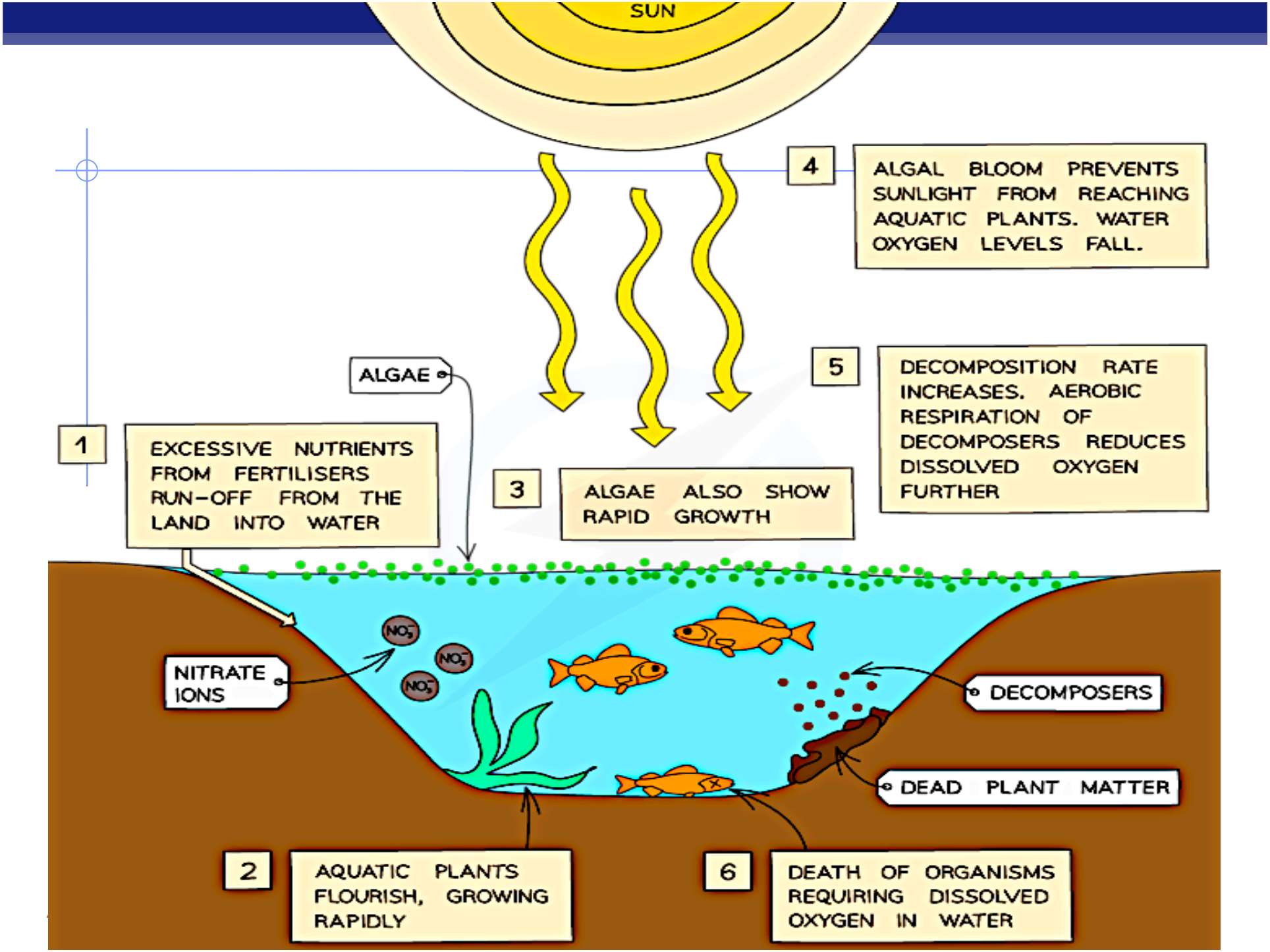
- Farmers often add more nutrients than than crops can take up *(add too much)*
  - Minerals are also found in sewage and industrial wastes
- Minerals not absorbed by soil can be leached by rain or irrigation into the ground water and carried off into lakes and oceans
  - This causes EUTROPHICATION *(Greek for "healthy and adequate nutrition")*
    - = Aquatic systems very rich in nitrates and phosphates
- Nitrogen is more commonly the key nutrient of marine waters
  - One consequence is an "algal bloom" or great increase of phytoplankton *(photosynthetic bacteria and protists)* in a water body as a response to increased levels of nutrients.
    - Algae population sizes explode due to increased minerals in water



Consequences of Algal Blooms are Devastating

- **Algae blooms due to water eutrophication spell big trouble!**
  - **Mineral runoff into lakes may lead to huge DEAD ZONES**
    1. **These algae take up the other necessary nutrients needed for plants and animals to survive.**
    2. **When algae die they sink to the bottom where they are decomposed by decomposers and the nutrients contained in organic matter are converted into inorganic form by bacteria.**
    3. **The decomposition process uses up (dissolved) oxygen gas and deprives the deeper waters of oxygen**
       - **Low oxygen condition kill fish and other organisms!**
         - **Ex: Algae blooms off Gulf Coast due to fertilizer run off and sewage run off, result massive death of fish *(causing ecosystem disruption & economic losses to humans)***



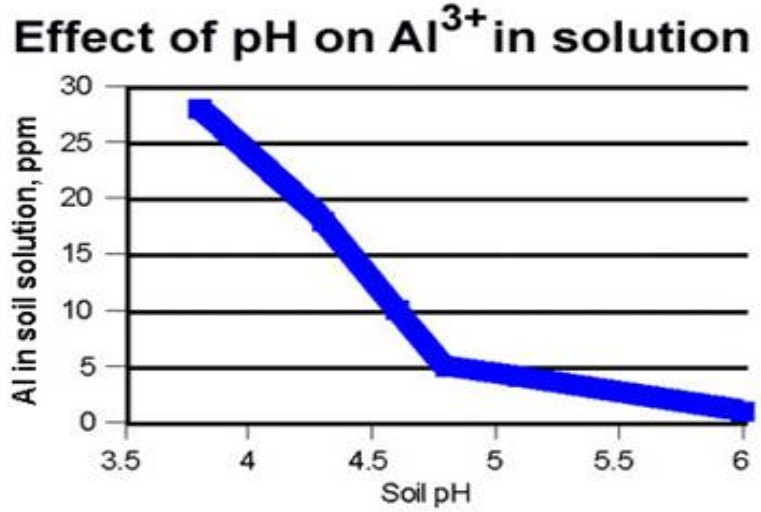

SUN
4
ALGAL BLOOM PREVENTS SUNLIGHT FROM REACHING AQUATIC PLANTS. WATER OXYGEN LEVELS FALL.
5
DECOMPOSITION RATE INCREASES. AEROBIC RESPIRATION OF DECOMPOSERS REDUCES DISSOLVED OXYGEN FURTHER
ALGAE
1
EXCESSIVE NUTRIENTS FROM FERTILISERS RUN-OFF FROM THE LAND INTO WATER
3
ALGAE ALSO SHOW RAPID GROWTH
NITRATE IONS
DECOMPOSERS
DEAD PLANT MATTER
2
AQUATIC PLANTS FLOURISH, GROWING RAPIDLY
6
DEATH OF ORGANISMS REQUIRING DISSOLVED OXYGEN IN WATER

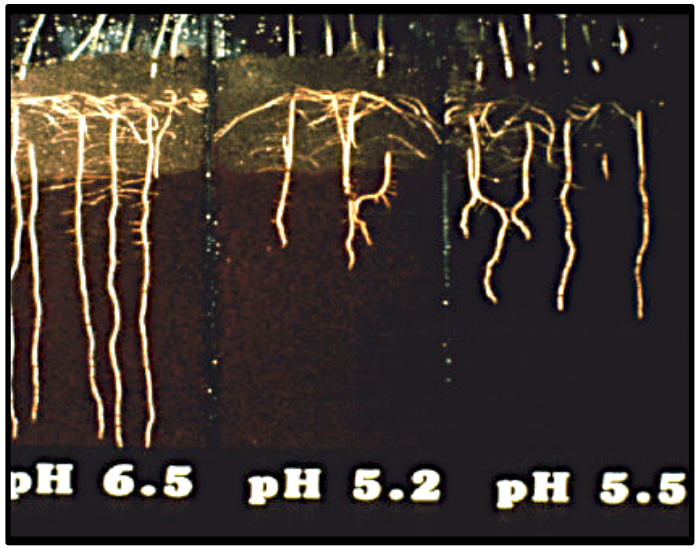
Other Consequences of Eutrophication

- **Poisoning and deterioration of water quality / safety**
  - Some cyanobacteria, like dinoflagelates, cause red tide, large concentration of released toxins.
    - Once the water reaches the anaerobic conditions, the growth of more toxic bacterial is promoted.
  - Red tide poisons can cause death in humans and animals even at the least concentration when ingested in drinking water.
  - Freshwater algal blooms can threaten livestock health.
  - The toxic compounds can make their way up the food chain, contributing to various negative health impacts such as cancers.
    - Biotoxins are linked to increased incidence of neurotoxic, paralytic, shellfish poisoning in humans.
    - High nitrogen concentration in drinking water is associated with the ability of inhibiting blood circulation in infants, a condition known as blue baby syndrome
- **Limiting availability of water**
  - The dense growth of algal blooms and photosynthetic bacteria in surface waters can also block water systems hence, limiting the availability of piped water.
    - In 2007, more than 2 million residents of Wuxi, China could not access piped drinking water for more than a week due to severe attack by algal blooms on Lake Taihu.
- **Endangers fishing & degrading recreational opportunities**
  - Increased growth of dense mats of floating algae and photosynthetic bacteria such as Nile cabbage and water hyacinths, endangering fishing (nets can't be cast and boats can't navigate waterways) and making swimming in water difficult.

Soil pH is critical for plant growth…

- **Soil pH affects mineral availability as well!**
  - At alkaline pH (>7.5) phosphate ions react with calcium (Ca) and magnesium (Mg) to form less soluble compounds.
  - Slightly lower pH (~6.5) helps weaken the attraction between negative soil particle and cations, making cations available for plants to absorb
    - Now plants can absorb positive phosphates, for example…
  - But a problem arises when soils become too acidic..
    - In very acidic soils, ions change to forms that cannot be used by plants or may cause dangerous Al^{3+} minerals to be absorbed
      - toxic levels of aluminum damage the growing root.
    - At acidic pH (<5), phosphate ions react with aluminum (Al) or iron (Fe) to form less soluble compounds.





Soil Health as a Global Issue

- **Soil conservation & sustainable agriculture**
  - maintaining healthy environment
  - sustainable production of food supply
  - economically viable farming industry

> "A sustainable agriculture does not deplete soils or people."
> – Wendell Berry

contour plowing

cover crops

crop rotation

Repairing the damage

- The Greenbelt Movement
  - planting trees in Kenya
  - restoring a sustainable ecosystem
  - establishing democracy
  - empowering women

Wangari Maathai

Nobel Peace prize 2004

Causes of Acidic Soils

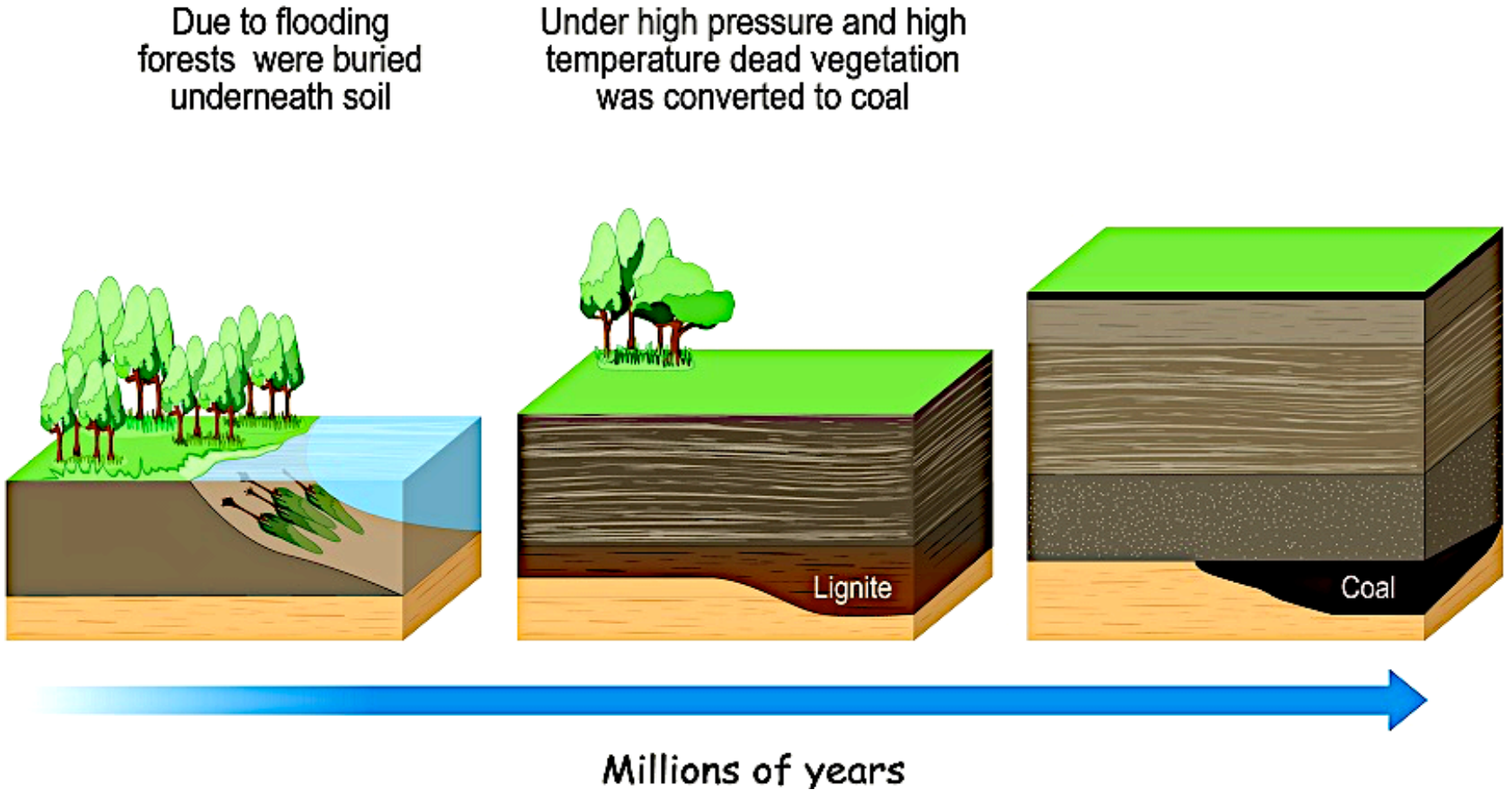
- **What causes Acidic Soils**
  1. **Acid Rain**
     - **Results from emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from power plants, cars and factories (= COMBUSTION OF FOSSIL FUELS).**
       - **Natural sources like volcanoes, forest fires and lightning strikes also add to the man-made pollution.**
     - **SO_2 and NO_x become acids when they enter the atmosphere and react with water vapor. The resulting sulfuric and nitric acids can fall as wet or dry depositions.**

$$SO_2 + H_2O + \tfrac{1}{2}O_2 = H_2SO_4$$

  2. **Leaching out of other ions due to excessive rainfall or artificial irrigation.**
  3. **The use of high-nitrogen synthetic fertilizers.**

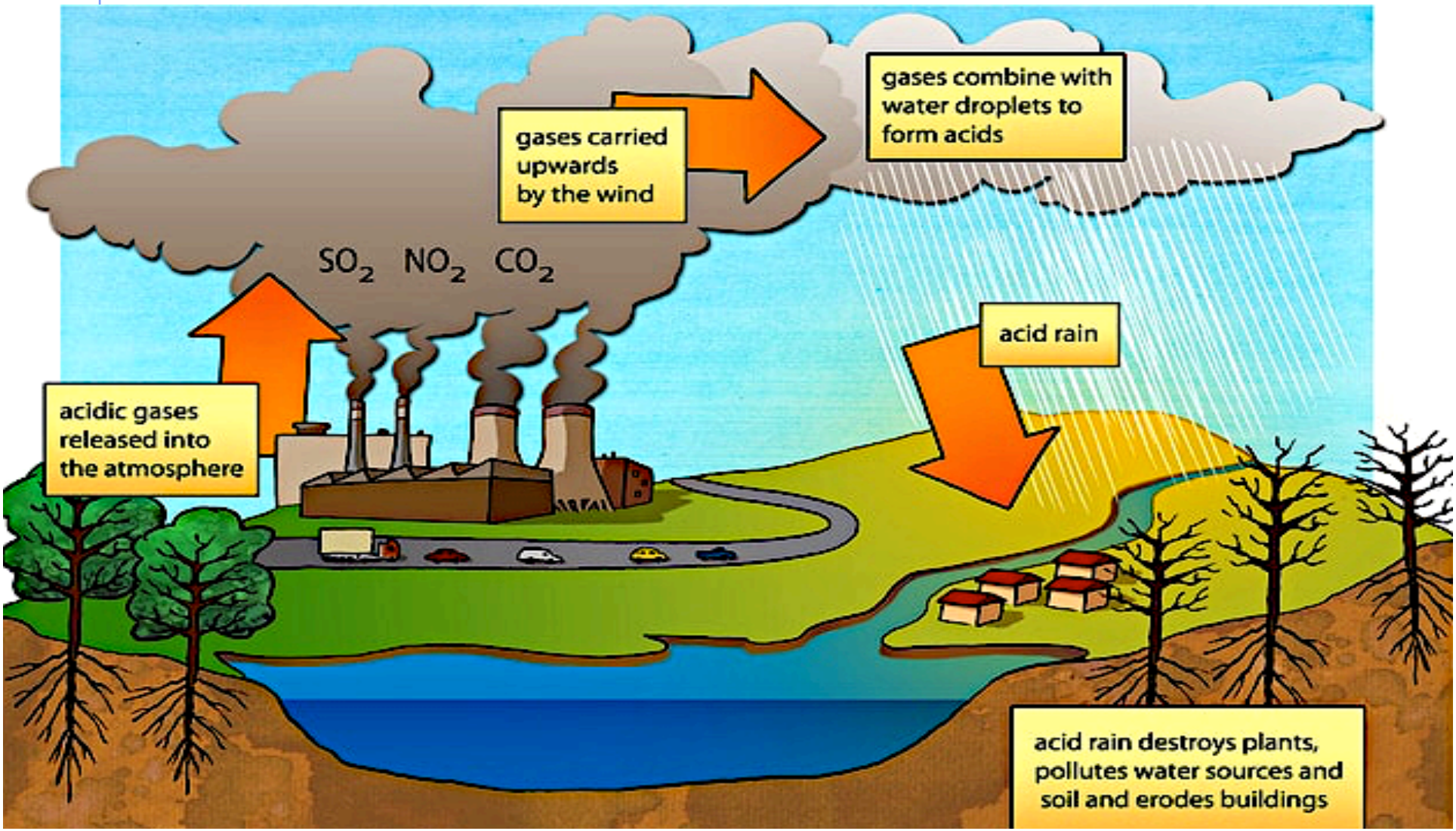
Reminder: What are Fossil Fuels?

- **Natural fuels such as coal, natural gas, petroleum/oil formed in the geological past from the remains of living organisms.**

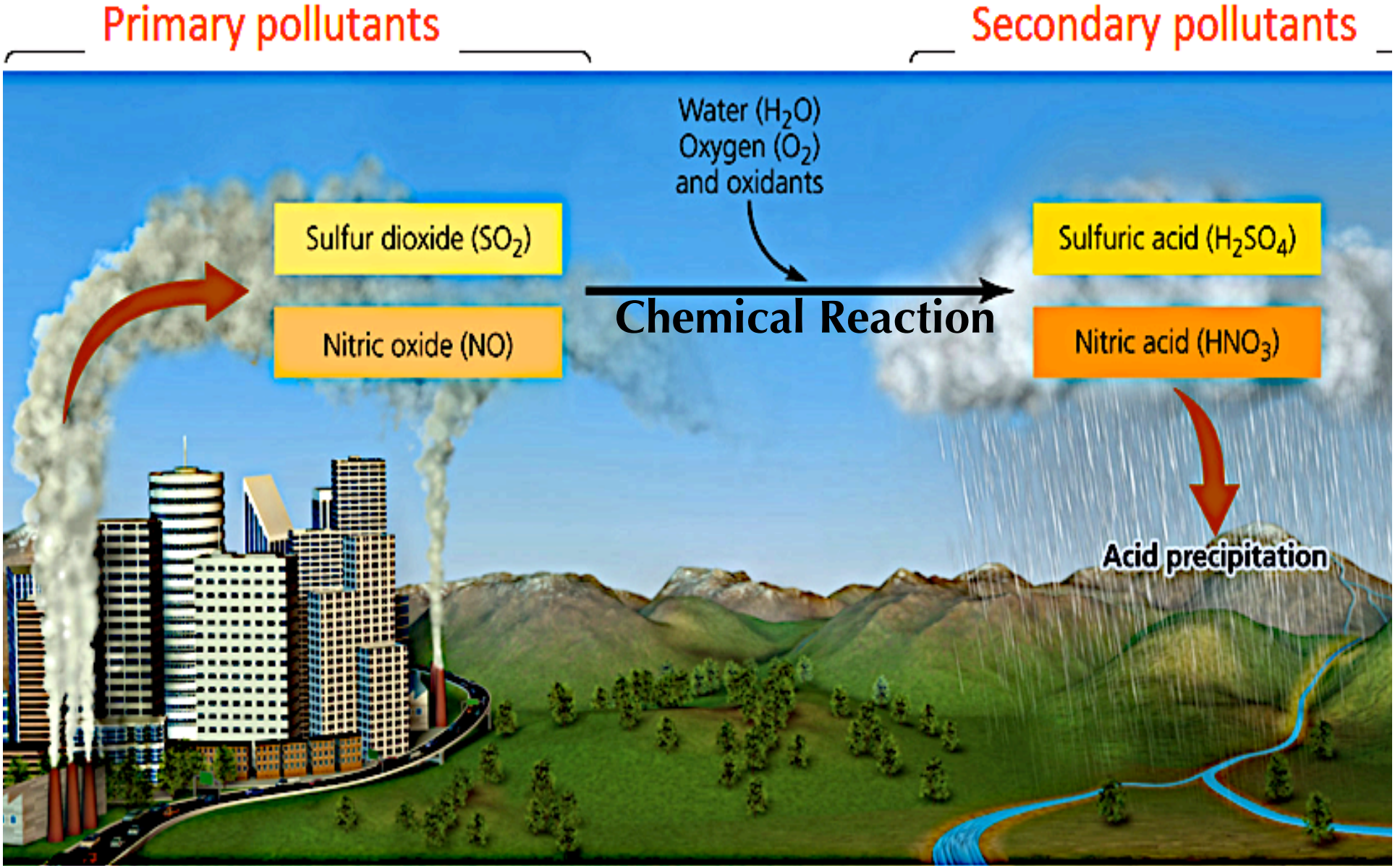


CO_2 level rise threatens our Environment by Altering pH of Rain & Oceans

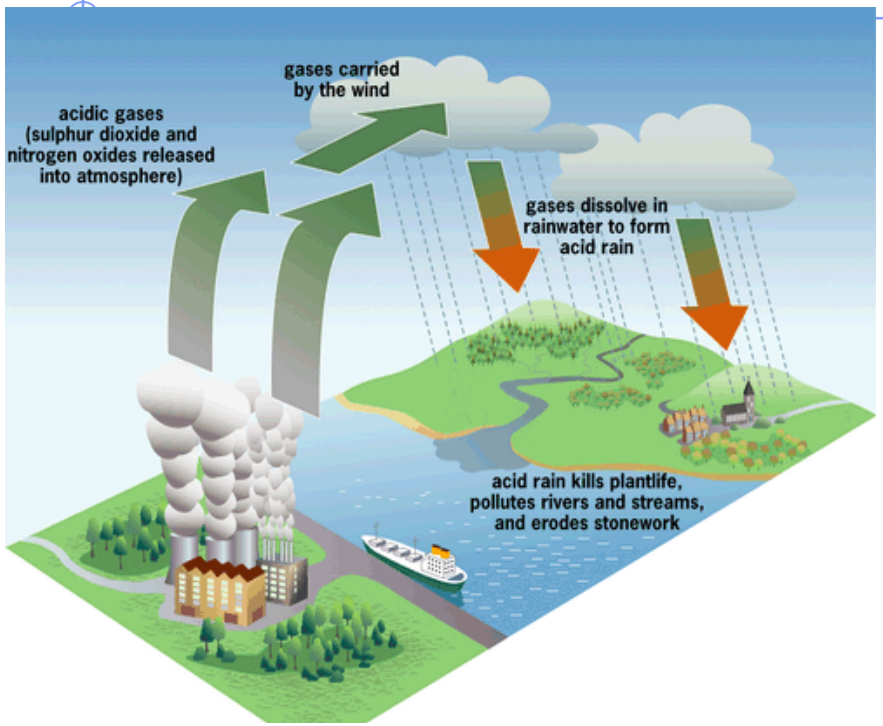
- **Acidification of rain threatens living organisms**

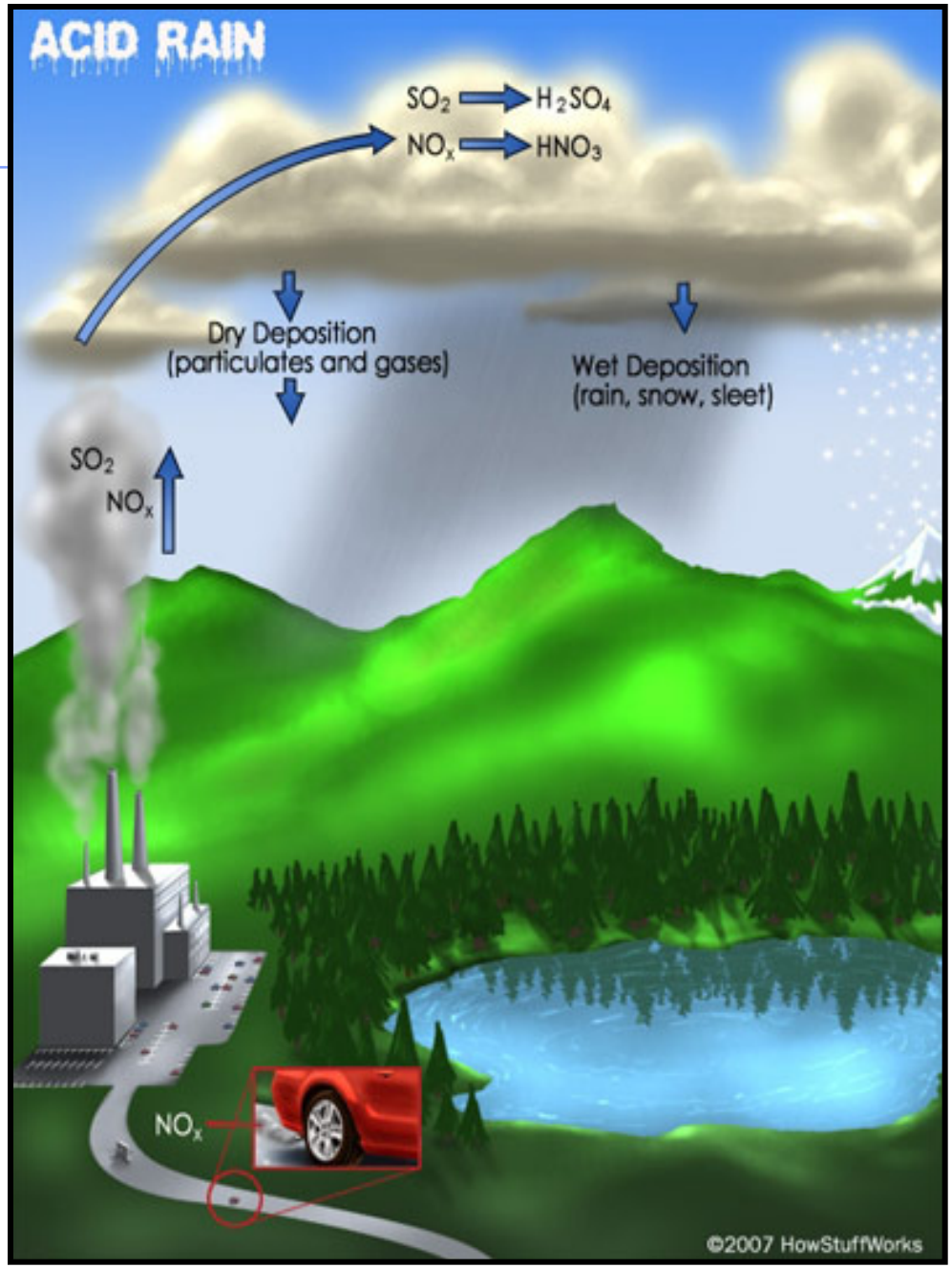


Acid Rain Production



ACID RAIN Consequences

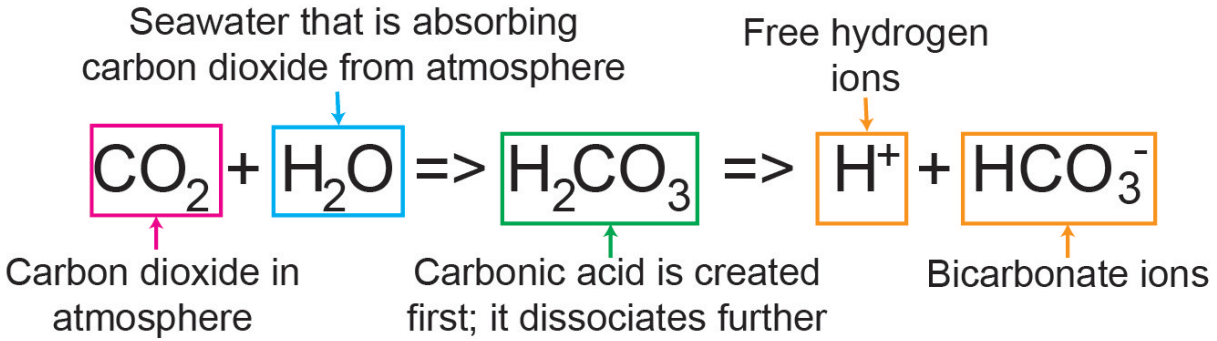




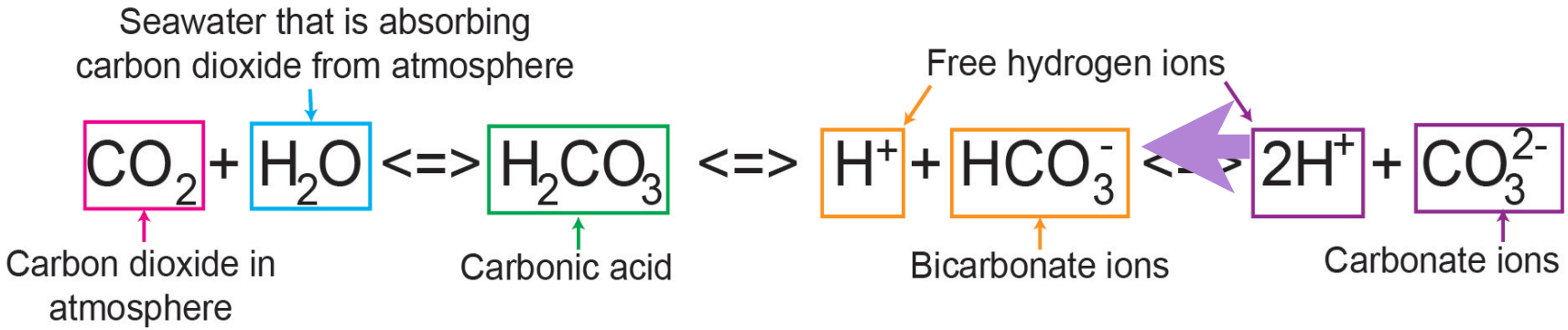
- Nutrients in soil destroyed or toxins released from soil particles, affecting plant growth
- Waxy layer (cuticle) on plants can be reduced, allowing the plant to dry out and be susceptible to disease.
- Acid rain alters pH of lakes and oceans
- Acid rain can hurt a food web by affecting food sources for other animals in the chain.

CO_2 level rise threatens our Environment by Altering pH of Rain & Bodies of Water

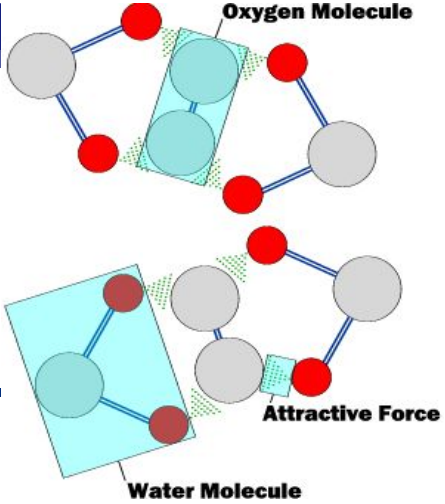
- **Acidification** of bodies of water (lakes, oceans, rivers etc..) **threatens aquatic life**, a source of nutrients for many other organisms too



- Increased H+ due to added CO_2 also react with **Carbonate Ions** in water, reducing their concentration, harming corals and shell fish which need carbonate to make their **calcium carbonate** shells and coral bodies



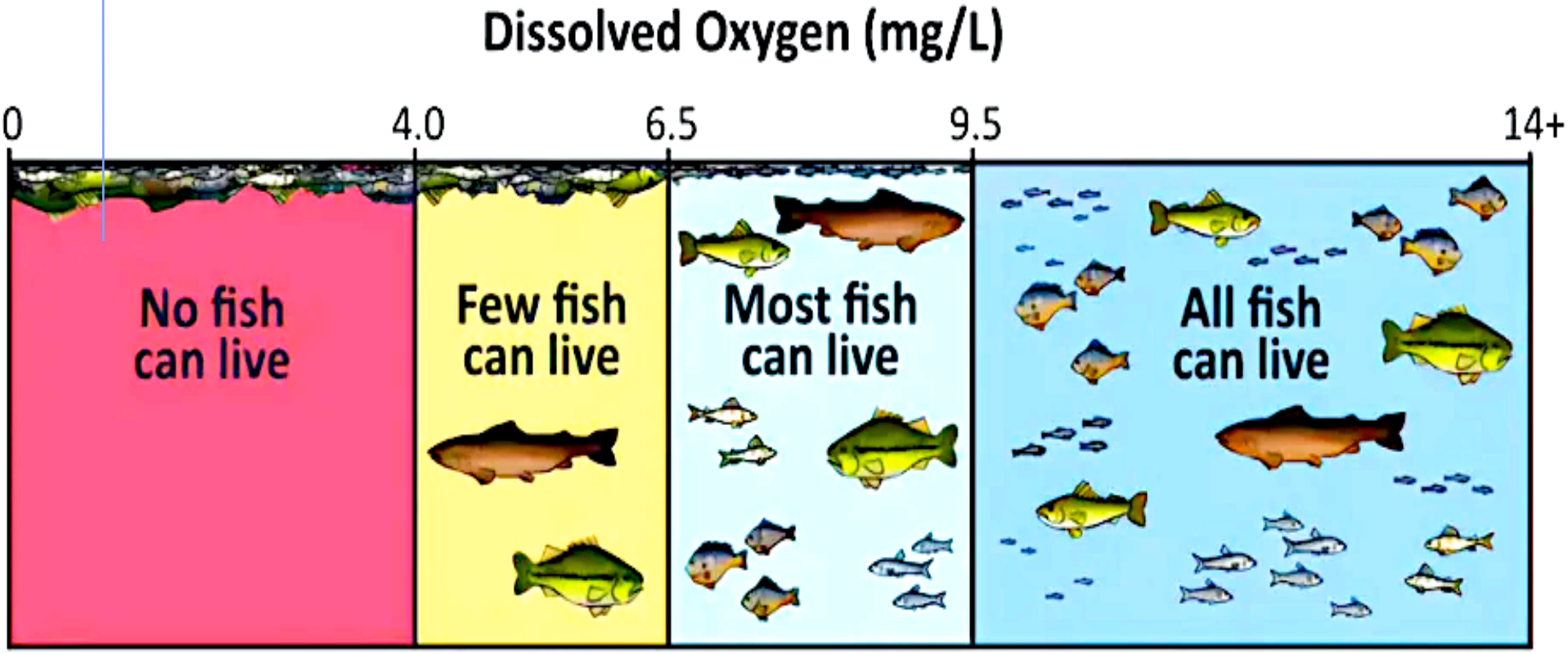
Dissolved Oxygen in Bodies of Water



- Dissolved oxygen (DO) is a molecule of O_2 that is dissolved (mixed among) water.
  - DO is a very important indicator of a water body's ability to support aquatic life.
    - Enough dissolved oxygen makes aquatic life possible.
      - Changes in oxygen concentration may affect species dependent on oxygen-rich water, disrupting the food chain.
  - DO are molecules of Oxygen, not the oxygen component of the water molecule H_2O.
    - Dissolved oxygen can get into the water two ways:
      1. Through atmospheric oxygen mixing & diffusing in
      2. By the release of oxygen from aquatic plants and algae during photosynthesis.

    - Dissolved oxygen is removed from the water two ways:
      1. Through aerobic respiration (by prokaryotes & eukaryotes)
      2. Though the decomposition of organic matter *(which involves fungi or bacteria and their aerobic cellular respiration again).*

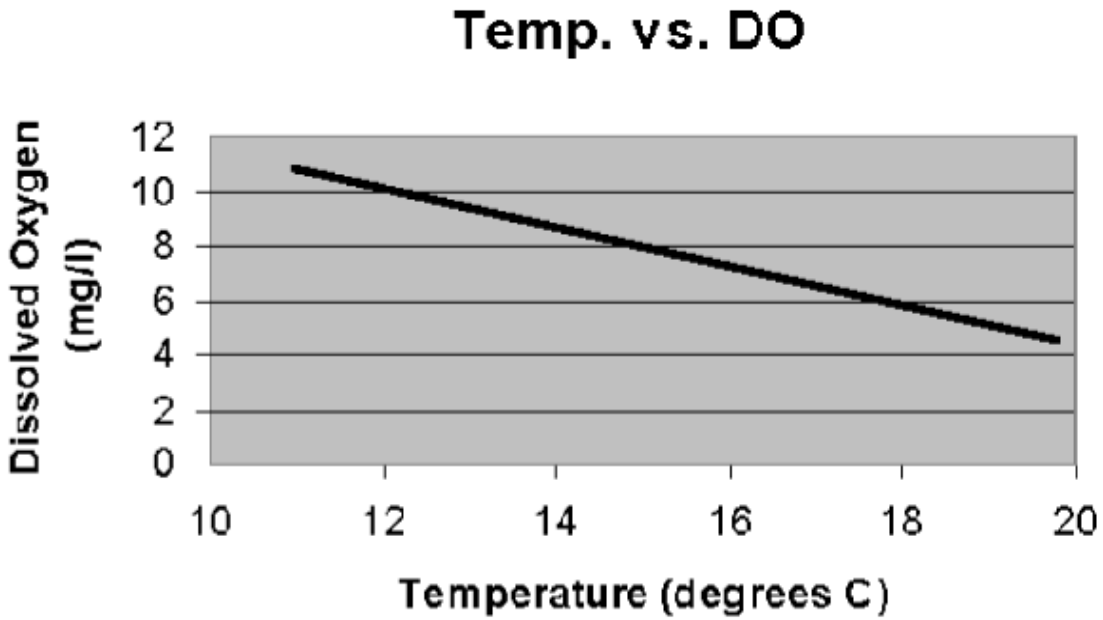
DO levels affect life in aquatic environments.



On FR Questions, State the Obvious Too!!!

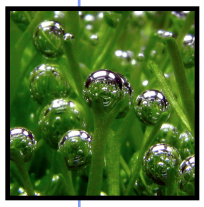
When given a graph…DESCRIBE the graph by *"walking along the x & reporting the changes in the y"* before EXPLAINING the biology behind the pattern seen *(even if a description is not asked for).*

- **The following graph describes the relationship between dissolved oxygen and temperature. Describe the relationship and explain it.**



Environmental Factors Influence Dissolved Oxygen

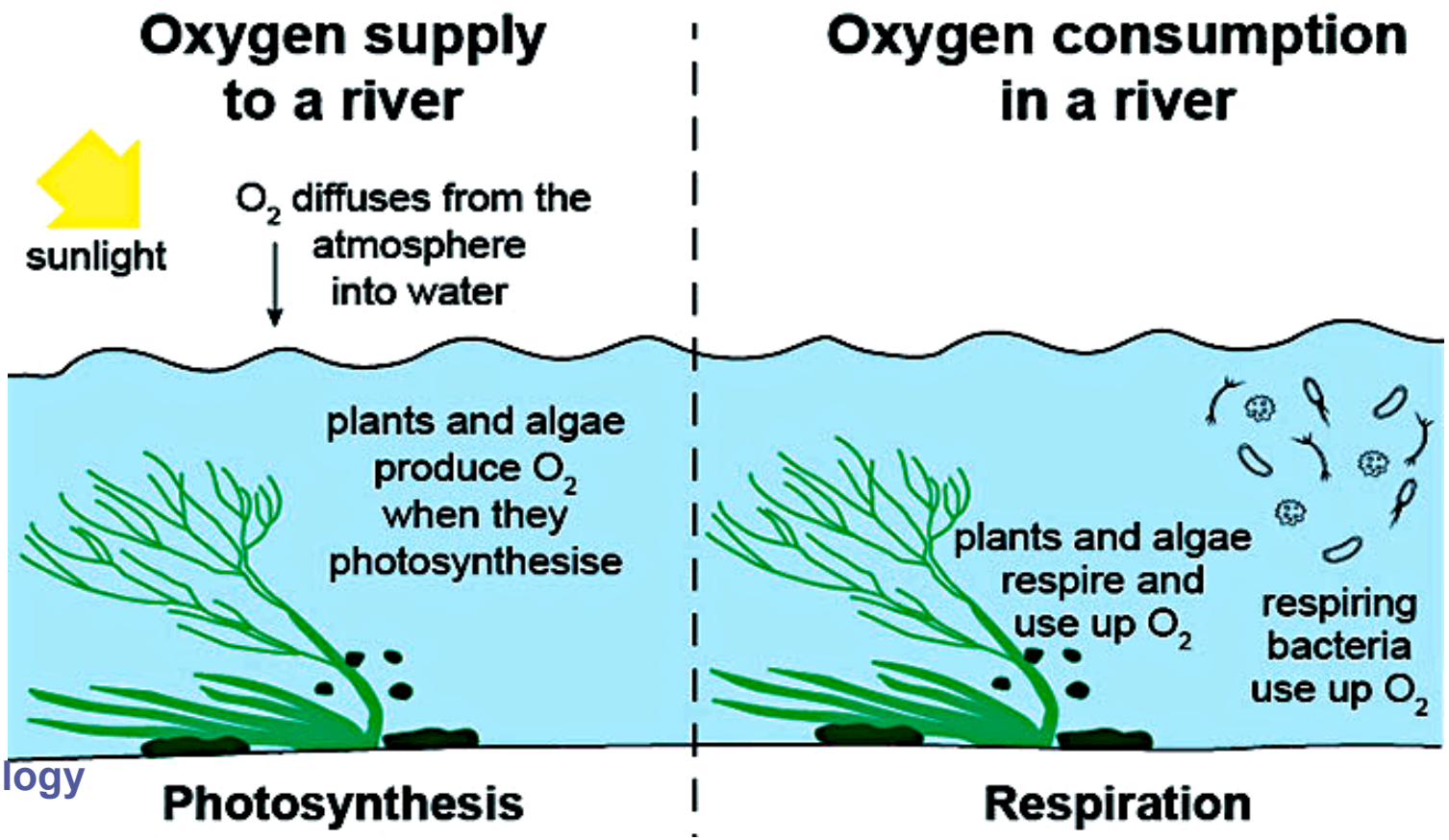
- **Aquatic life - Type & # of Living Organisms in Water**
  - Plants and algae release oxygen during photosynthesis



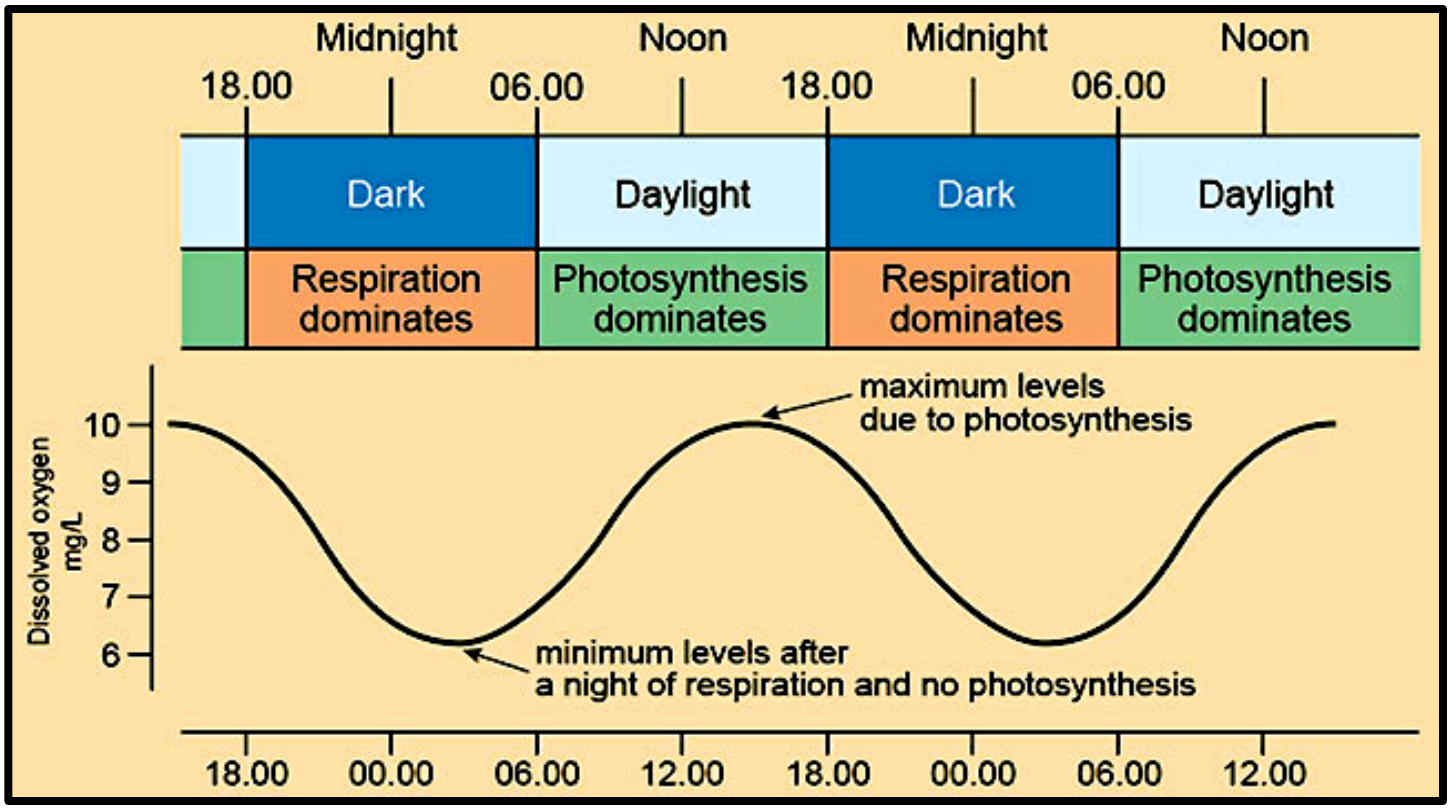
    - If many plants are present, the water can be supersaturated with DO during the day, as photosynthesis occurs.
    - Concentrations of oxygen can decrease significantly during the night, due to respiration.
      - DO concentrations are usually highest in the late afternoon, because photosynthesis has been occurring all day.
  - Animals living in water use up dissolved oxygen during respiration.

  - Bacteria and fungi use up oxygen as they decompose materials.
    - Dissolved oxygen levels drop in a water body that contains a lot of dead, decomposing material.

- Oxygen levels in river water are a balance between oxygen supply (from the atmosphere and by photosynthesis) and oxygen consumption due to the respiration of plants, animals and microbes.
  - Non-photosynthetic bacteria use organic matter (including plant and animal remains) in water as a food (energy & carbon) source.
  - The more organic matter, the greater the number of bacteria respiring in the water, and hence the more oxygen that gets used up by the bacteria.
    - Therefore, excess organic matter in rivers can cause low oxygen conditions.



- **Example of Dissolved Oxygen Fluctuations based on the types of metabolism (photosynthesis and respiration) occurring at certain times of the day.**
  - **Imagine a streams rich in aquatic plants. These plants will photosynthesize by day *(more than they respire)*, and respire at night *(doing no photosynthesis)* causing marked changes in the DO content of the river over 24 hours.**
    - **The rate of photosynthesis will change depending on the strength and duration of sunlight, so a sunny day will be associated with higher rates of photosynthesis compared to a cloudy one.**

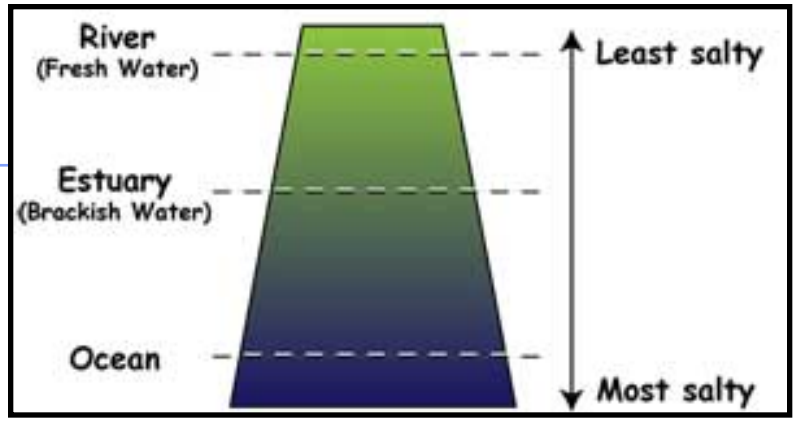


Environmental Factors Influence Dissolved Oxygen

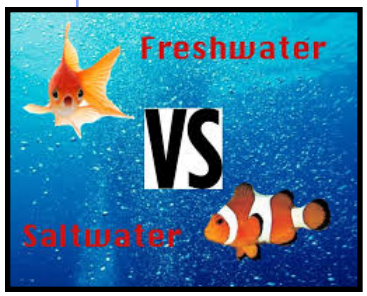
- **Altitude / Elevation**
  - The amount of oxygen in the atmosphere decreases as elevation increases.
    - Streams get much of their oxygen from the atmosphere
  - Streams at higher elevations will generally have less oxygen.
  - Streams at lower elevations will generally have more oxygen.

- **Turbulence**
  - More turbulence creates more opportunities for oxygen gas to enter streams.

Environmental Factors Influence Dissolved Oxygen



- **Water Salinity (saltiness)**
  - Salty water holds less oxygen
    - Oxygen is more easily dissolved into water with low levels of dissolved or suspended solids.



- Waters with high amounts of salt, such as the ocean (contains about 35 grams of salt per 1000 grams of water) have low concentrations of DO.
- Freshwater lakes, streams, and tap water generally contain much less salt, so DO concentrations are higher.
  - An increase in salt concentration due to evaporation of water from an ecosystem tends to reduce the dissolved oxygen available.
  - Runoff from roads and other paved surfaces carrying dissolved solids can bring salts and sediments into stream water, reducing dissolved oxygen.

Environmental Factors Influence Dissolved Oxygen

- **Temperature, Climate, & Season**
  - Cold water holds more dissolved oxygen than warmer water.
    - DO concentrations at one location are usually higher in the winter than in the summer.
    - More sunlight and warmer temperatures in summer time bring increased activity levels in plant and animal life
      - Depending on what organisms are present, this may increase or decrease the DO concentration.
  - During rainy seasons, oxygen concentrations tend to be higher because the rain interacts with oxygen in the air as it falls.
    - During dry seasons, water levels decrease and the flow rate of a river slows down.
      - As the water moves slower, it mixes less with the air, and the DO concentration decreases.

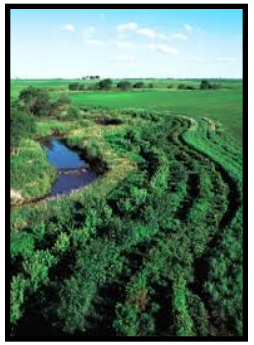
Environmental Factors Influence Dissolved Oxygen

- **Volume & Velocity of water flow**
  - In fast-moving streams, rushing water is aerated by bubbles as it churns over rocks and falls down hundreds of tiny waterfalls.
    - These streams, if unpolluted, are usually saturated with oxygen.
  - In slow, stagnant waters, oxygen only enters the top layer of water
    - Deeper water is often low in DO concentration due to decomposition of organic matter by bacteria
      - Dams slow water down

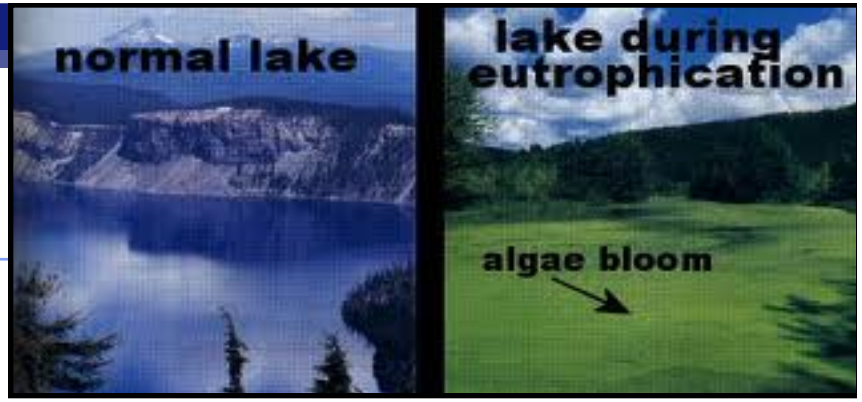
- If water is released from the top of the reservoir, this water can be warmer with slightly more DO.
- If dams release water from the bottom of a reservoir, this water will be cooler, but may be low in DO due to decomposition of organic matter by bacteria.

Environmental Factors Influence Dissolved Oxygen

- **Riparian (water's edge) Vegetation**
  - Shading tends to lower average summer temperature and reduce the daily duration of higher temperature, which increases DO concentrations
    - Removing trees *(e.g., development or overgrazing)* reduces shade on the creek, allowing the sun to warm the water.
      - As water temperature increases, & DO drops.
  - Bare soil exposed from removing the tree can erode, increasing the amount of dissolved and suspended solids in the water.
    - Increased solids decreases DO concentrations.
  - However, direct sunlight, along with increased nutrients can increase the growth rate of aquatic plants.
    - Plants add oxygen to the water during
    - Plants remove oxygen from the water night.



Environmental Factors Influence Dissolved Oxygen



- **Amount of nutrients**
  - Water with high amounts of nutrients (eutrophication) can produce algae in large quantities.
    - When these algae die, bacteria decompose them, and use up oxygen.
      - Leads to fish kills.

However, nutrients can also lead to increased plant growth instead of algae.

- Leads to high DO concentrations during the day as photosynthesis occurs
- Leads to low DO concentrations during the night when plants and animals use the oxygen during respiration.

  - Nitrate and phosphate are nutrients.
    - Nitrate is found in sewage discharge, fertilizer runoff, and leakage from septic systems.
    - Phosphate is found in fertilizer and some detergents.

Environmental Factors Influence Dissolved Oxygen

- **Organic Wastes** *(detritus)*
  - Organic wastes are the remains of any living, including leaves, grass clippings, dead plants or animals, animal droppings, and sewage
    - Organic waste is decomposed by bacteria which use up DO during respiration.
      - Directly downstream from where sewage is discharged to a river, DO content often decreases, because of the increase in growth rate of bacteria that consume this organic matter.
      - Clearing land (e.g., construction, logging) may send excess organic matter into streams too.

Environmental Factors Influence Dissolved Oxygen

- **Groundwater Inflow**
  - The amount of groundwater entering a river or stream can influence oxygen levels.
    - Groundwater usually has low concentrations of DO, but it is also often colder than stream water.
      - Groundwater flowing into a body of water may at first lower the DO concentration, but as groundwater cools the stream or river, the ability of the water to hold oxygen improves.