Stream ecosystems

UCI – Environmental Science 101

What is an ecosystem?

What is an ecosystem?

- The **physical** and **chemical** environment

- The biological **populations** that compose the **community** using that environment

Where does energy for life come from?

Where does energy for life come from?

* Though some life has been discovered that uses chemical energy, rather than solar. These organisms are typically deep in the earth or in hydrothermal vents

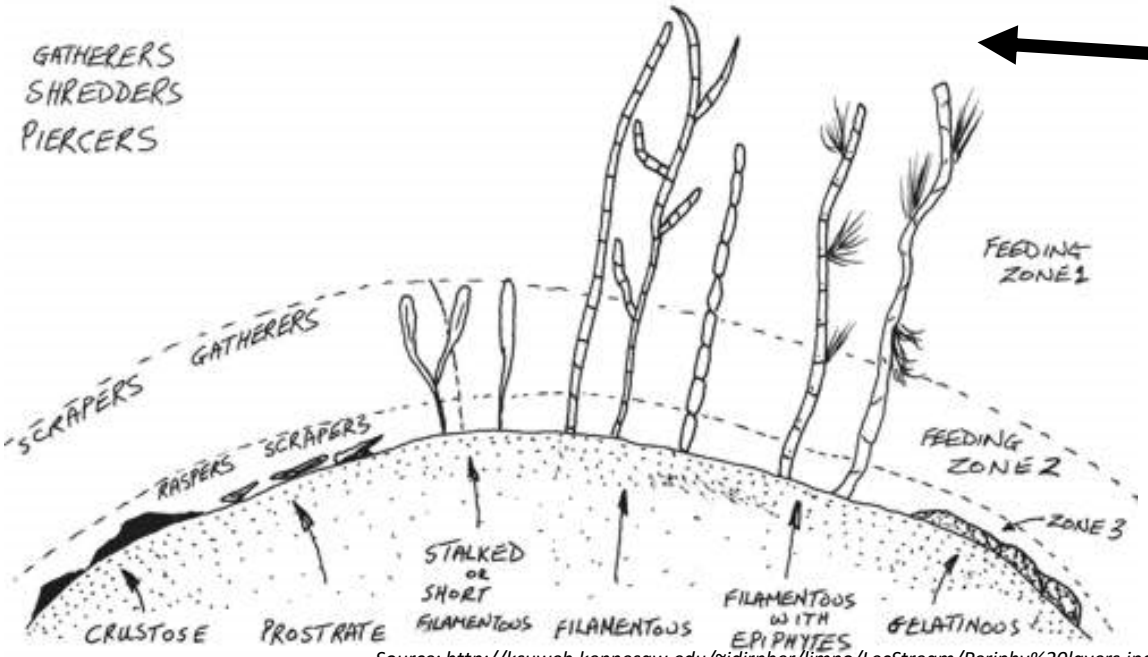
What organisms can use solar energy?

- ***Autotrophs***, otherwise known as **primary producers** (plants, algae, bacteria)
- Use solar radiation, combined with water and CO_2 to generate energy via **photosynthesis**

Organisms that cannot perform photosynthesis (*heterotrophs*) get their energy from *autotrophs*

What types of organisms live in streams?

Primary producers – Benthic algae

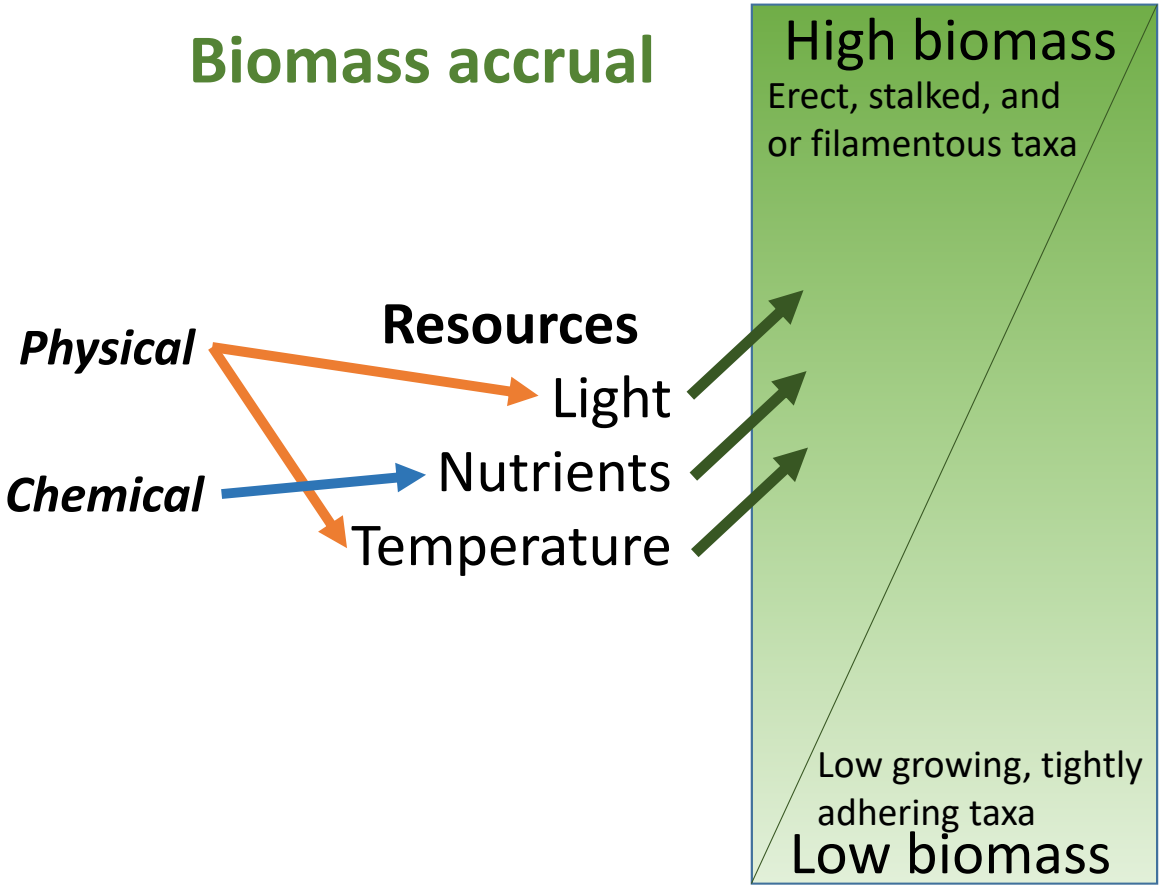


Source: http://ksuweb.kennesaw.edu/~jdirnber/limno/LecStream/Periphy%20layers.jpg

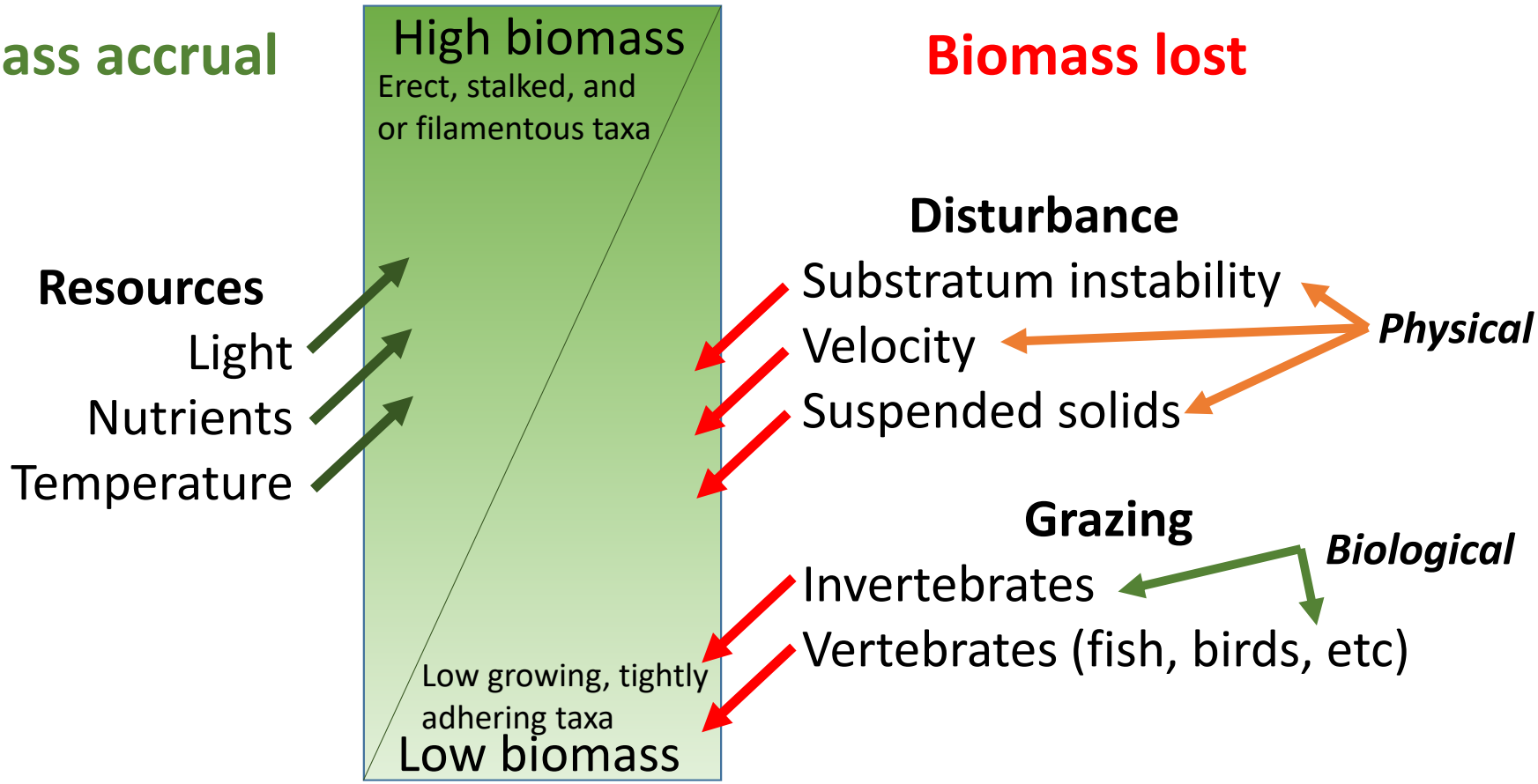
Categorized by:

- Growth form & size
- Attachment site:
  - Epilithon (rocks)
  - Epipelon (sediment)
  - Epyphyton (plants)
- Types
  - Diatom
  - Green algae
  - Cyanobacteria
  - Red algae
  - Crysophytes (“golden” algae)

Primary producers – Benthic algae



Primary producers – Benthic algae



Primary producers – Macrophytes

- Flowering plants
- Mosses
- Liverworts

Typically found in backwaters/slow water zones

Increase habitat heterogeneity (structural variation)

Can slow current and trap sediments and particulate organic matter

Primary producers – Phytoplankton

- Algae suspended in water column
- May be sourced from detached benthic algae
- Can be self sustaining in high residence time areas (can double 1-2x per day)
- Light penetration (self shading, suspended particles)

Source: https://3c1703fe8d.site.internapcdn.net/newman/gfx/news/hires/2015/1-phytoplankto.jpg

Consumers – Heterotrophs

+ bacteria and fungi!

Consumers – Heterotrophs

Consumers – Heterotrophs

https://www.tnaqua.org/our-animals/fish/paddlefish

https://www.youtube.com/watch?v=kL0RkWgnFgo

What happens when organisms die?

Everything dies! – Decomposition

All forms of non-living organic carbon, including:

- Fallen leaves and woody debris
- Waste products and animal carcasses
- Unknown origin organics and organic compounds

Coarse Particulate Organic Matter (CPOM)

> 1mm in size

- Leaves and needles
- Macrophyte die back
- Woody debris (very slowly utilized)
- Plant and animal parts

- Material structure/composition drives breakdown rates
- Typically breakdown is faster at warmer temperatures
- Often driven by invertebrates, microbes

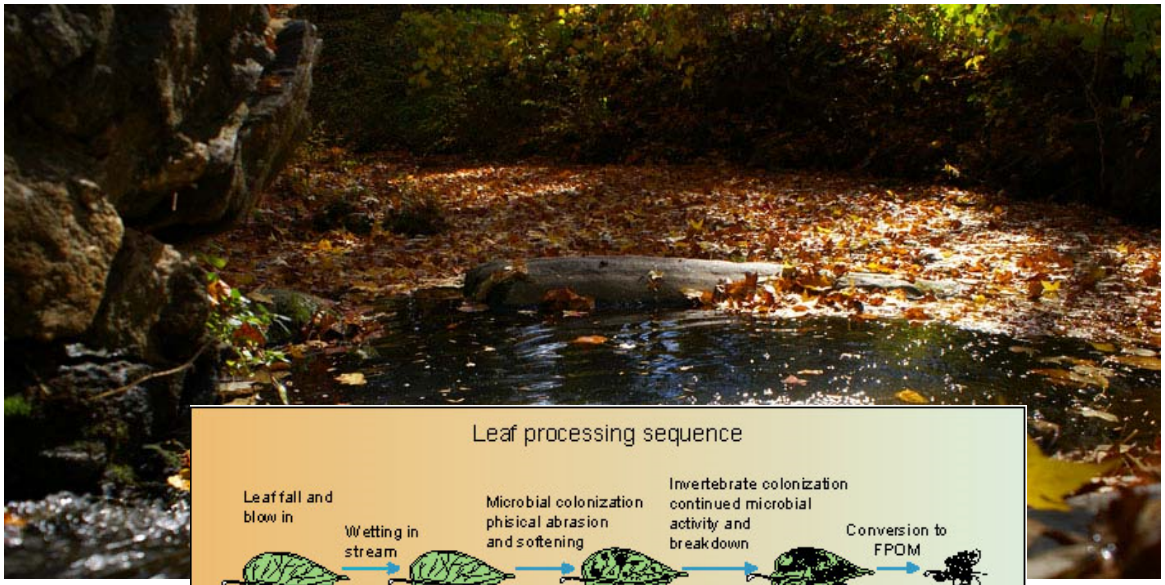


Figure: The processing or 'conditioning' sequence for a deciduous tree leaf in a temperate stream.

Source: http://mekong.riverawarenesskit.org/images/chapter7/Figure%208.2.4.2x.jpg

Fine Particulate Organic Matter (FPOM)

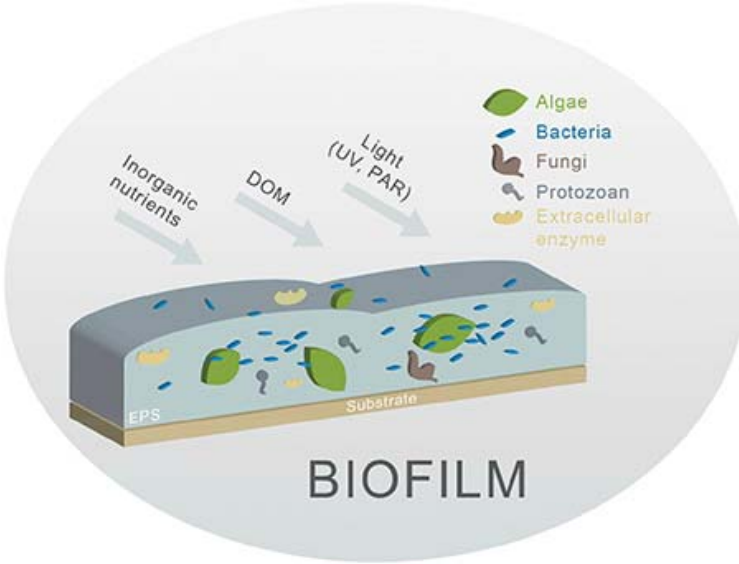
Seston: suspended particles in water

0.5 μm to 1mm

- Breakdown of CPOM
- Feces of small consumers
- Microbial uptake of dissolved organic matter
- Sloughing of algae
- Soil, forest floor litter

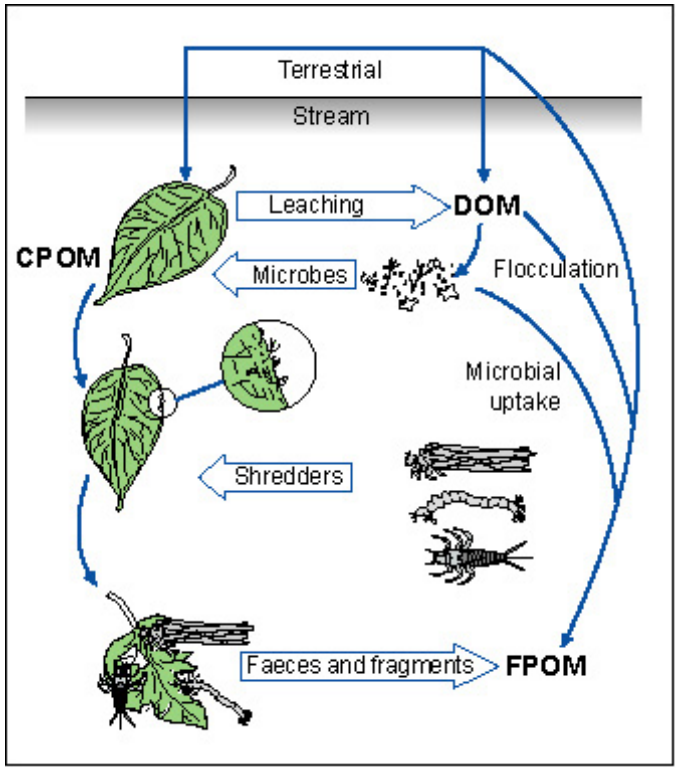
Dissolved Organic Matter (DOM)

- Largest pool of organic carbon in running waters, size <0.45 μm
- Sources:
  - leached from leaves and POM
  - extracellular release from algae and plants
  - soil and groundwater

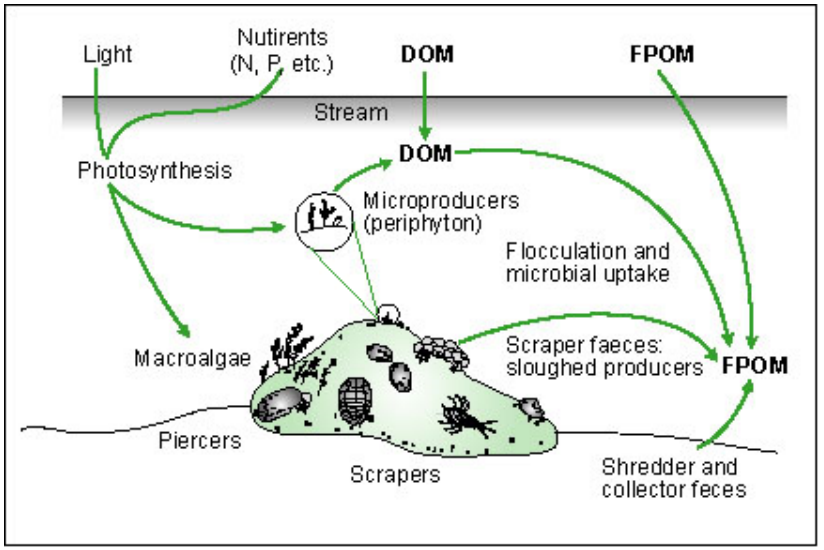


Source: http://www.frontiersin.org/files/Articles/185217/fenvs-04-00014-HTML/image_m/fenvs-04-00014-g002.jpg

Invertebrate feeding roles



Source: http://ksuweb.kennesaw.edu/~jdirnber/limno/LecStream/LecStreamEcologyBioEco.html



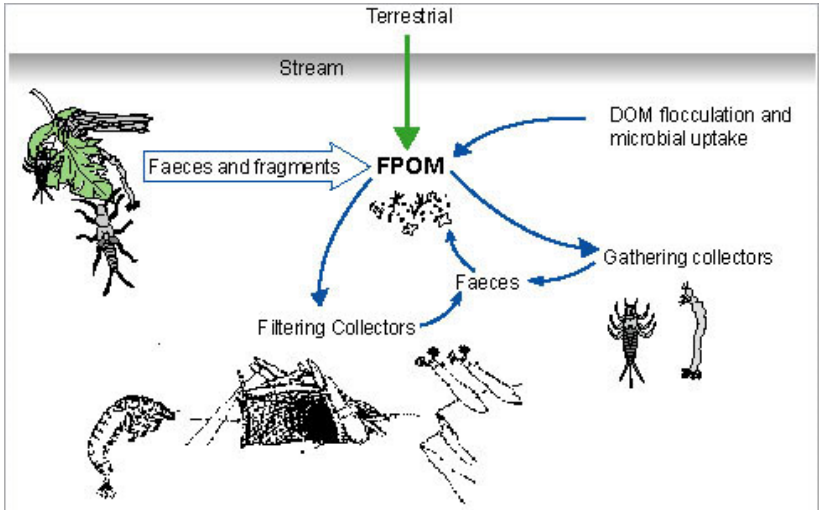


Figure: The collector-FPOM-bacterial linkage modeled for a small stream

What happens to the community if it is disturbed?

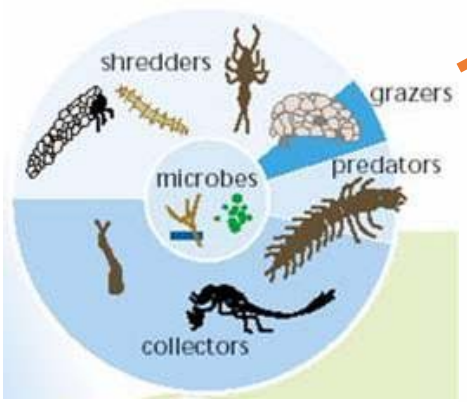
Chemical environment

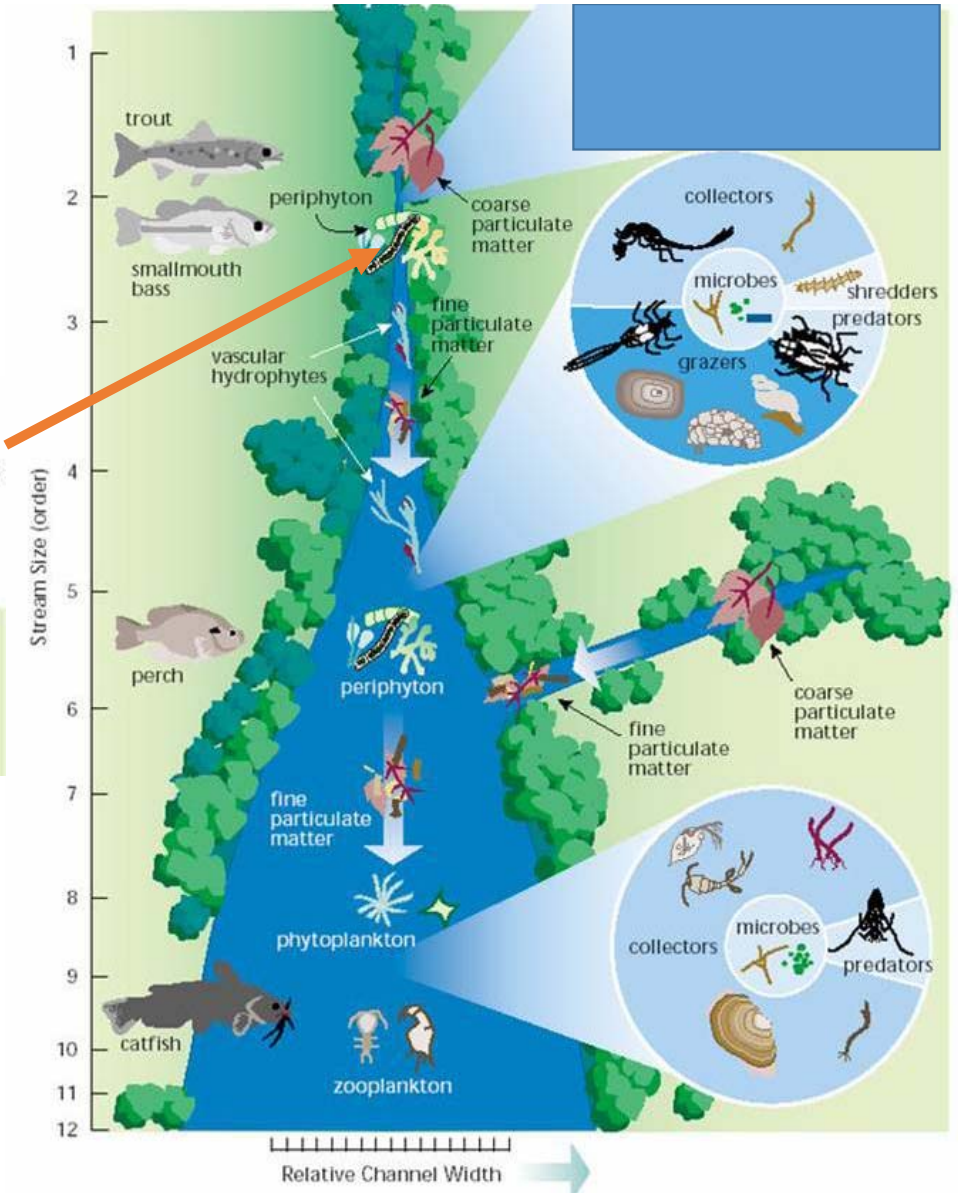
- Pollution (nutrients, other chemicals)

Physical environment

- Changes to river habitat
- Changes to flow patterns

Everything lives down stream: River continuum concept





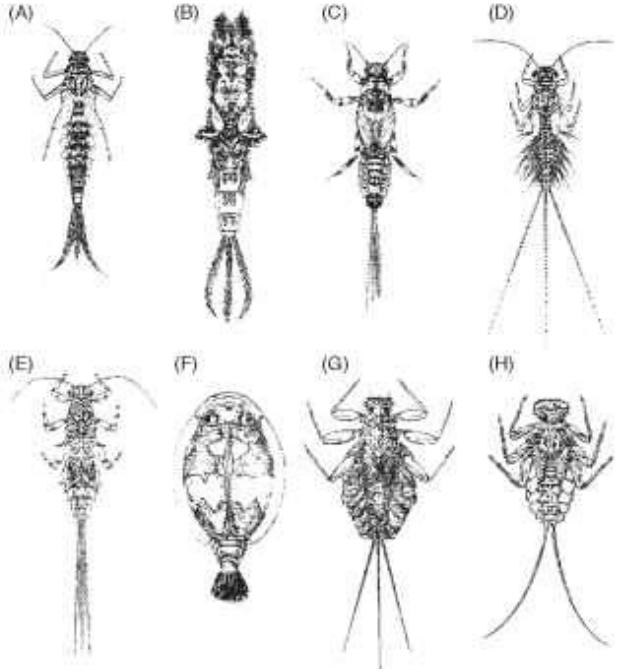
(Vannote et al 1980)

Source: https://limnonews.files.wordpress.com/2017/02/imagem1.jpg

Ephemeroptera (Mayflies)

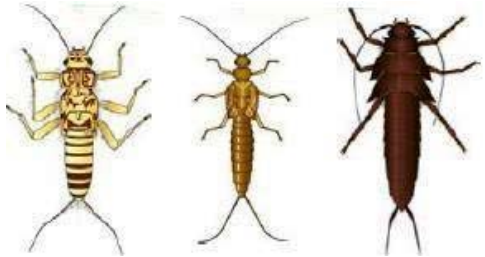
Source: https://projects.ncsu.edu/cals/course/ent425/images/compendium/ephemeroptera/mayfly1b.gif

Source: https://genent.cals.ncsu.edu/wp-content/uploads/2015/07/ephemero01a.jpg



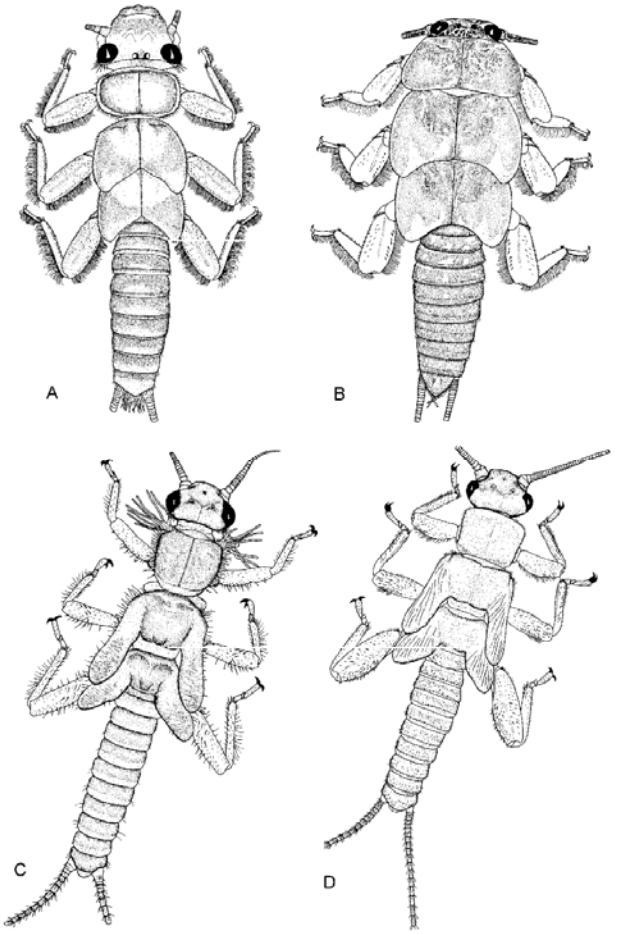
Source: http://lh5.ggpht.com/_X6JnoL0U4BY/S8GLF-34G9I/AAAAAAAAX6Y/HpvfefbfyVA/tmp4A12_thumb_thumb.jpg?imgmax=800

Plecoptera (Stoneflies)



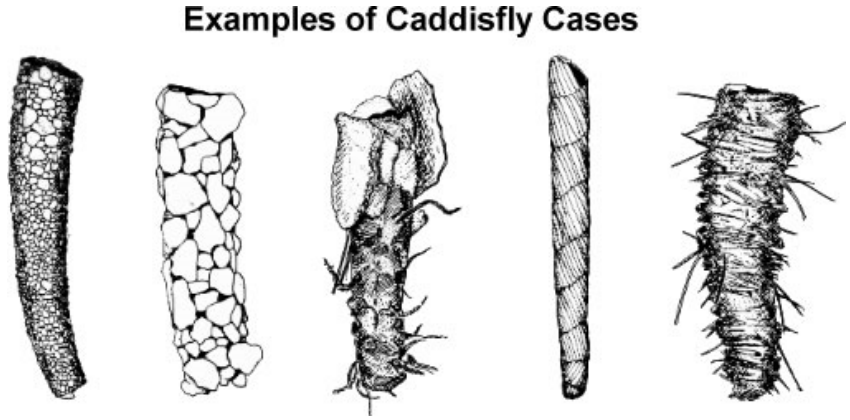
Source: http://www.dep.wv.gov/WWE/getinvolved/sos/PublishingImages/Plecoptera.JPG

Source: http://www.troutnut.com/im_regspec/picture_2418_medium.jpg

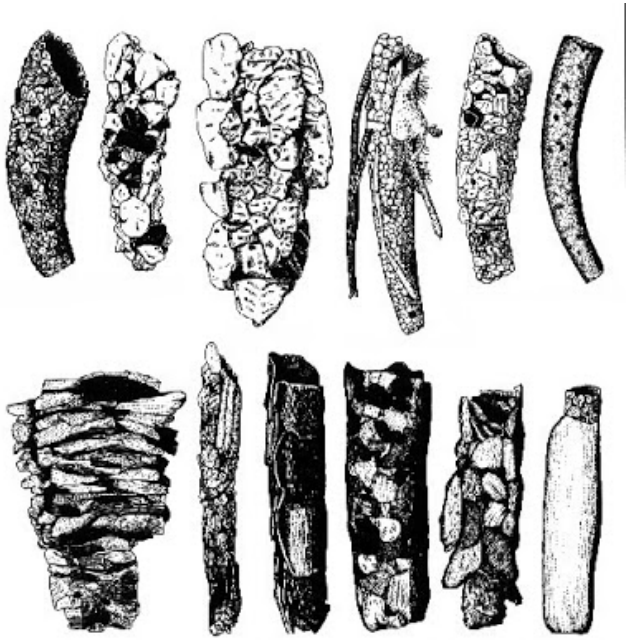


Source: https://www.researchgate.net/profile/Catherine_Yule/publication/233727122/figure/fig4/AS:349575845040135@1460356784841/Figure-5-Nymphs-A-Neoperla-Perlidae-B-Cryptoperla-Peltoperlidae-C.png

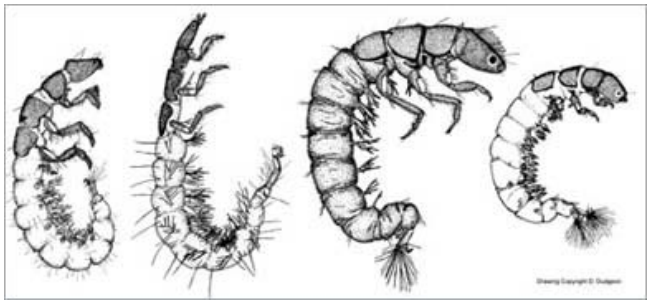
Trichoptera (Caddisflies)



Source: http://genent.cals.ncsu.edu/wp-content/uploads/2015/07/id_trichoptera_cases.jpg



Source: http://2.bp.blogspot.com/_qxT7IHE6lIE/S3yayb1m2MI/AAAAAAAAAUM/5f3OEIyWW0k/s400/Trichoptera.jpg

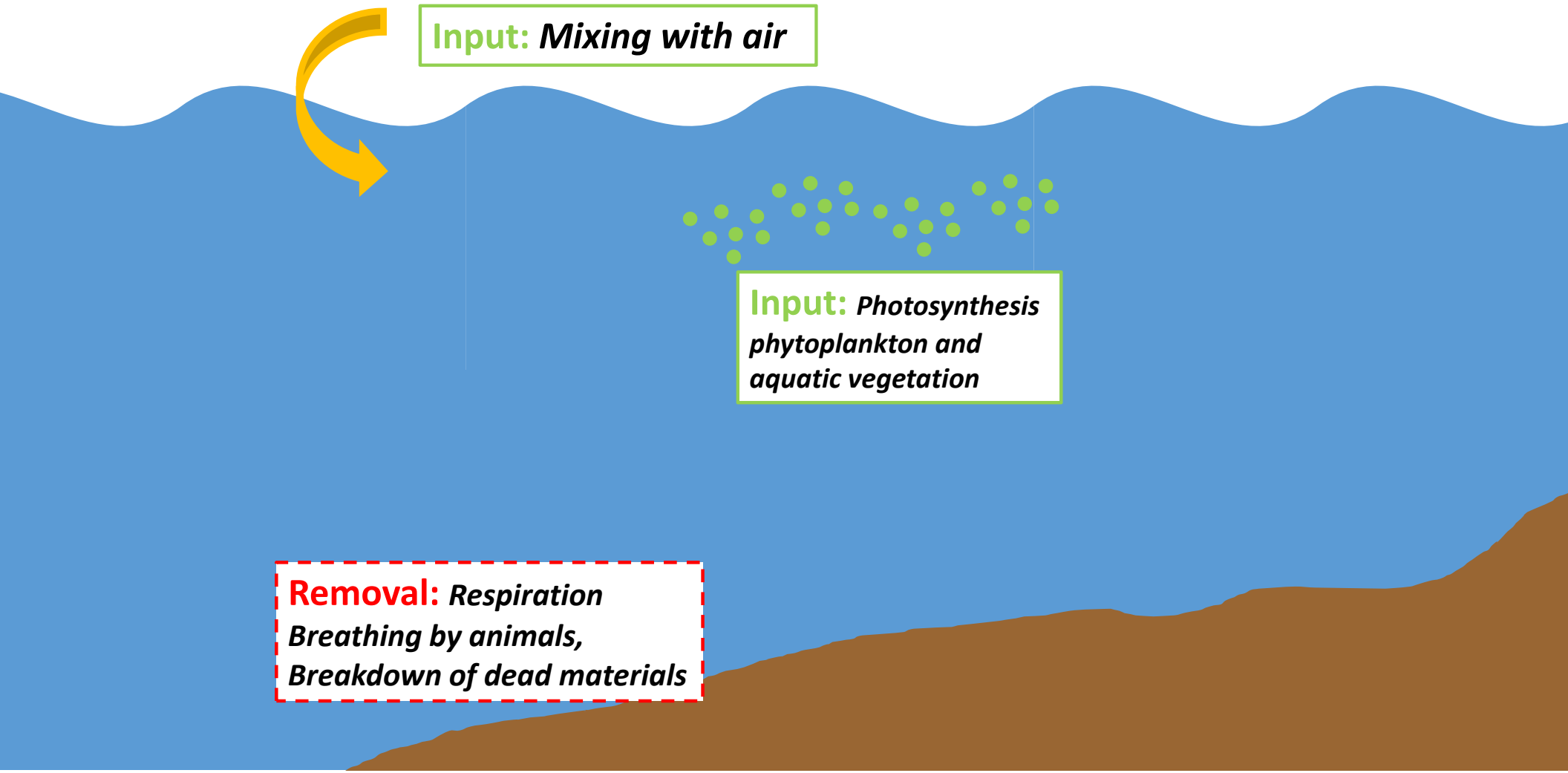


Source: http://mekong.riverawarenesskit.org/images/chpt6/insects/DD7.4.4.5.2.jpg

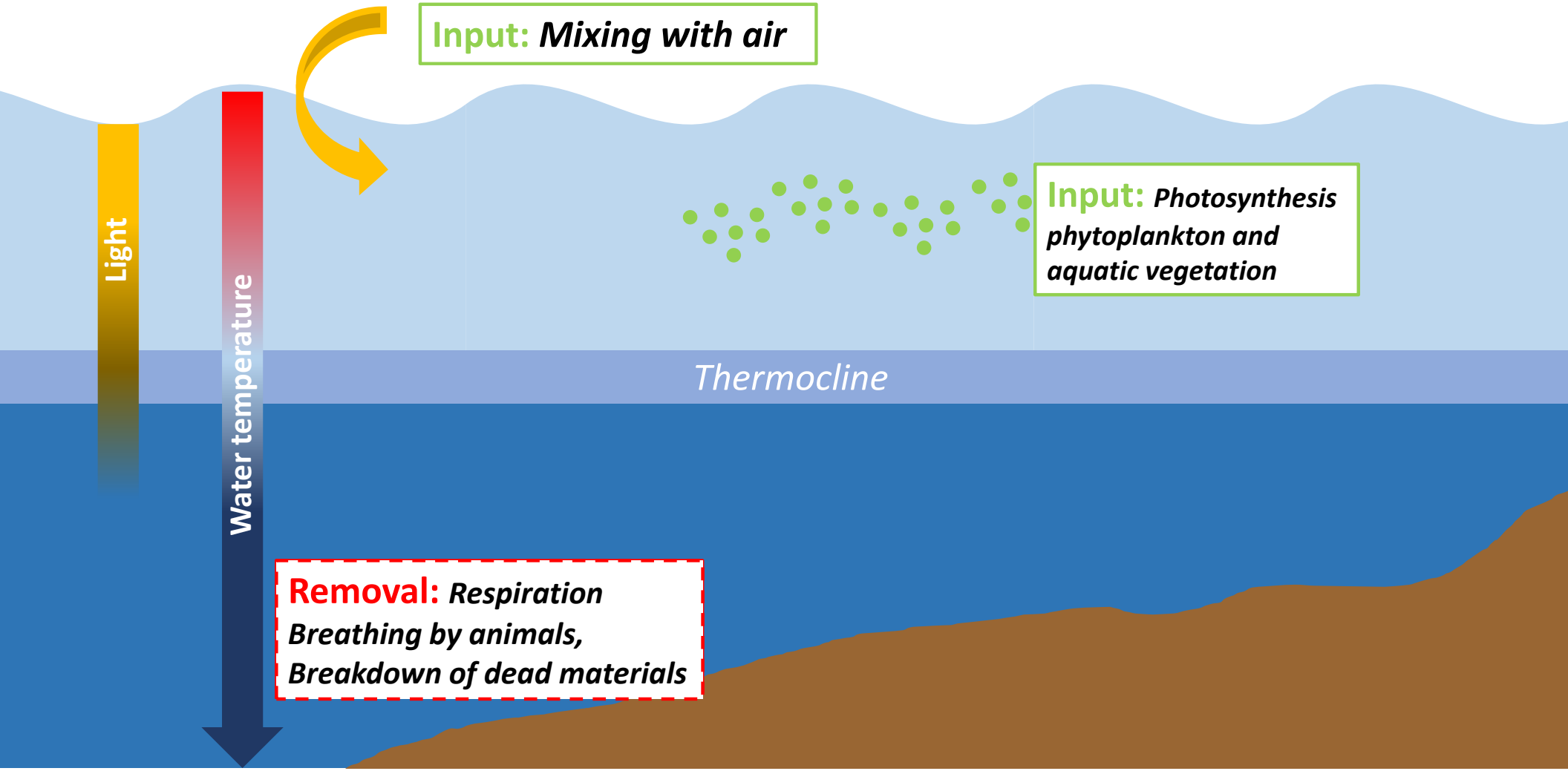
Source: http://www.troutnut.com/im_regspec/picture_3240_medium.jpg

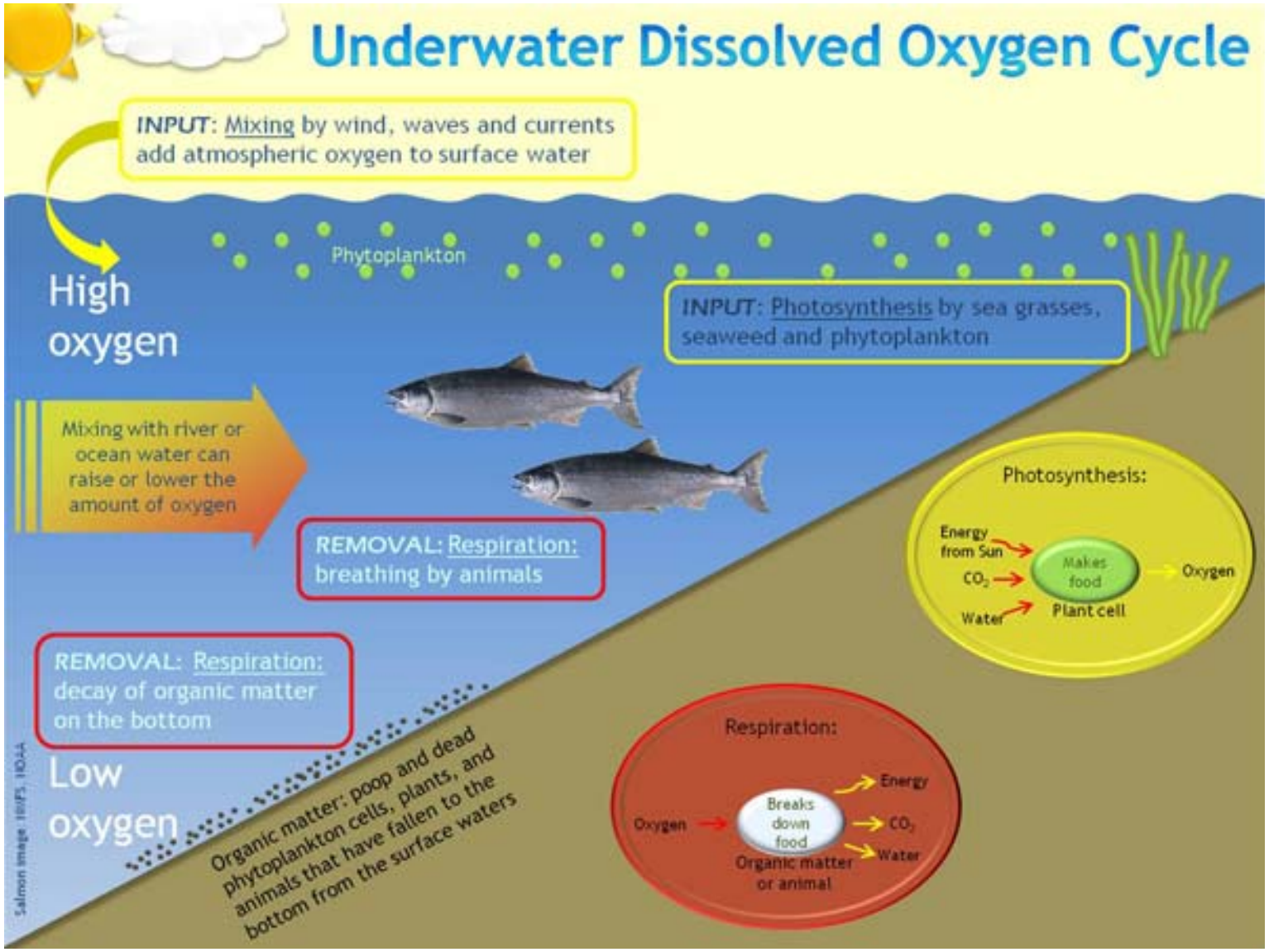
Chemical environment: Water quality

Dissolved oxygen in water



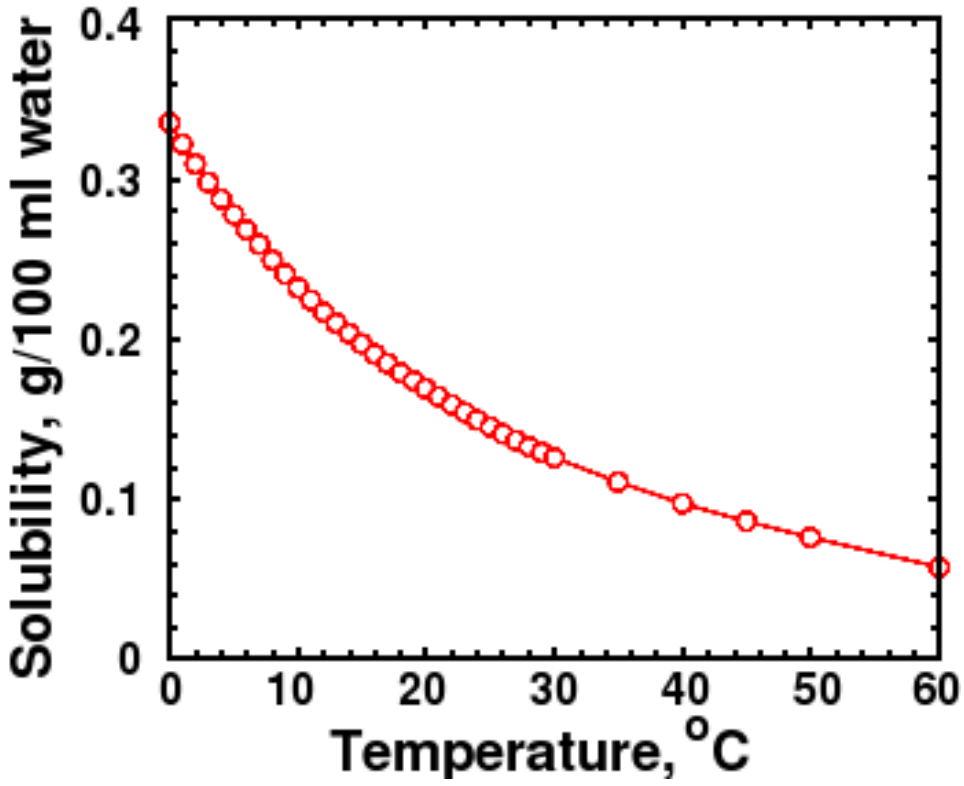
Stratification (layering) of lakes





Source: http://www.globalspec.com/ImageRepository/LearnMore/201310/dissolved_oxygen_cycle33b97f68d64d45018720d4179b349e97.png

Dissolved gasses



- Temperature and partial pressure dictate saturation potential of gasses
- CO_2 and O_2 are driven by reaeration/diffusion and biological processes (production and respiration)

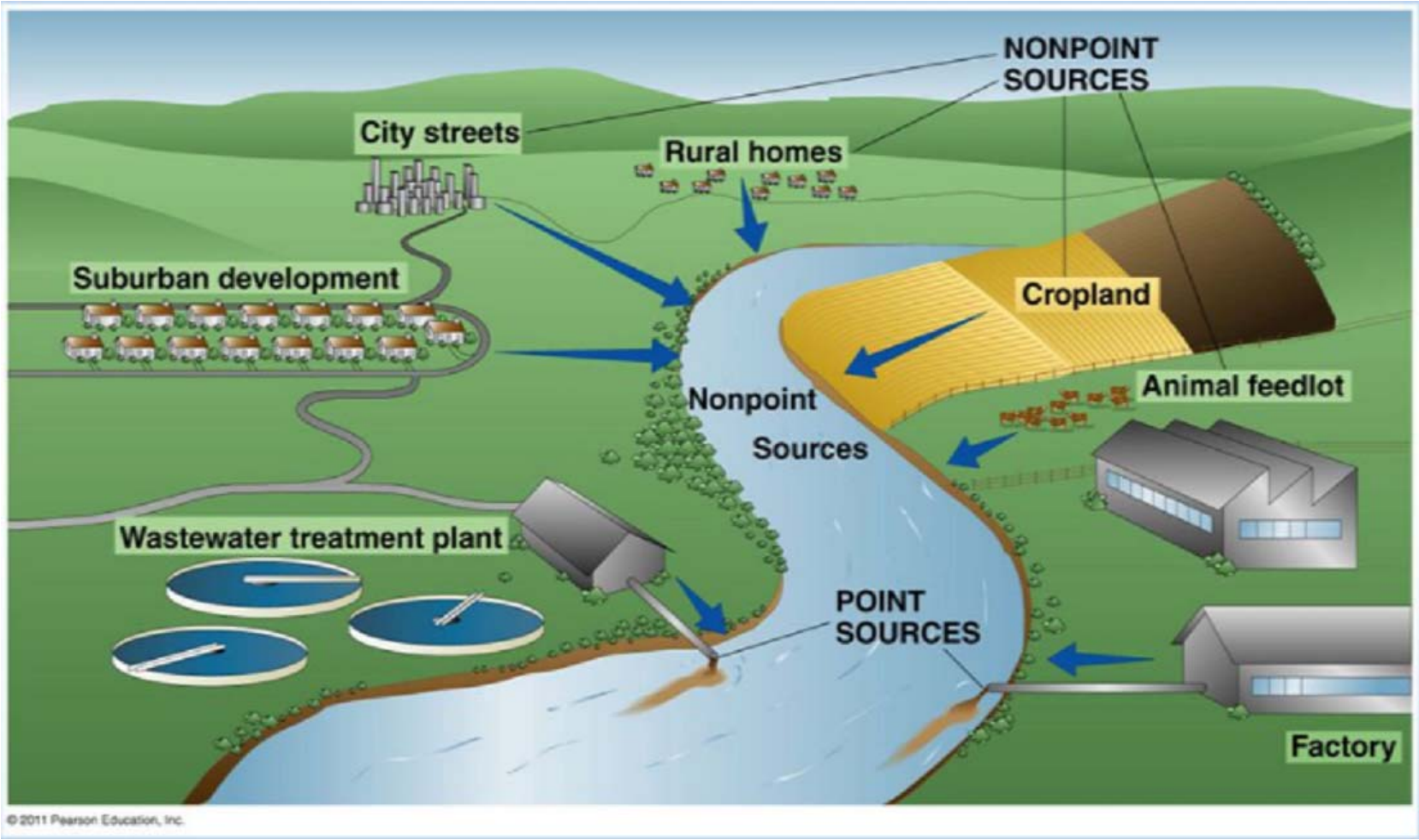
Dissolved chemicals (ions)

- **TDS (total dissolved solids)**: sum of the concentration of dissolved major ions
  - *Cations* -- Na^+ K^+ Ca^{2+} Mg^{2+}, *Anions* -- HCO_3^- CO_3^{2-} SO_4^{2-} Cl^-
- Nitrogen ions, phosphorus, iron are biologically important, but minor contributors to total ions
- Bicarbonate (HCO_3^-), Sulfate (SO_4^{2-}), Chloride (Cl^-) are associated with weathering of sedimentary rocks, and typically make up the majority of TDS in river systems
- **Conductivity:** electrical conductance of water

Dissolved constituents (ions)

- **Calcium** (most abundant cation in rivers): rock weathering
  in combination with magnesium, dictates “hardness” – formation of insoluble compounds
- **Sodium** (generally with chloride): mostly rock weathering but also rain in regions near oceans; human impacts (road salt, sewage, fertilizer)
- **Bicarbonate**: weathering of minerals, decomposition of organic matter
- **Sulfate** from weathering, pollution (fertilizers, mining, fossil fuels), volcanic activity
- **Hydrogen** ions = **pH**

Sources


NONPOINT
SOURCES
City streets
Rural homes
Suburban development
Cropland
Animal feedlot
Nonpoint
Sources
Wastewater treatment plant
POINT
SOURCES
Factory
© 2011 Pearson Education, Inc.

Dissolved load

Load = concentration of constituent x discharge

US Clean Water Act for impaired waters defines as the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards

Dissolved load

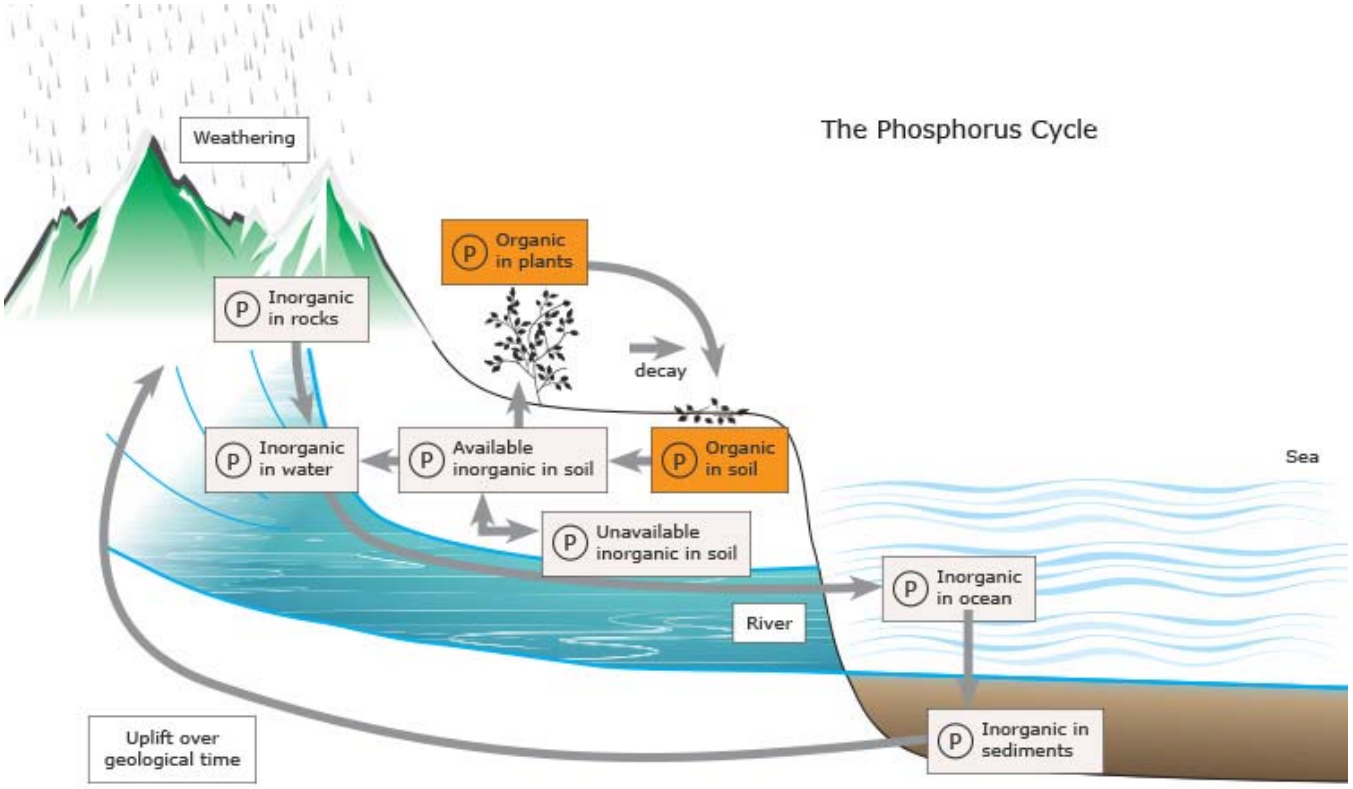
Load = concentration of constituent x discharge

Total **M**aximum **D**aily **L**oad = TMDL

TMDL = ΣWLA + ΣLA + MOS

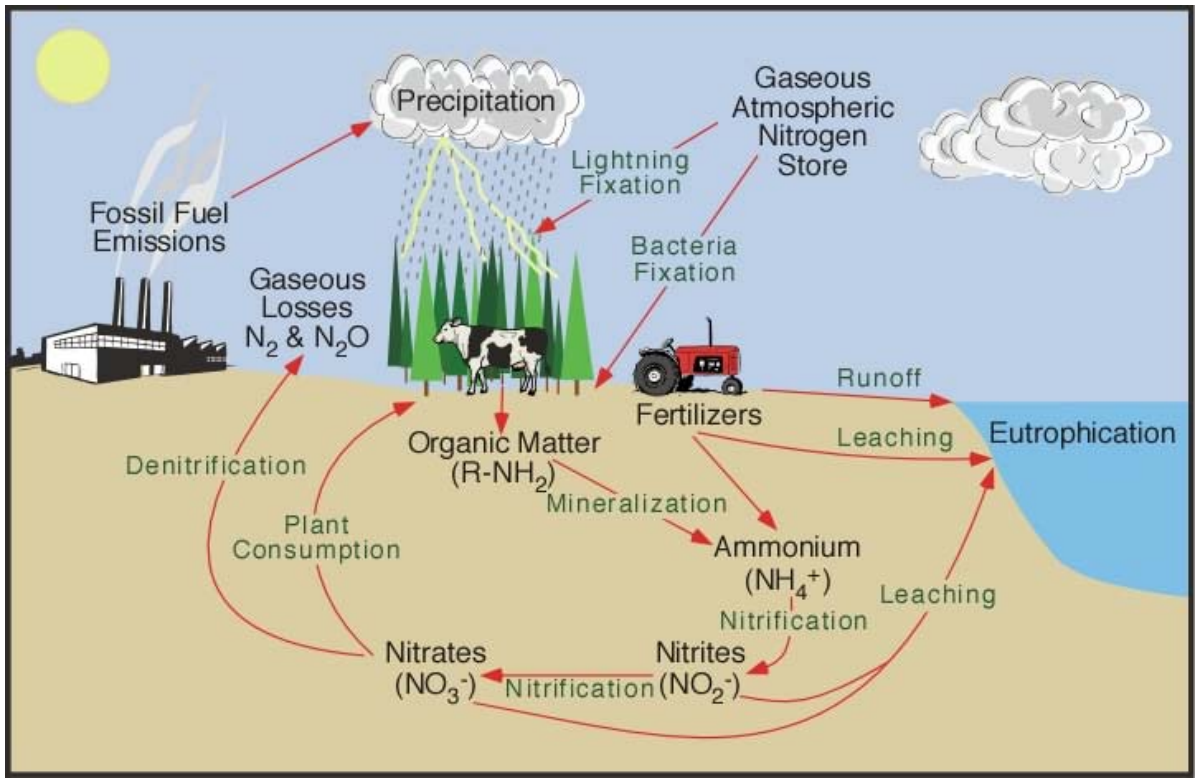
WLA = wasteload allocations (point sources)
LA = load allocations (nonpoint sources and background)
MOS = margin of safety

Phosphorus cycle

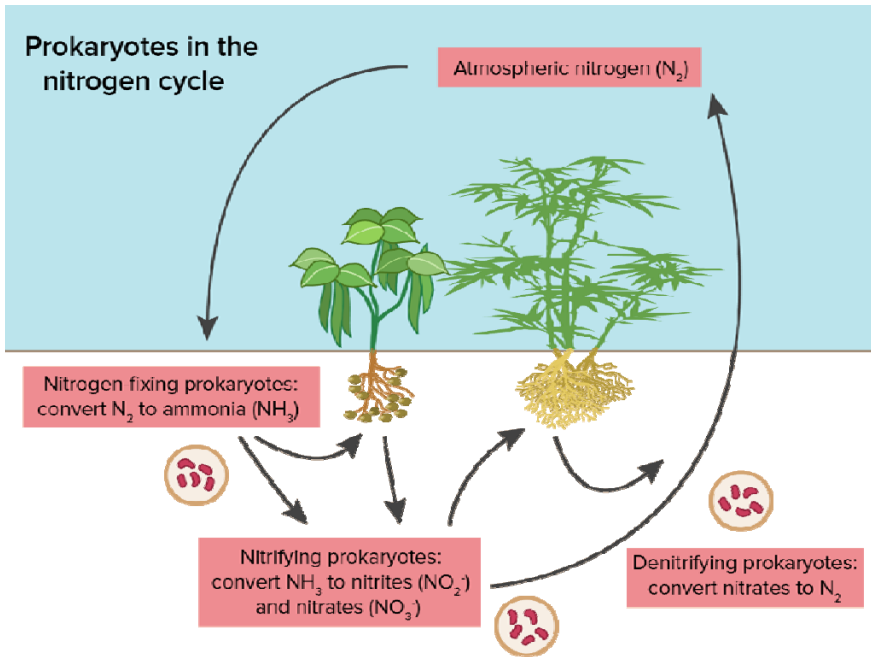


- Essential nutrient, component of many key molecules, including ATP
- Not very abundant in biosphere
- Often in recalcitrant forms in soil

Nitrogen cycle

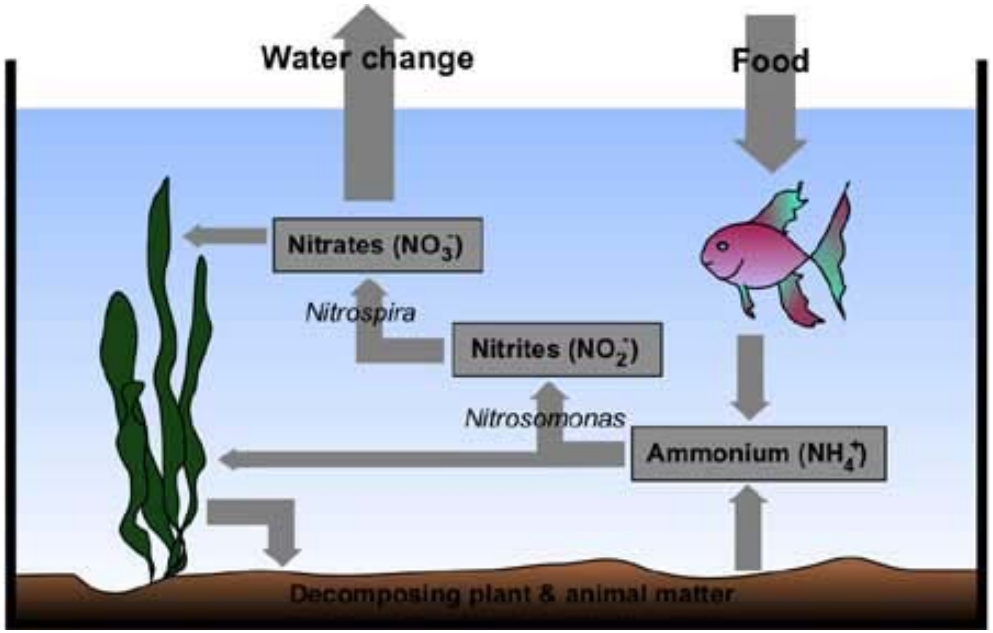


Source: http://www.physicalgeography.net/fundamentals/images/nitrogencycle.jpg



Source: https://fastly.kastatic.org/ka-perseus-images/3ad78bcb8eab01a28553180d78ea0cb640c7ddc0.png

Nitrogen cycle



Source: https://www.fishlore.com/NitrogenCycle.htm

Consequences of nutrient enrichment

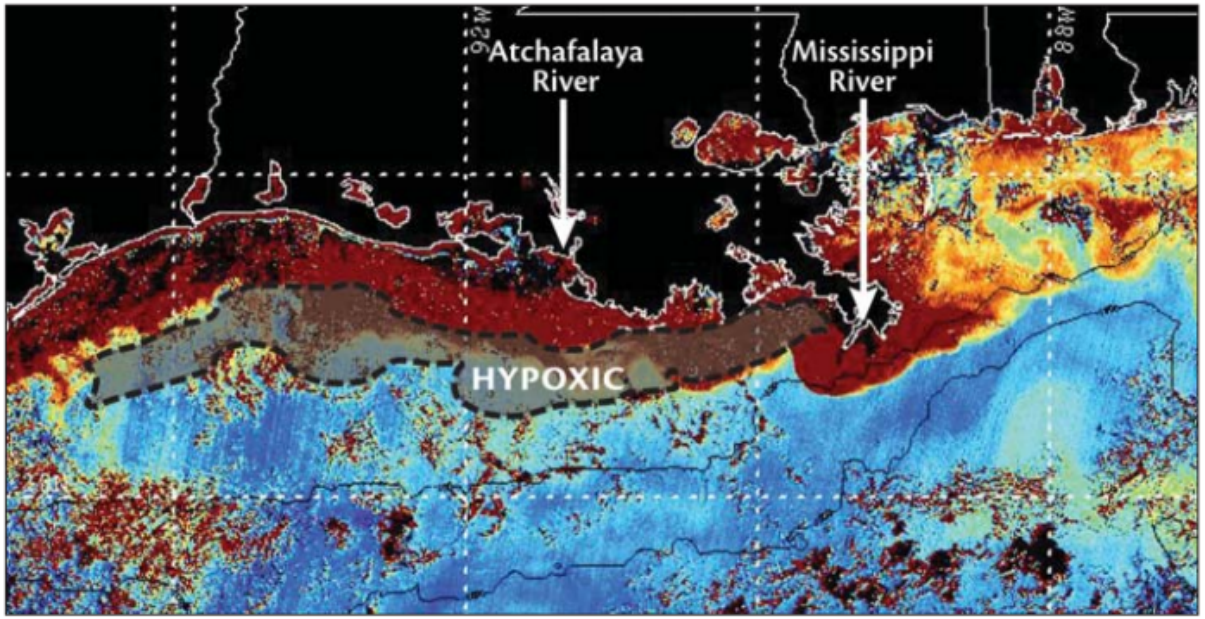


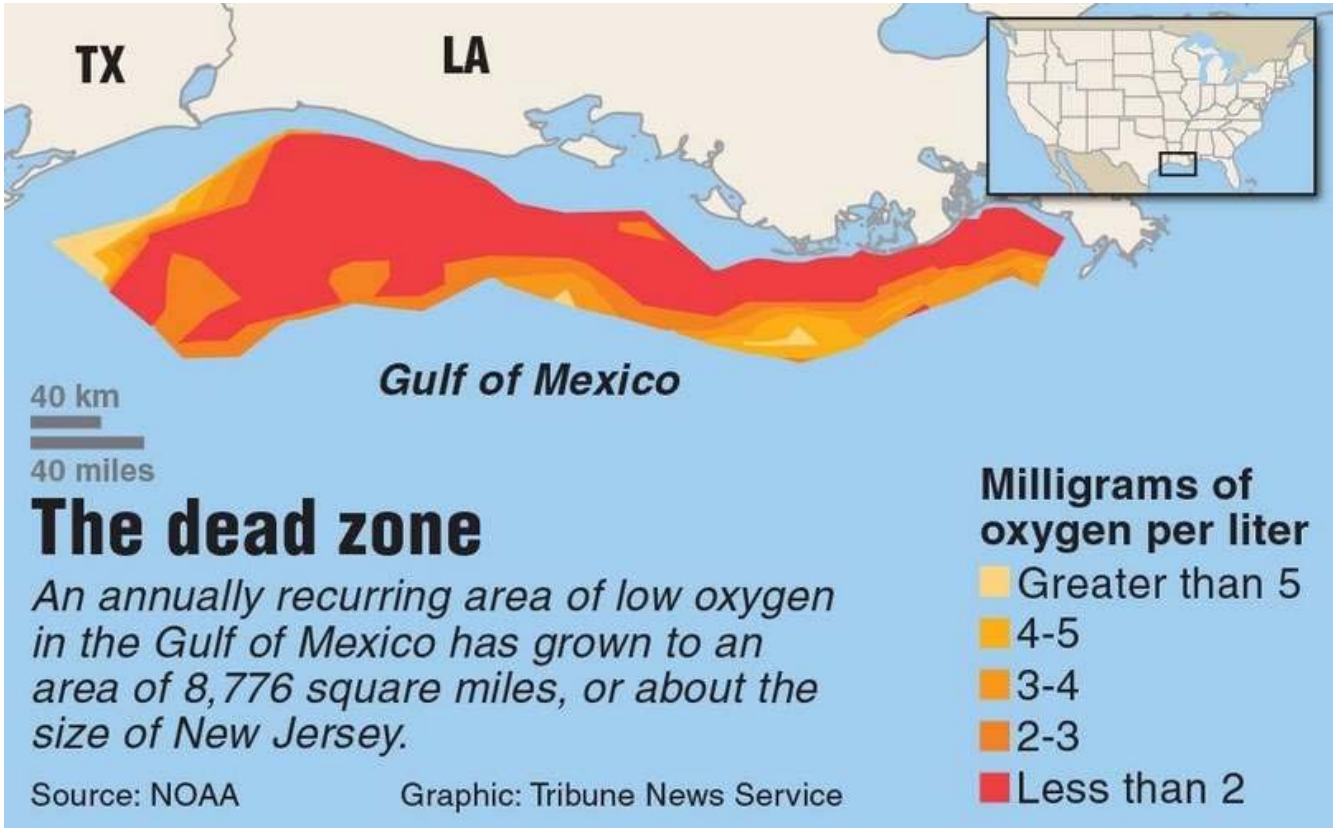
Fig. 1. High chlorophyll a concentrations along the inner shelf off Louisiana and Texas (orange and red) on 11 June 2008 (Indian Space Research Organization Oceansat 1 Ocean Color Monitor image provided by the Louisiana State University (LSU) Earth Scan Laboratory; http://www.esl.lsu.edu/imagery/ocm/) in relation to an overlay of the bottom hypoxia (<2 milligrams per liter, gray area outlined by dashes) during 21–27 July 2008. In June, chlorophyll a concentrations ranged from 22 micrograms per liter (inshore) to 7 micrograms per liter (offshore) (N. N. Rabalais, unpublished data, 2008).

Source: Boesch et al 2009

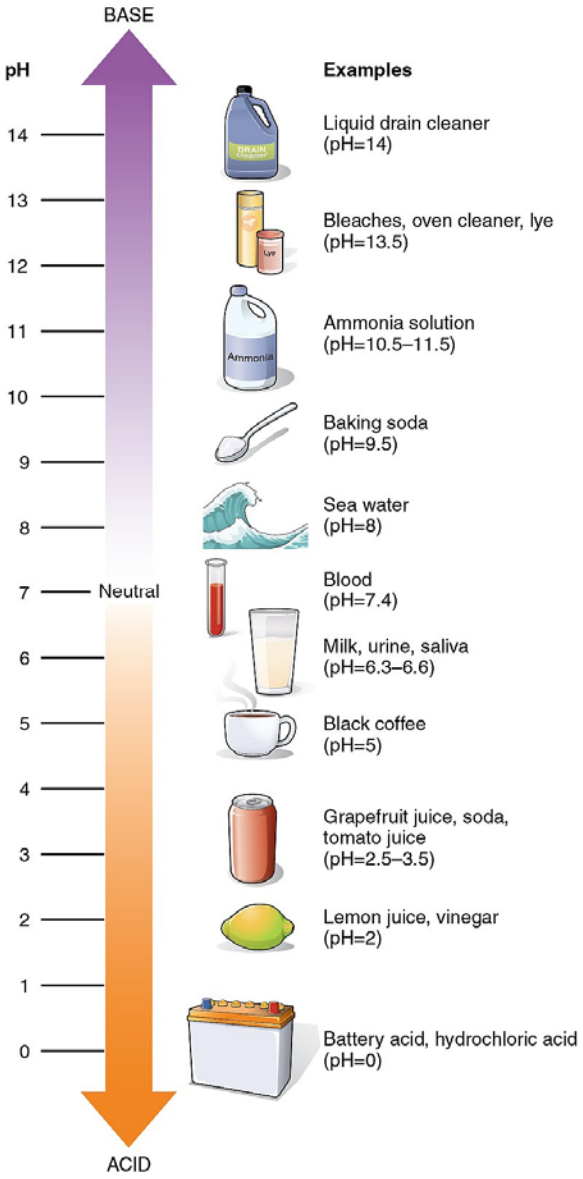
Dead zones

- https://www.facebook.com/worldeconomicforum/videos/10155320138876479/

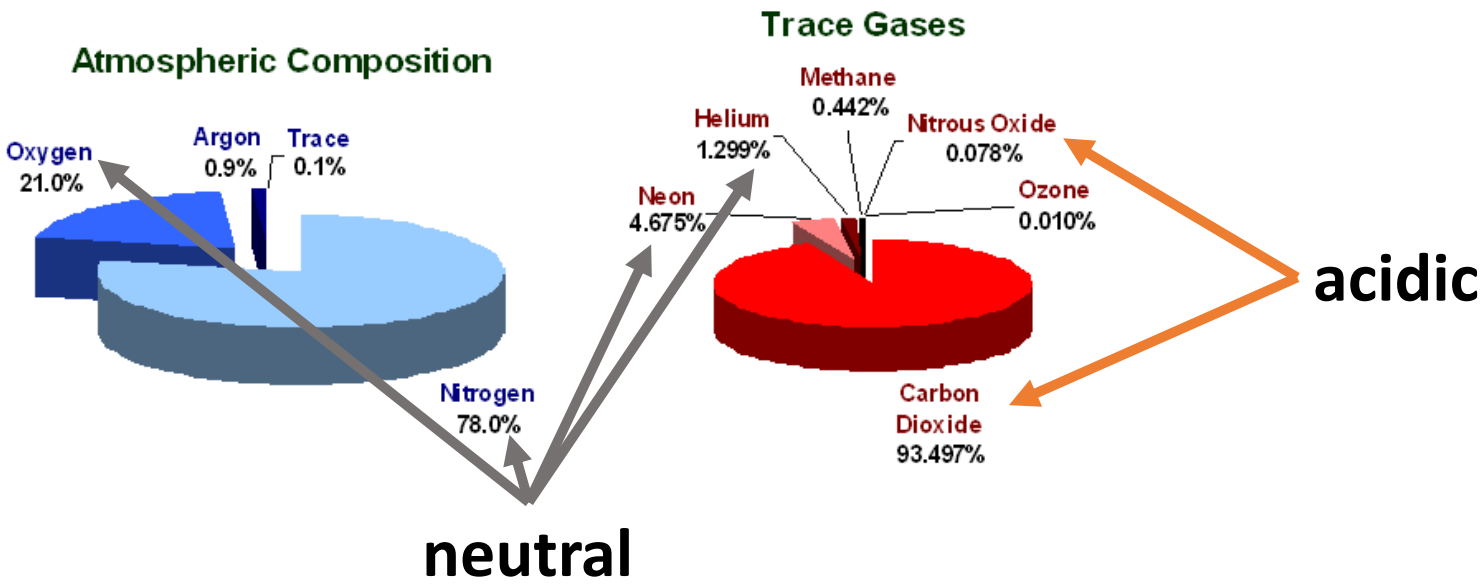
Consequences of nutrient enrichment



pH


BASE
pH
Examples
14
13
12
11
10
9
8
7
Neutral
6
5
4
3
2
1
0
ACID
Liquid drain cleaner
(pH=14)
Bleaches, oven cleaner, lye
(pH=13.5)
Ammonia solution
(pH=10.5–11.5)
Baking soda
(pH=9.5)
Sea water
(pH=8)
Blood
(pH=7.4)
Milk, urine, saliva
(pH=6.3–6.6)
Black coffee
(pH=5)
Grapefruit juice, soda,
tomato juice
(pH=2.5–3.5)
Lemon juice, vinegar
(pH=2)
Battery acid, hydrochloric acid
(pH=0)

Atmosphere composition



Is rain pure water?

Is rain acidic or basic?

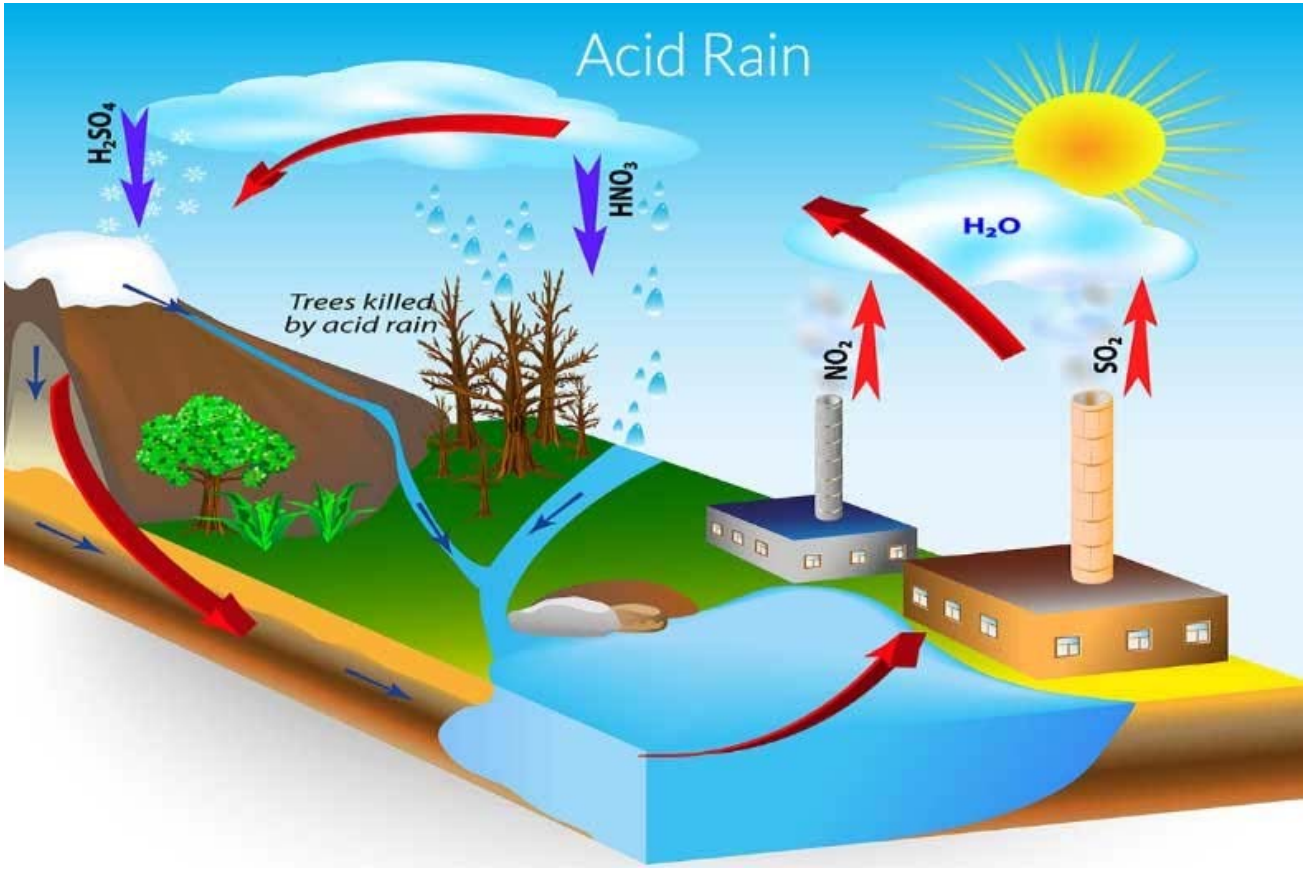
Are streams acidic or basic?

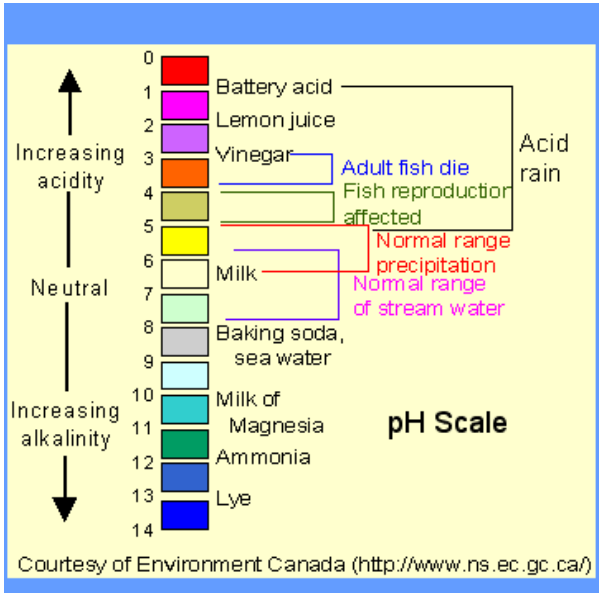
pH in the environment

- Rain is usually acidic (about pH 5.7) due to CO_2 content and naturally occurring sulfate
- Rain becomes neutralized in contact with the soil, up to the buffering capacity of the geology
- Anthropogenic acid precipitation (H_2SO_4, HNO_3) form in the atmosphere as a product of burning fossil fuels

- Alkalinity is the capacity of solutes to neutralize acid

Acid Rain


Acid Rain
H_2SO_4
HNO_3
H_2O
Trees killed by acid rain
NO_2
SO_2


Increasing acidity
Neutral
Increasing alkalinity
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Battery acid
Lemon juice
Vinegar
Milk
Baking soda, sea water
Milk of Magnesia
Ammonia
Lye
Adult fish die
Fish reproduction affected
Acid rain
Normal range precipitation
Normal range of stream water
pH Scale
Courtesy of Environment Canada (http://www.ns.ec.gc.ca/)

Salinization of freshwaters

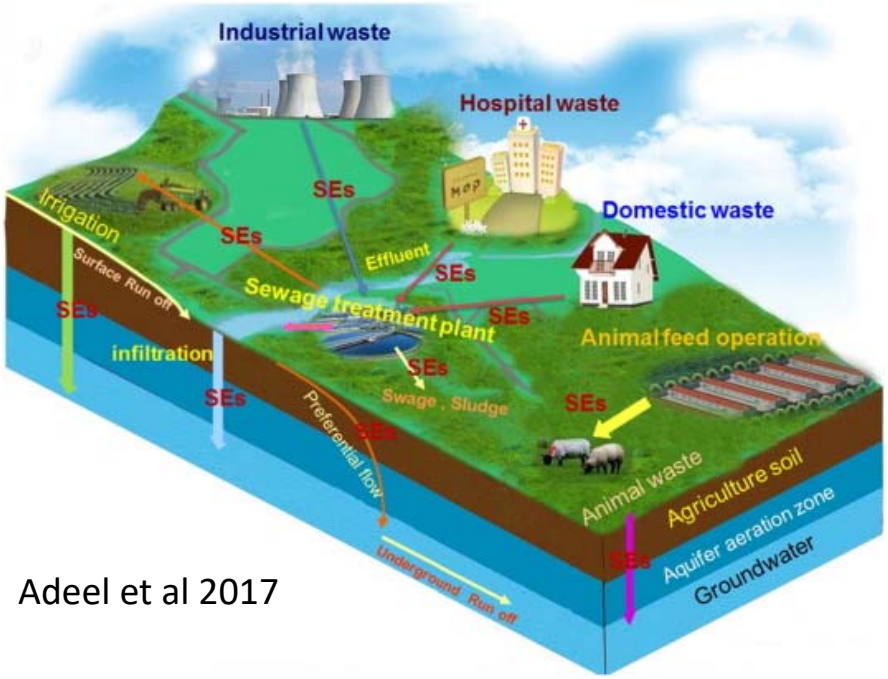
- Common in arid and semi-arid areas
- Results from irrigation concentrating salts through evaporation and the more concentrated solution leaching salt from the soil
- Road salt application
- Extraction of groundwater adjacent to salt water
- Diversion of water from estuaries

Pollution in the news

Water pollution

- Arsenic and fluoride
  - naturally occurring
  - Mine runoff, mine waste
- Pathogens (bacteria, viruses, helminths)
  - Typically from feces
- Nitrate
  - Agriculture, biological waste
- Organic compounds (VOCs, aromatic hydrocarbons, chlorinated solvents)
  - Industrial waste, pesticides, spills
- Metals
  - Depend on pH/oxidation status of water
  - Naturally occurring, industrial activities, waste disposal
- Pharmaceuticals

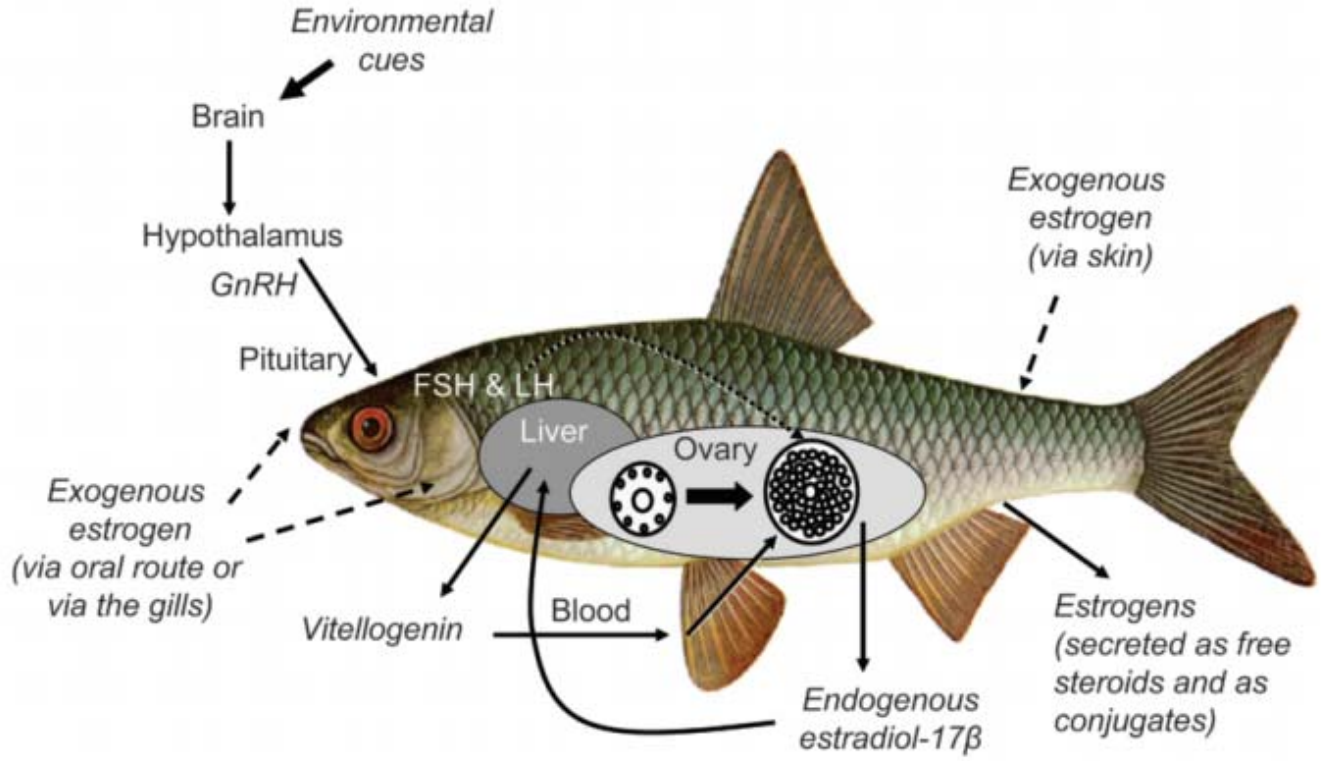
Pharmaceuticals: estrogens



Adeel et al 2017

- Estrogen is the primary female sex hormone
- Some synthetic chemicals have similar structure to estrogen

Pharmaceuticals: estrogens



Source: Tyler and Jobling 2008

- Roach downstream of a wastewater treatment lagoon were intersex
- Gonads contain both testicular and ovarian tissue
- Vitellogenin found in males (a precursor to yolk in eggs), typically only found in females under stimulation of estrogen

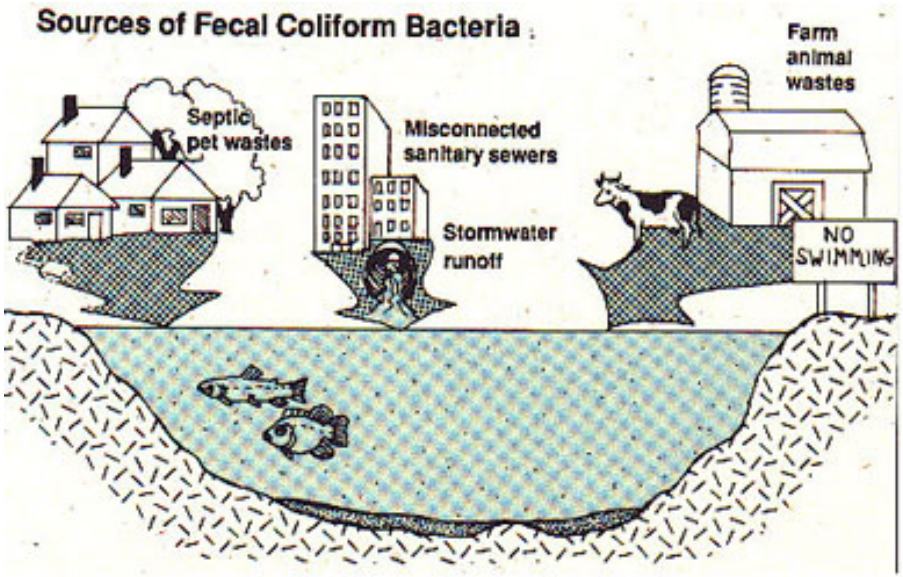
Plastics in the environment

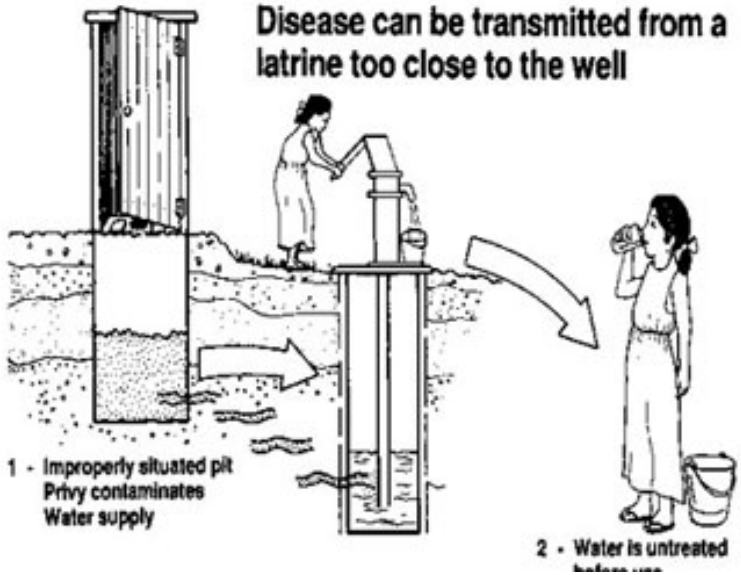
This rainbow runner had consumed 17 plastic fragments. Marine plastic pollution plays an unknown role in human exposures to toxic chemicals.

Microplastics

- Primary (manufactured small) vs secondary (resulting from fragmentation)
- Ubiquitous in the marine environment
- Bioavailable due to small size
- Can adsorb waterborne contaminants e.g., aqueous metals, hydrophobic compounds
- Can leach toxic additives (photo-oxidation) e.g., endocrine disruptors
- “biodegradable” plastics often contain synthetic polymers in addition starch/oils

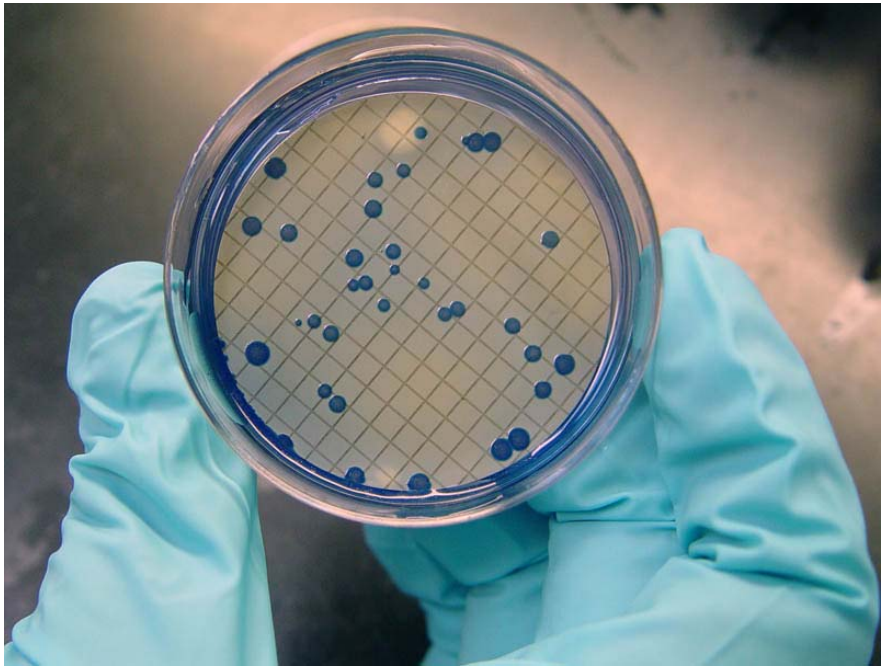
Poop in the water? Fecal coliform





Fecal coliform

- Facultative anaerobic, rod-shaped, gram-negative, non-sporulating bacterium
- Coliform bacteria include genera that originate in feces (E. coli) as well as non fecal genera
- Assay does not distinguish, is an indicator of fecal contamination, but doesn't necessarily indicate presence of feces
- Assay incubates a filtered water sample with lactose for 48hrs at 44C, on agar with a reactive die, colonies are counted



Source: http://hoopmanscience.pbworks.com/f/1320862561/2005-06-20-coliforms.jpg