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AQUATIC SYSTEMS and ENVIRONMENTAL HEALTH

Water Biology
PHC 6937

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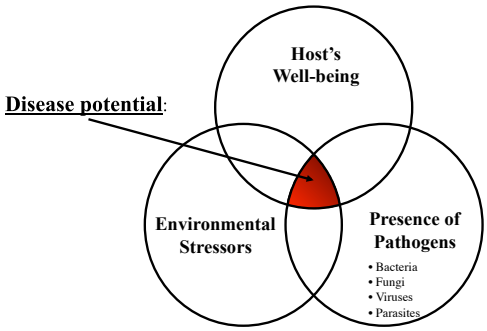
Water Quality and Aquatic Habitats

Components that describes habitat suitability from a biotic standpoint:

Salinity (freshwater vs. brackish vs. saltwater)
Salinity tolerance (stenohaline vs. euryhaline)
Water flow (lotic vs. lentic)
Substrate type
Benthic vs. pelagic species
Warm vs. cool vs. cold water species
Temperature tolerance (stenothermic vs. homeothermic)
Other factors affecting water quality/habitat adequacy

Water quality as a biotic stressor



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Some Water Facts

- One-half of one percent of the world's water is available for all humans to use: 97% of the water on earth is salty (ocean water), 2% is locked (frozen) in the polar ice caps, 0.6% is in fresh surface waters; <1/2% is in the atmosphere.
- The United States has about 8% of the world's renewable freshwater supply.
- The Great Lakes constitute one of the largest systems of freshwater reservoirs on earth, with 18% of the world's fresh surface water.
- Florida has more than 7,700 freshwater lakes and more than 8,000 miles of shoreline.
- Among all the states east of the Mississippi River, Florida ranks first in terms of amount of water consumed in agricultural irrigation.
- In developing countries, 80% of illnesses are water-related.
- A 1993 outbreak of cryptosporidiosis in Milwaukee, Wisconsin, is the largest outbreak of waterborne disease in the United States. Over 400,000 persons were affected by the disease, more than 4,000 were hospitalized, and over 50 deaths have been attributed to the disease.
- An adult's body contains about 40 quarts of water (10 gallons).
- A woman's body is 50-60% water, a man's body is 60-65% water. (Fat tissues contain virtually no water)
- About 83% of our blood is water. It helps digest our food, take in oxygen, transport body wastes, and control body temperature.
- The human body loses between 2 and 3 quarts of water everyday from perspiration and normal elimination.

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Some Water Facts

- Typically less than 1% of all water treated for drinking is actually consumed by people. 99% of all water treated for drinking is used for showers, lawn sprinkling, to flush toilets, etc.
- A full grown tree emits 70 gallons of water into the atmosphere every day.
- Many homes lose more water from leaky taps than they need for cooking and drinking.
- A faucet that leaks one drop per second will waste 3,000 gallons of water in one year.
- Estimates vary, but each person uses about 80-100 gallons of water per day at home.
- In the U.S. in 1995 about 44,400 wastewater treatment plants sent about 44,600 million gallons per day of treated water back into the environment. About 983 million gallons per day was used again (reclaimed) after treatment, mainly as irrigation water.
- Toilet flush volumes: Pre-1994 3.5-5.0 gallons of water per flush. Modern toilets are 1.6 gallons per flush.
- Florida law limits shower fixtures installed in new construction to 3 gallons of water per minute. Many existing fixtures use 4.7 gallons per minute

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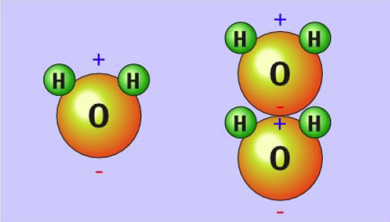
States of water

Evaporation=vaporization, condensation, transpiration, sublimation, deposition

Polarity of water



The atomic structure of a water molecule consists of two hydrogen atoms joined to one oxygen atom. The unique way in which they are joined causes one side of the molecule to have a negative charge, and the other side to have a positive charge. The resulting polarity causes water molecules to be attracted to each other, forming strong covalent bonds.

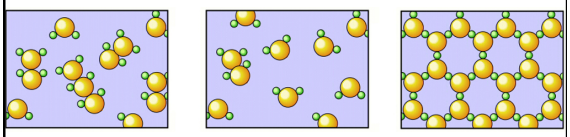
Water is highly polar: "Universal Solvent"

In general, ionic and polar substances such as acids, alcohols, and salts are relatively soluble in water, and non-polar substances such as fats and oils are not.

Water is highly polar: "Universal Solvent" (NOT)

Non-polar solutes are driven together in water, not primarily because they have a high affinity for each other, but because water bonds strongly to itself.

Polarity of water

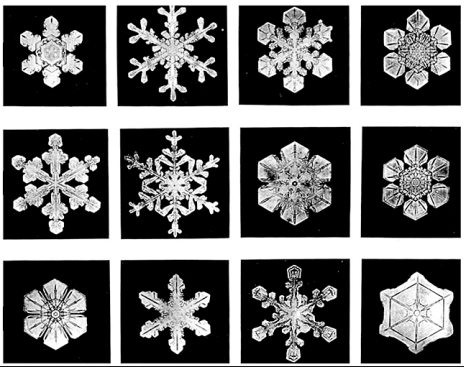


Semi-ordered molecular structure of liquid water

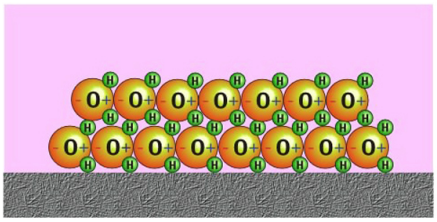
Random molecular structure of vaporized water

Ordered molecular structure of frozen water

Ordered crystal lattice



Surface tension



Cartoon of a film of water, two molecular layers thick. This illustrates how water molecules are attracted to each other to create high surface tension, allowing water to exist as a thin film over solid surfaces.

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Surface tension

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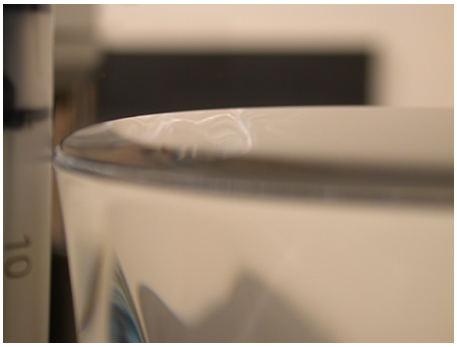
Surface tension



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Surface tension

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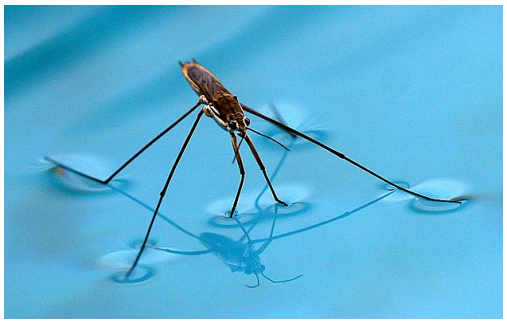
Surface tension



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Surface tension

The covalent bonding property of water molecules allows for the formation of water droplets.

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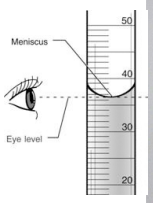
Adhesion

Adhesive forces exist because the polar nature of water can be more strongly attracted to other molecular surfaces, such as smooth glass, than to itself. Conversely, the attraction between mercury atoms (cohesion) is stronger than its attraction to the glass (adhesion). Therefore, the atoms pull together and away from the glass.



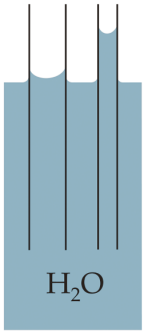
Capillary action

Combination of surface tension (caused by cohesion within the liquid) and adhesion between the liquid and (polar) glass, against the force of gravity.

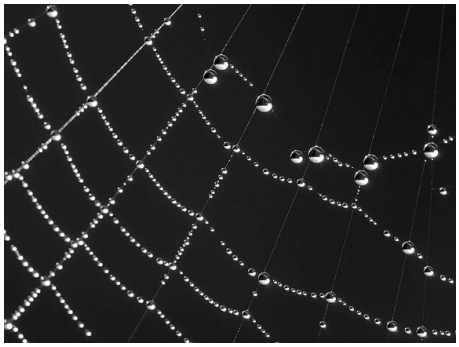
Xylem flow

Water movement through sediment

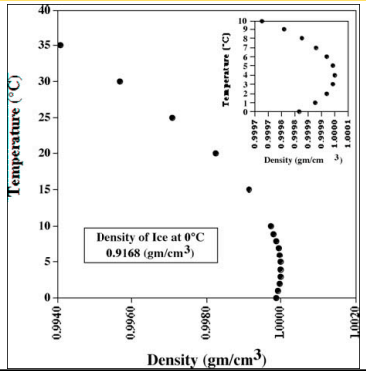
Wicking action



Dew drops adhering to spider web



Water Density



Salinity

Measure of total dissolved salts

Expressed as g/Kg, PSU or more commonly as parts per thousand (PPT, ‰)

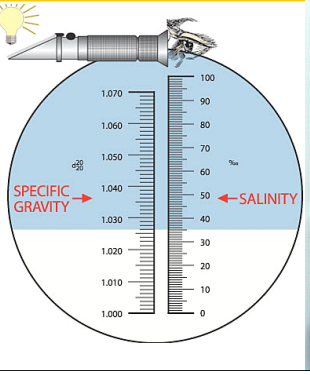
Salinity of freshwater <0.5‰
Full strength seawater ~34‰
Brackish water = in between

Can also be measured with conductivity meter, refractometer, hydrometer

Effects on gills and kidney; use in parasite trtmt; stress reduction for holding & transport

Salinity Measurements

- Conductivity meter
- Refractometer
- Hydrometer



Buffering capacity: Alkalinity

Measure of the ability of a solution to neutralize acids; Equal to the sum of the bases in solution.

In most natural waters carbonate alkalinity tends to make up most of the total alkalinity due to the dissolution of carbonate rocks and the presence of CO_2 in the atmosphere.

Other bases that can contribute to alkalinity include phosphate, silicate, borate, hydroxide, nitrate and ammonia.

Total alkalinity varies in natural waters from less than 5mg/L to more than 500mg/L

Buffering capacity: Hardness

Concentration of multivalent cations in solution, primarily Ca^{+2} and Mg^{+2}

Ca^{+2} and Mg^{+2} are primary contributors to hardness since limestone and dolomite are common minerals;
- Limestone is a common source for calcium-containing minerals;
- Dolomite is a source for both magnesium and calcium

The ability to precipitate soap

Expressed as mg/L $CaCO_3$:
0-75 mg/L "Soft"
75-150 mg/L "Moderate"
150-300 mg/L "Hard"
>300 mg/L "Very Hard

pH

pH is -log[H+], or the negative logarithm of the hydrogen ion concentration.

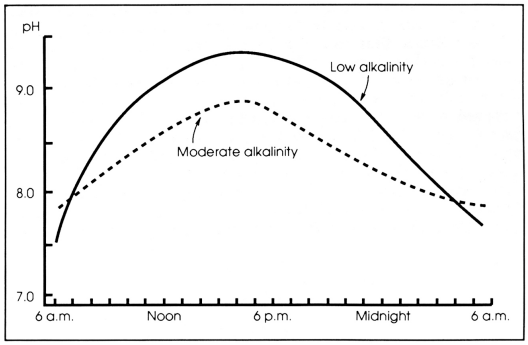
The pH scale varies from 0 to 14, and is negatively logarithmic, i.e., for a decrease in 1 pH unit there is a 10-fold increase in hydrogen ion concentration.

Values of pH less than 7.0 are considered acidic; values greater than 7.0 are alkaline; pH 7.0 is neutral (equal concentrations of hydrogen and hydroxyl ions).

Homeostasis
Diel fluctuations
Varies in different habitats
May alter bioavailability and toxicity of certain chemicals

pH Measurement

Diel fluctuations in pH



Temperature

Specific-specific preferences & tolerances
Thermal shock
Effect on chemical reactions and solubility of gasses
Effect on respiration, uptake and metabolism.

Temperature affects density of water:
- Thermal stratification
- Inversion of water masses

Dissolved oxygen

Many aquatic animals derive oxygen from water via gill structures.

Some organisms (e.g., amphibians, some fish) have some degree of dermal respiration as well

Concentration increases with decreasing temperature.

Distillation and boiling remove oxygen from solution.

Supersaturation

Measured as mg/L D.O.

Dissolved Oxygen – Methods

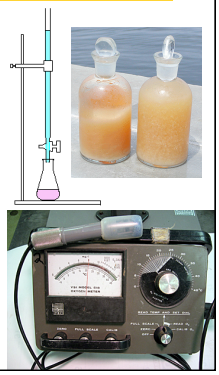
Winkler Method

Manganese(II) sulfate + potassium iodide (in KOH) added to water sample to create a brown precipitate. In the alkaline solution, DO will oxidize manganese(II) to (III) and/or (IV) state.

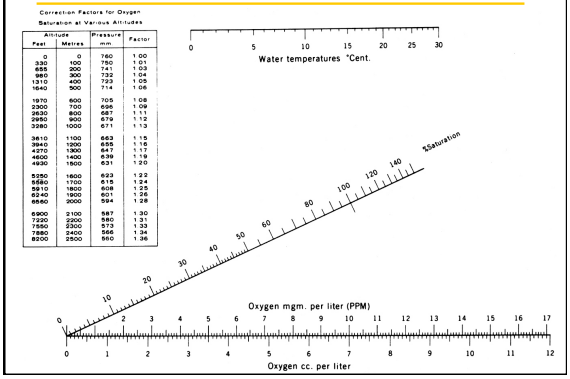
The solution is then acidified (and preserved) to dissolve the precipitate back into solution, releasing elemental Iodine.

Thiosulfate solution is used, with a starch indicator, to titrate the iodine.

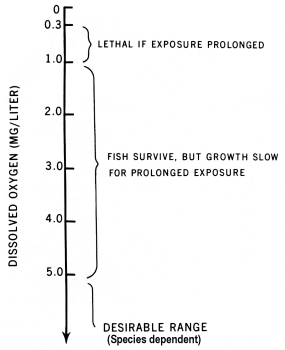
1 mole of O_2 → 2 moles of $MnO(OH)_2$ → 2 mole of I_2 → 4 mole of $S_2O_3^{2-}$



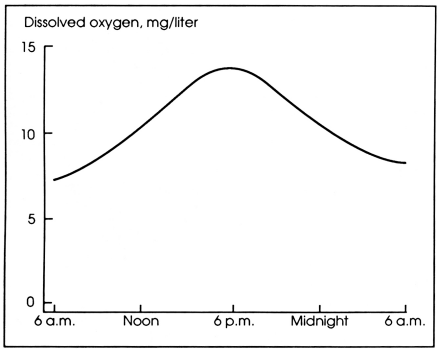
D.O. Saturation Nomogram



Effects of D.O. on Aquatic Organisms



Diel fluctuations in O_2



Light in the aquatic environment

Solar radiation critical to drive ocean currents and wind-driven waves

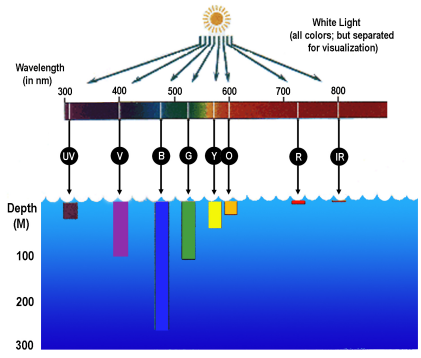
Provides essential warming to oceans and light energy for Chlorophyll-bearing plants to make food.

Uppermost, sunlit layer of the ocean, where 70 percent of the entire amount of photosynthesis in the world takes place, is called the euphotic zone. Generally extends to ~ 100 meters.

Much light is reflected from the water surface. Light is refracted under water since it travels slower in water < air; also scattered or absorbed by particles.

Longer wavelengths are absorbed within 50 meters

Light Penetration in Water



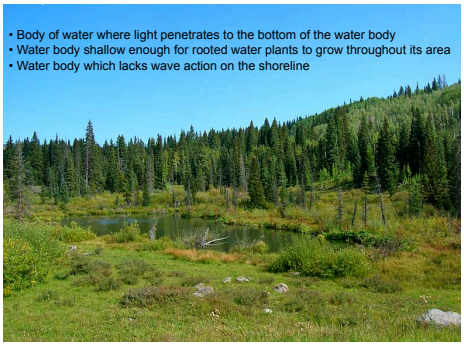
Light Penetration in Water


Assignment

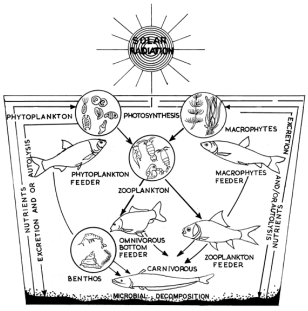
- Pond
- Pool
- Lake
- Creek
- Stream
- Canal
- River
- Tributary
- Marsh
- Swamp
- Bog
- Delta
- Estuary
- Ocean
- Watershed
- Lotic
- Lentic

Ponds

- Body of water where light penetrates to the bottom of the water body
- Water body shallow enough for rooted water plants to grow throughout its area
- Water body which lacks wave action on the shoreline

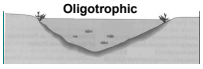


Pond Ecosystem



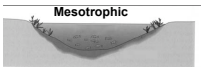
Trophic states of lakes

Oligotrophic



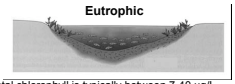
Total chlorophyll is typically less than 3 µg/L
Total phosphorus is typically less than 15 µg/L
Total nitrogen is typically less than 400 µg/L
Water clarity is typically greater than 13 feet

Mesotrophic



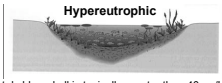
Total chlorophyll is typically between 3-7 µg/L
Total phosphorus is typically between 15-25 µg/L
Total nitrogen is typically between 400-600 µg/L
Water clarity is typically between 8-13 feet

Eutrophic



Total chlorophyll is typically between 7-40 µg/L
Total phosphorus is typically between 25-100 µg/L
Total nitrogen is typically between 600-1500 µg/L
Water clarity is typically between 3-8 feet

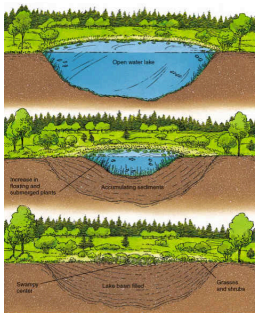
Hypereutrophic



Total chlorophyll is typically greater than 40 µg/L
Total phosphorus is typically greater than 100 µg/L
Total nitrogen is typically greater than 1500 µg/L
Water clarity is typically less than 3 feet

Adapted from Florida Lakewatch Circular

Succession



Bog -> Marsh -> Meadow

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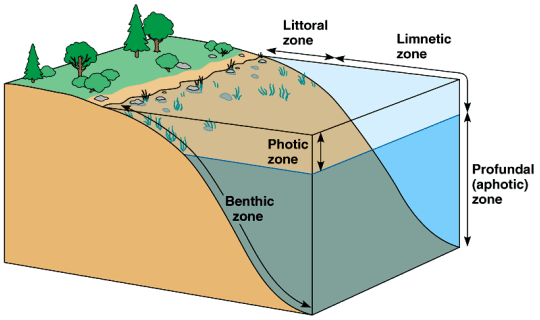
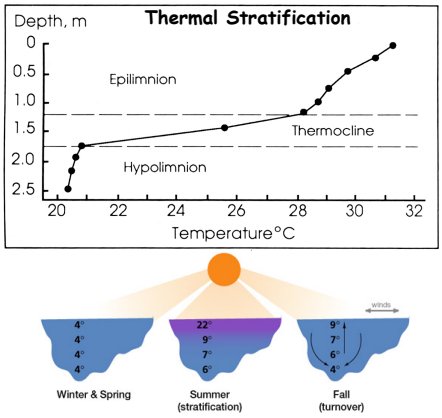
Zonation



Thermal Stratification



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Anatomy of a river

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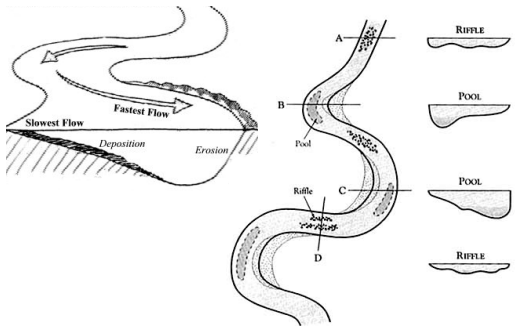
Anatomy of a river



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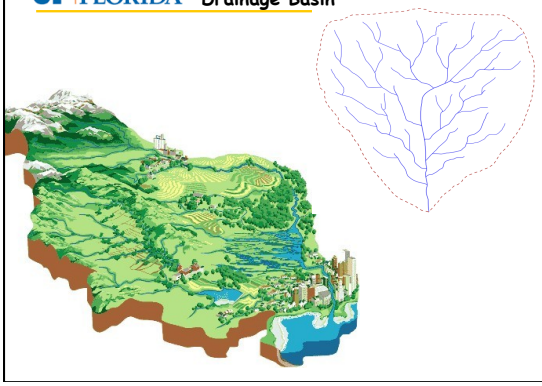
Drainage Basin



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Anthropogenic change