Hydrology and water properties

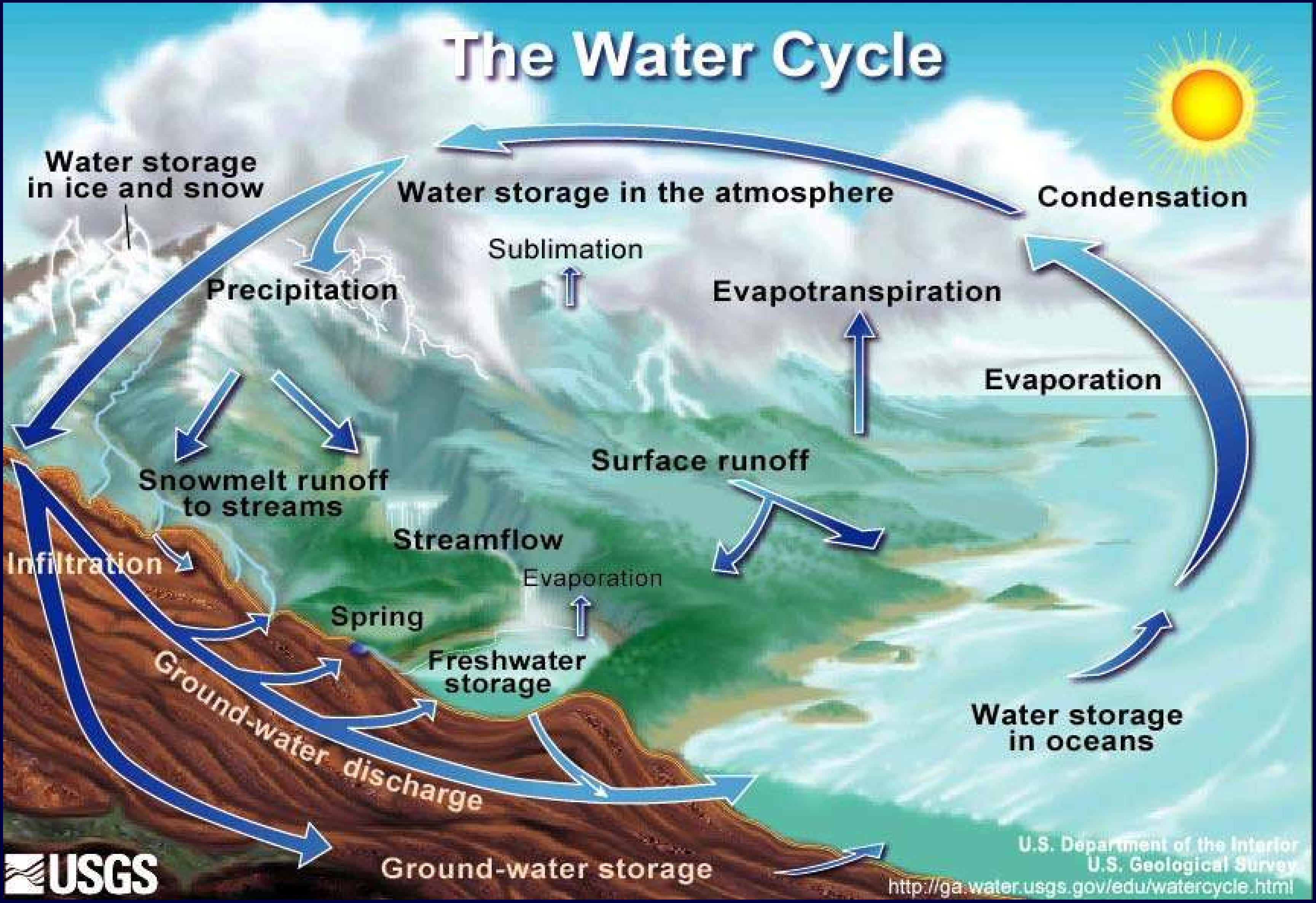
Limnology

Lecture 4

Outline

- Hydrology
- Properties of Water

Hydrological cycle



Lake water balance

Mass balance

Input

- Direct precipitation to lake surface
- Watershed run-off
  - surface and subsurface flows
- Groundwater infiltration

Output

- Drainage (stream)
- Evaporation and evapotranspiration
- Seepage into groundwater

Lake water balance

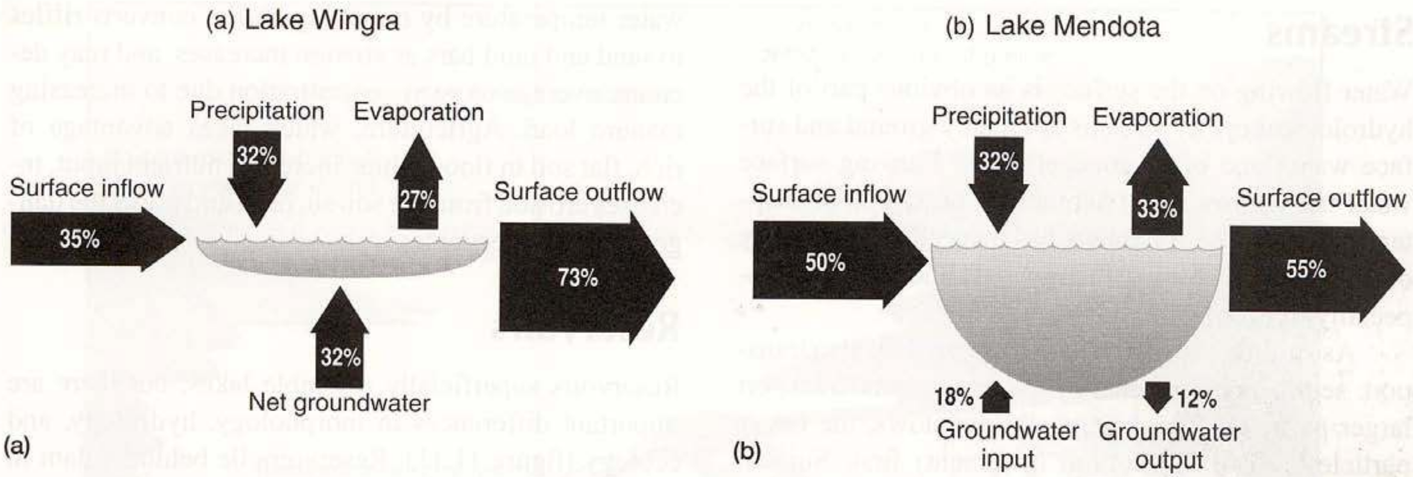
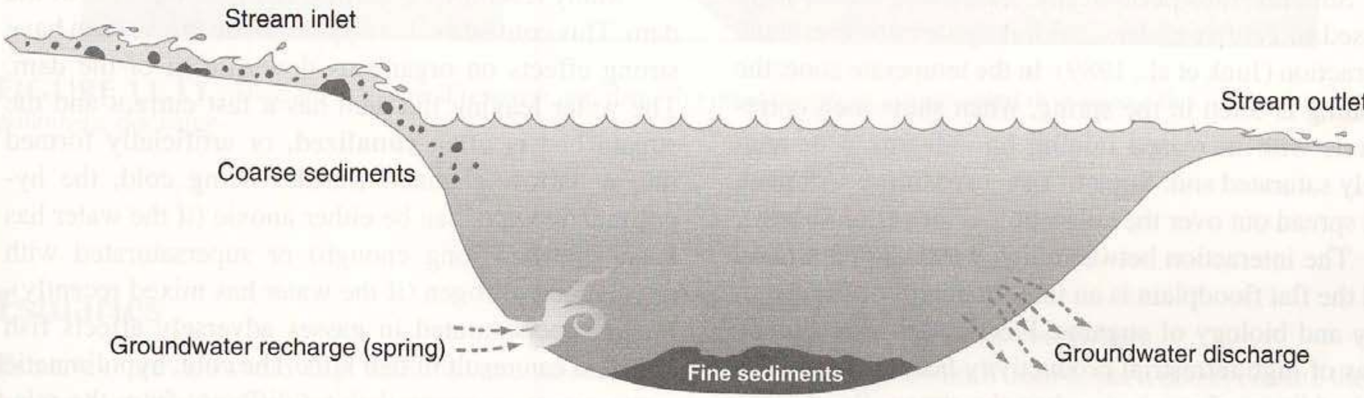


FIGURE 11.9 (a) A model of the annual water budget for Lake Wingra, Wisconsin. (b) A model of the annual water budget for Lake Mendota, Wisconsin. The percent of input and output are on an annual basis. **Source:** Data from IES, 1999 and Brock, 1985.



Lake water balance

Open vs. closed lakes

Closed = evaporation only escape of water

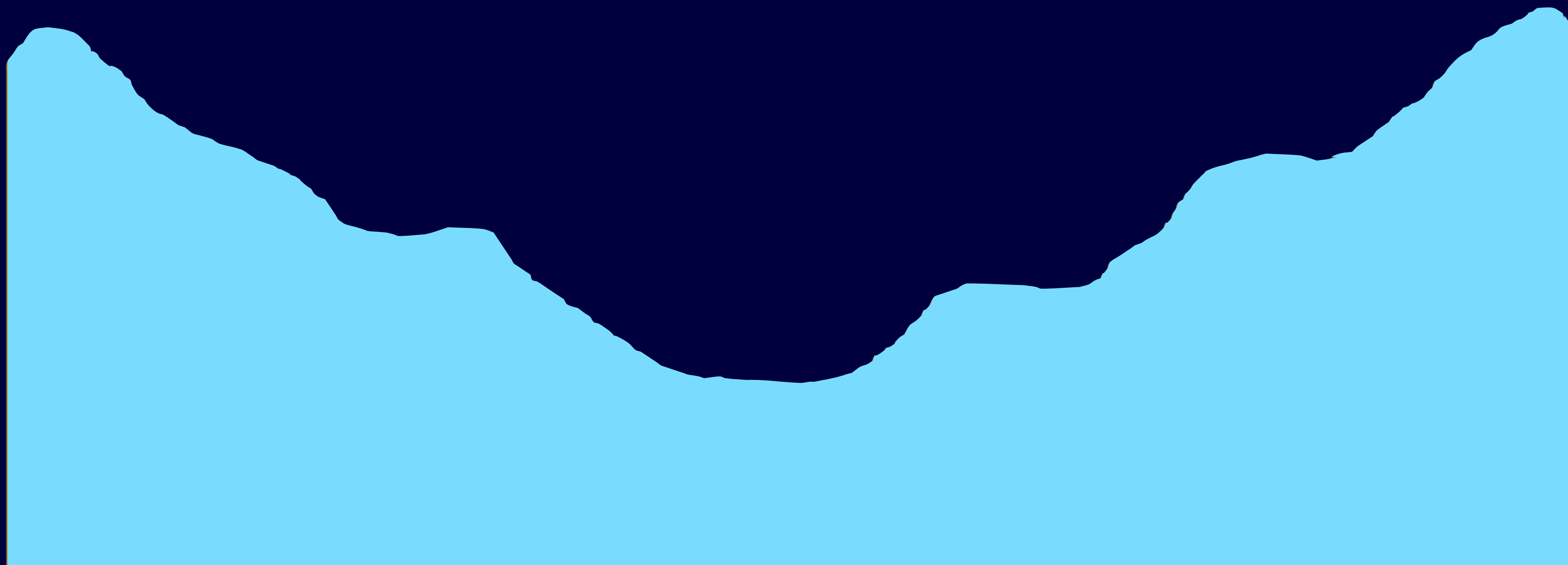
Open = stream outlet or seepage

Depends on landscape location and local topography

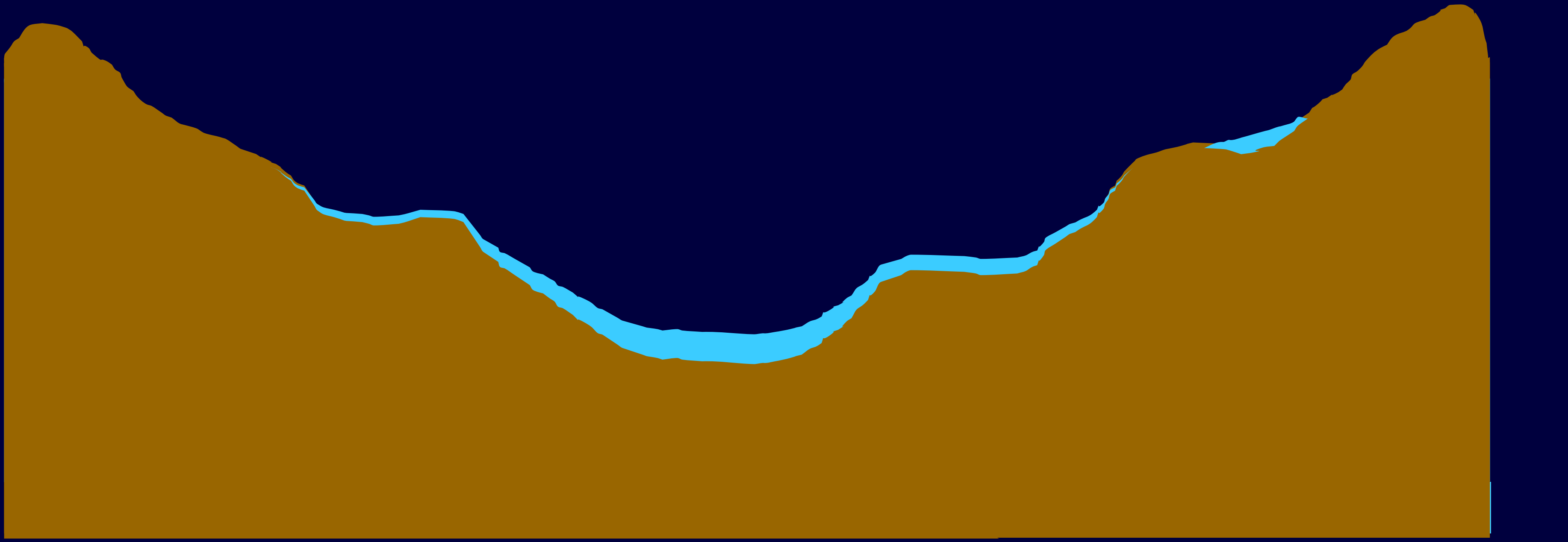
e.g., closed lakes often in between mountain ranges

affects chemistry and biology → salinity high in closed lakes

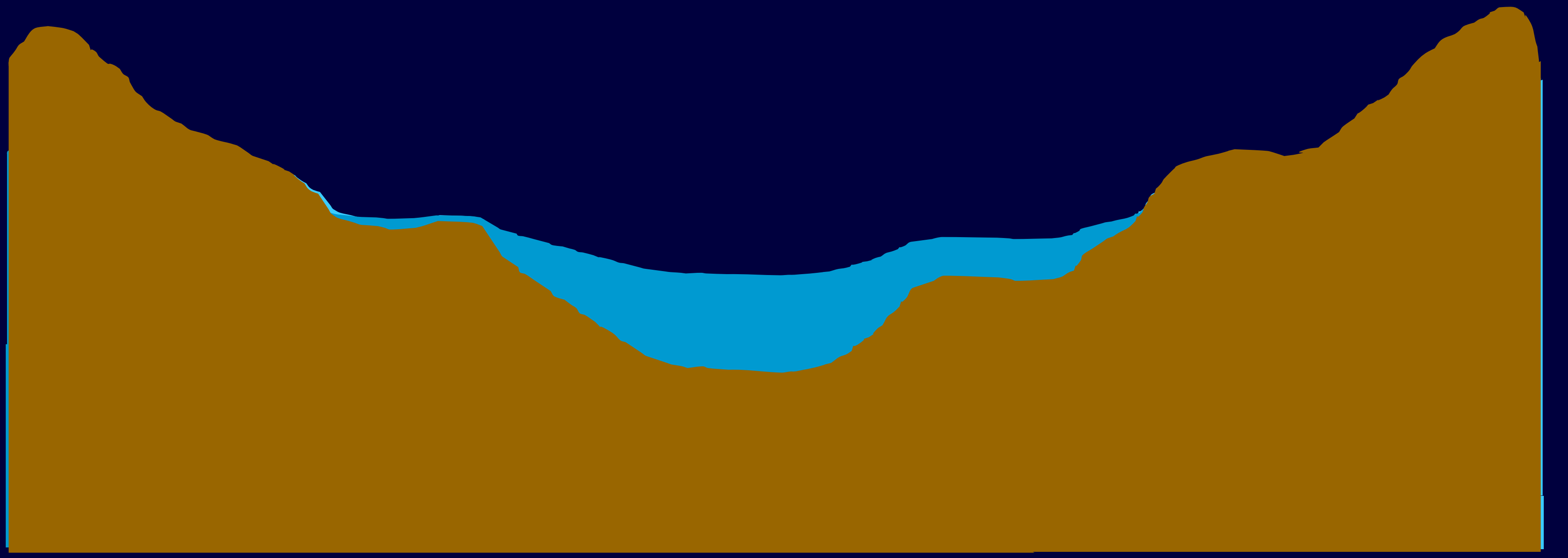
Hydrology



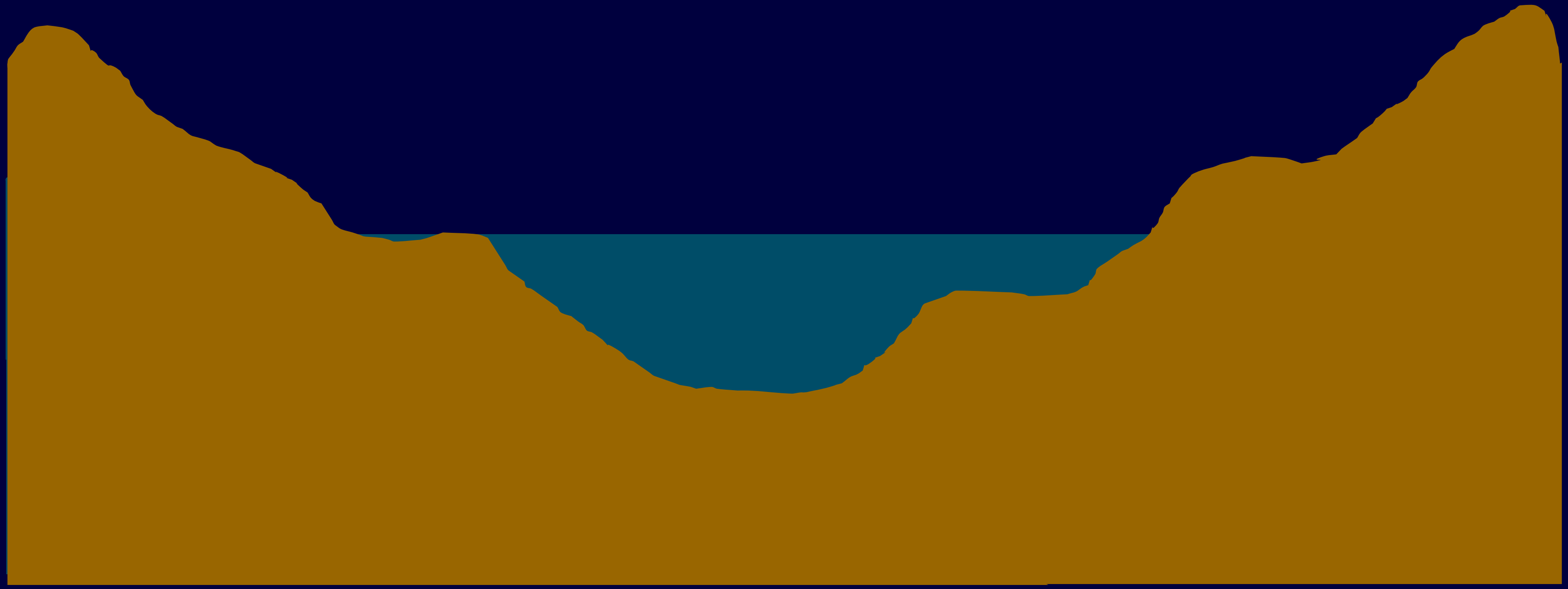
Hydrology



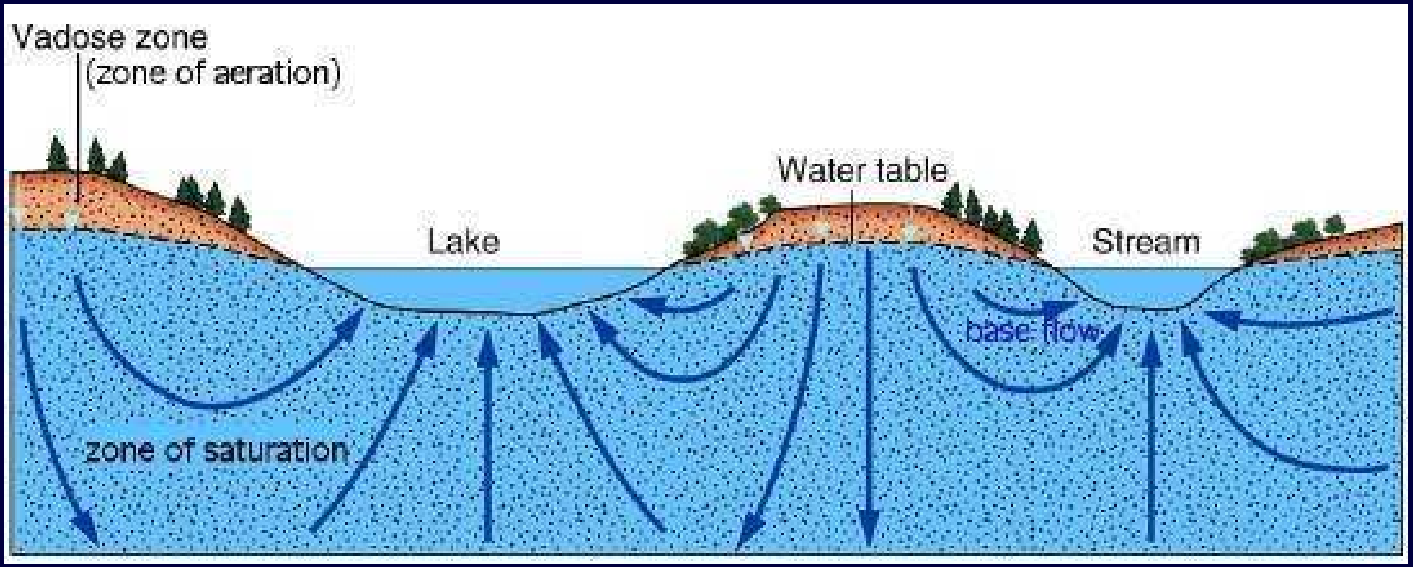
Hydrology



Hydrology

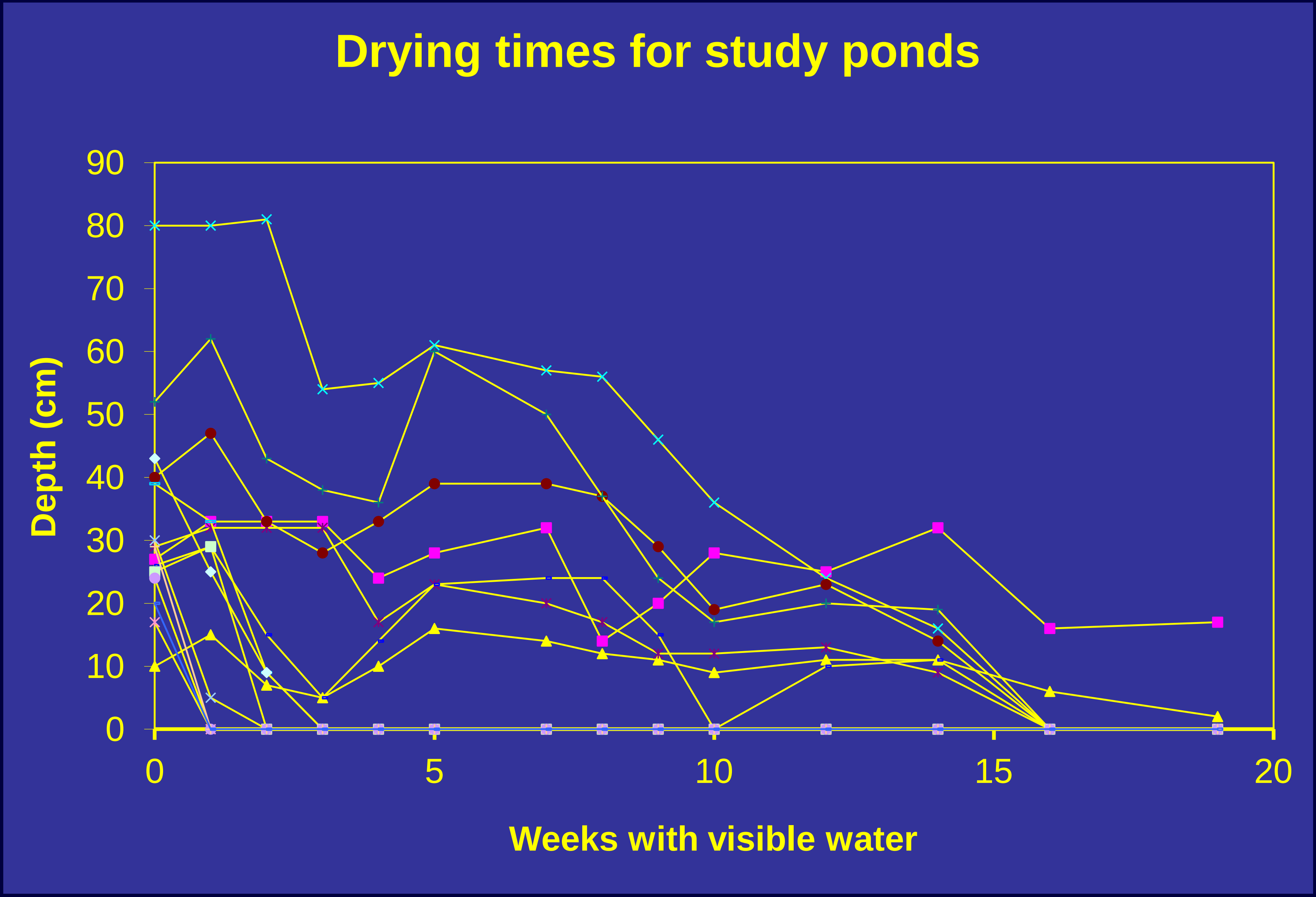


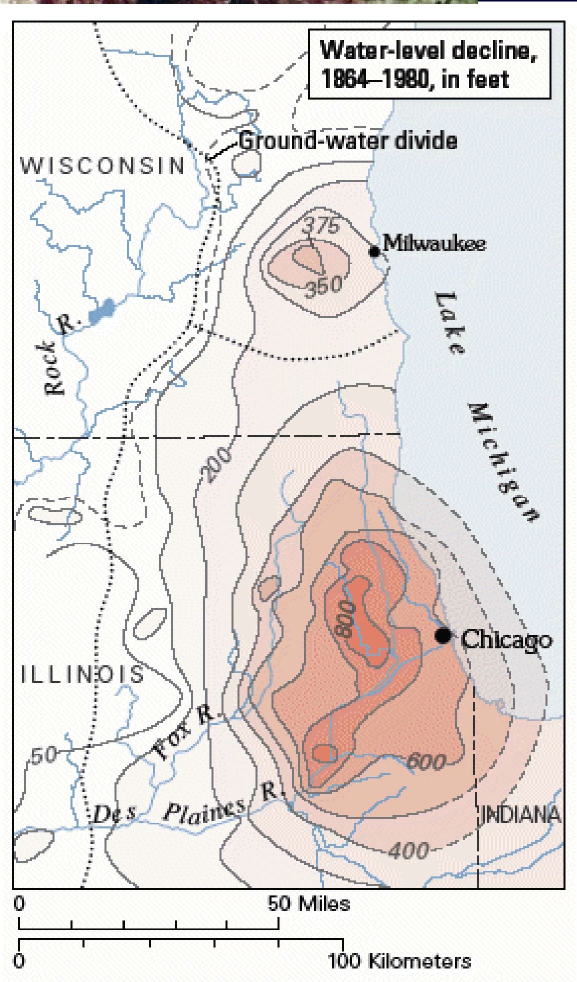
Hydrology



Vadose zone – non-saturated top surface
water kept here by adhesion and capillary action
Saturation zone
Base flow – relatively constant groundwater input to streams
Groundwater Recharge – flow to surface waters
Groundwater Discharge – flow to groundwater

Does depth predict drying in temporary ponds?



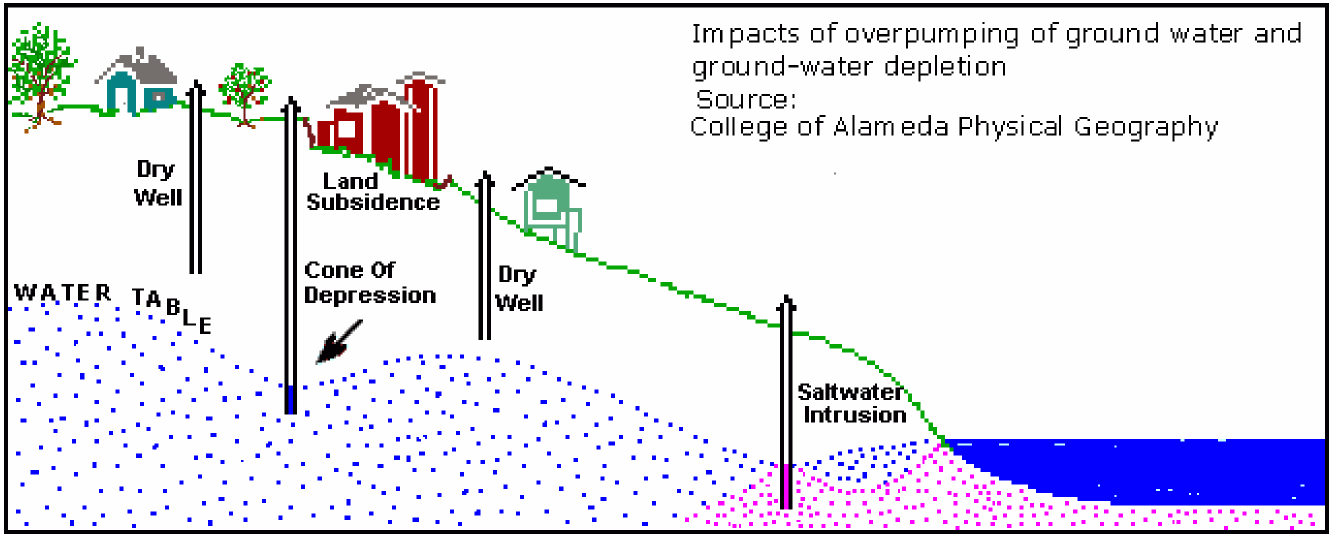


Human effects

Depleting groundwater

- leads to lowered water tables
- subsidence
- saltwater intrusion along coasts (LI)

Depleting surface water



Human effects

Depleting surface water

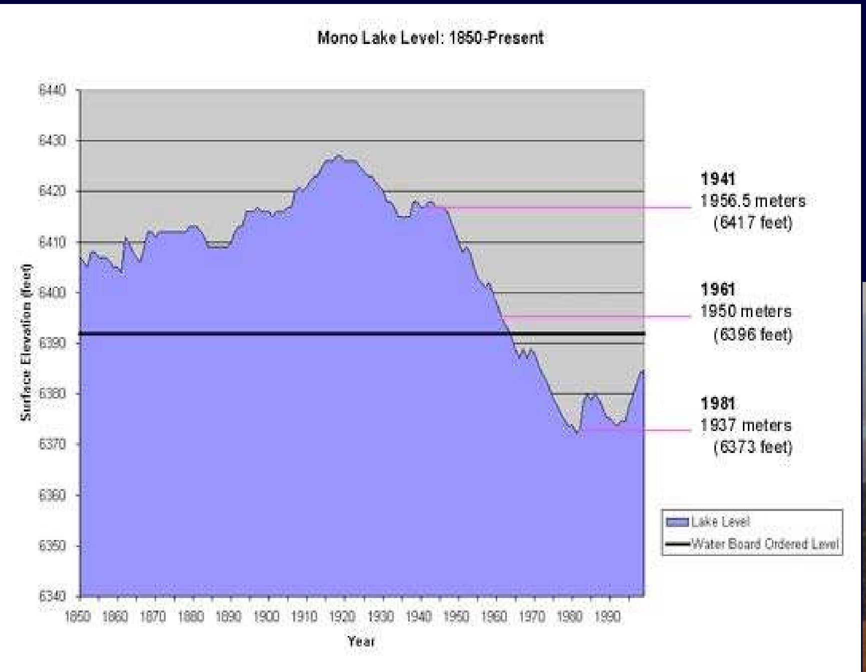
E.g., Mono Lake, CA

Since 1941 water diverted ~ 250 miles to LA

1976 - water dropped 39 feet

Undergrad study galvanizes interest

Current target – 6392 feet



Human effects

Increase in evaporation

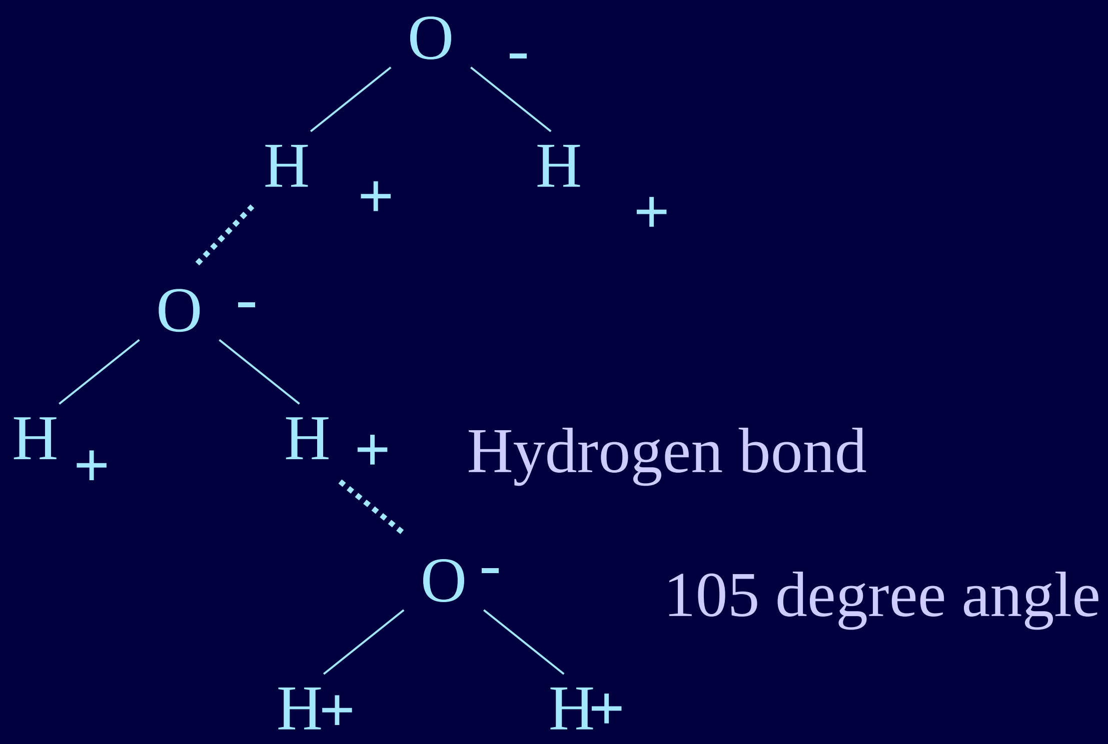
irrigation, canals and reservoirs

account for ~10% of continental evaporation

→ 50%

Wonderful water

Properties of water



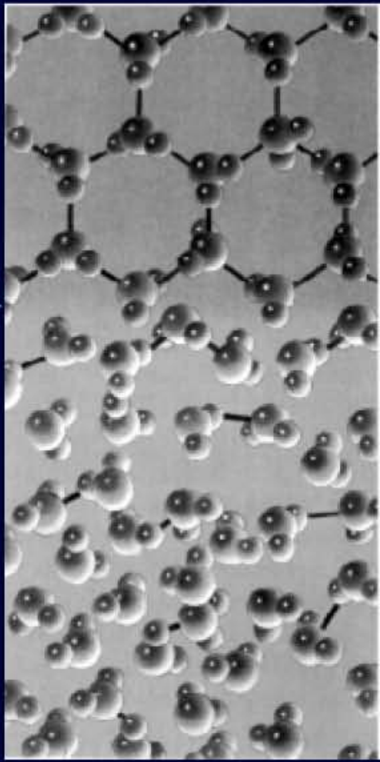
Bipolar – positive and negative sides of molecule

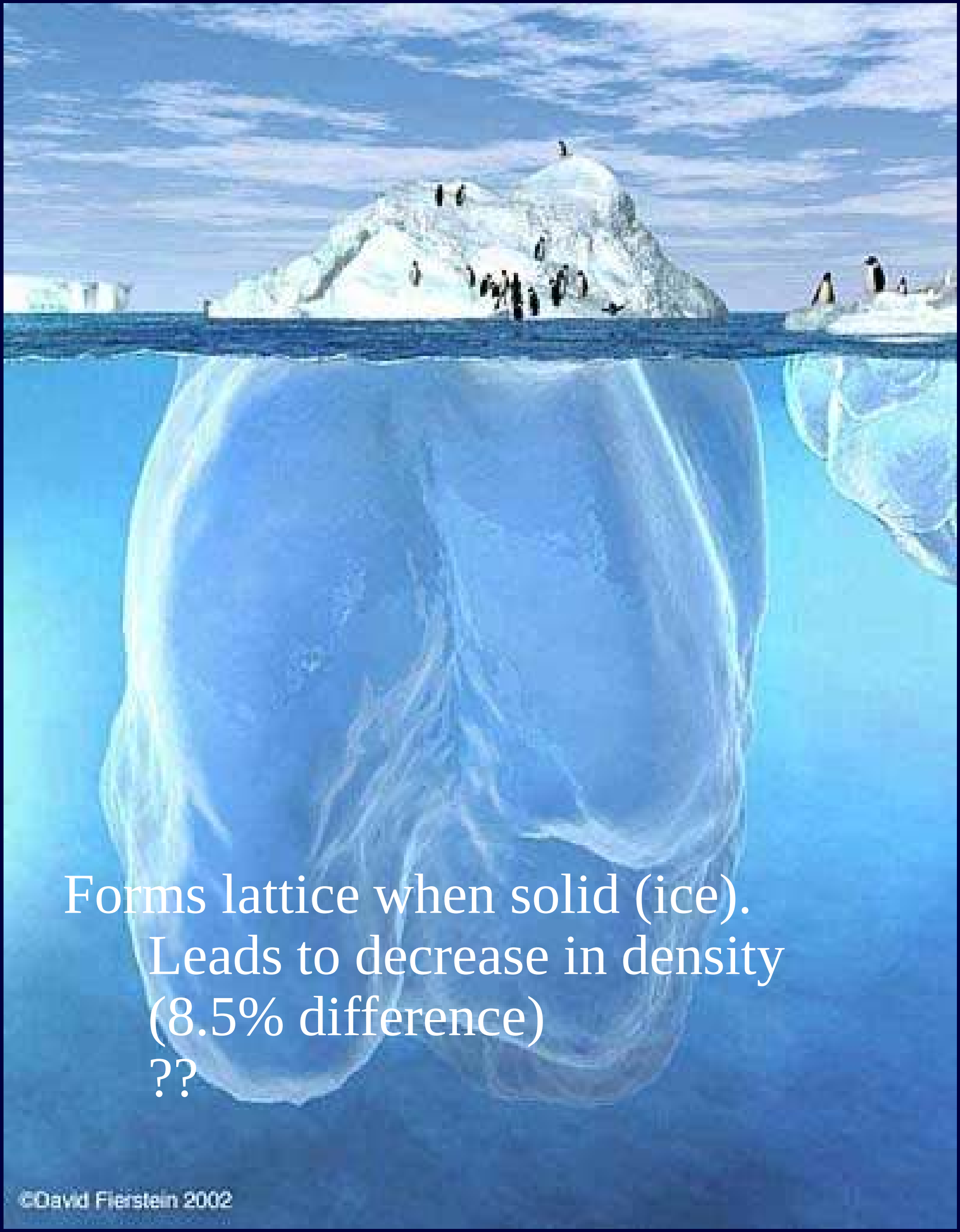
→ associate with one another

→ dissolve many substances

Thermal Features of Water

- Thermal buffering
  - High Specific Heat
    - Takes much energy to warm water
    - Only exceeded by ammonia and liquid hydrogen
  - High Latent Heat
    - Retains heat well
    - Large lakes freeze later and maybe not at all





Forms lattice when solid (ice).

- Leads to decrease in density (8.5% difference)
- ??

Surface Effects

- Surface tension (high cohesion)
  - Very high due to hydrogen bonds
  - Highest except for mercury
- Adhesion (binds to surfaces)
  - Hydrophilic (high)
  - Hydrophobic (low)

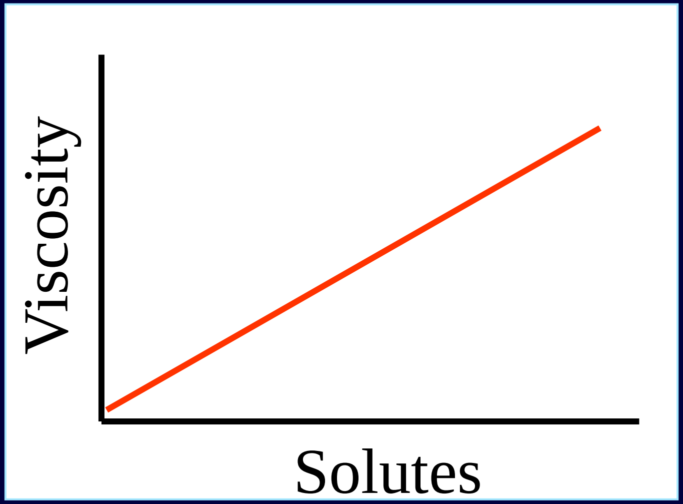
Viscosity

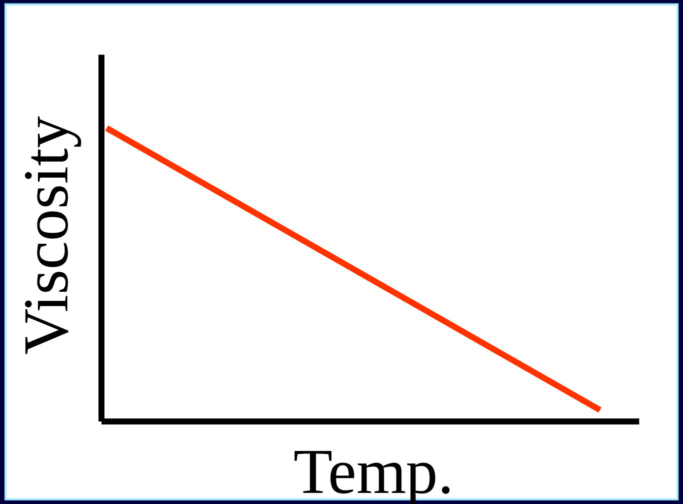
- Resistance to flow
- Internal friction
- Depends on
  - Temperature
  - Solutes
- Measurement unit

  = Pascal Second (PaS)

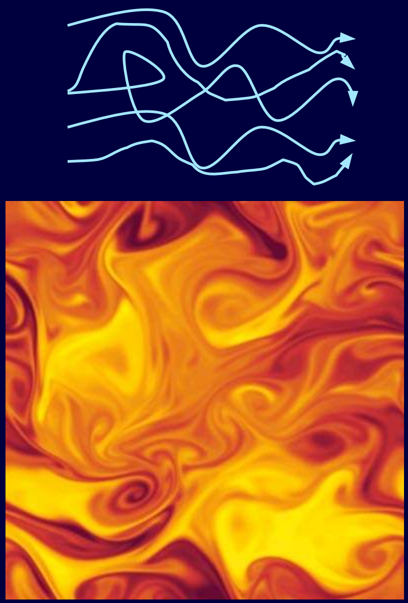
  = 1 kg m^{-1} s^{-1}

  = force needed to move 1 kg liquid 1 m in 1 s

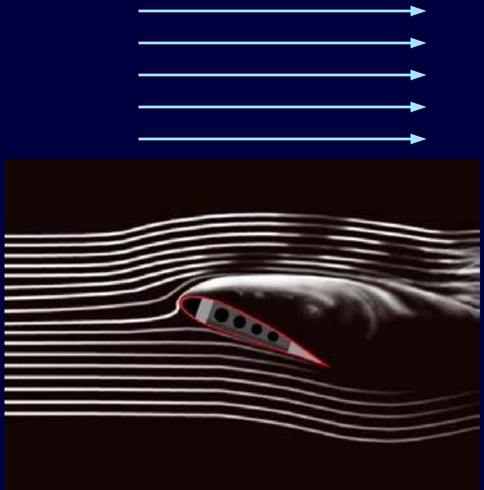




Viscosity → Laminar vs. Turbulent Flow

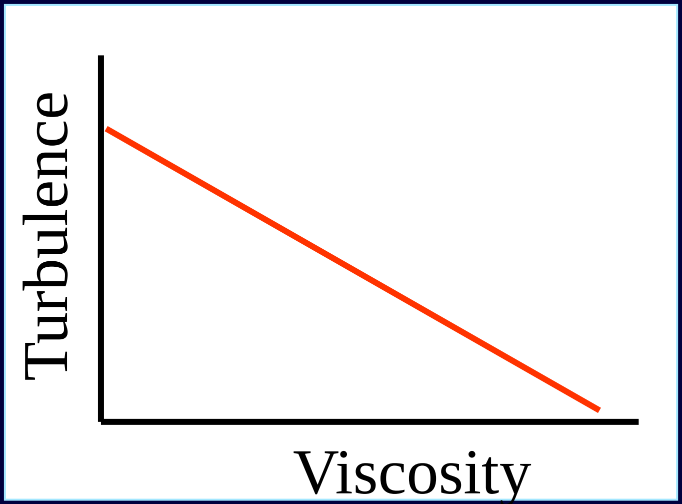


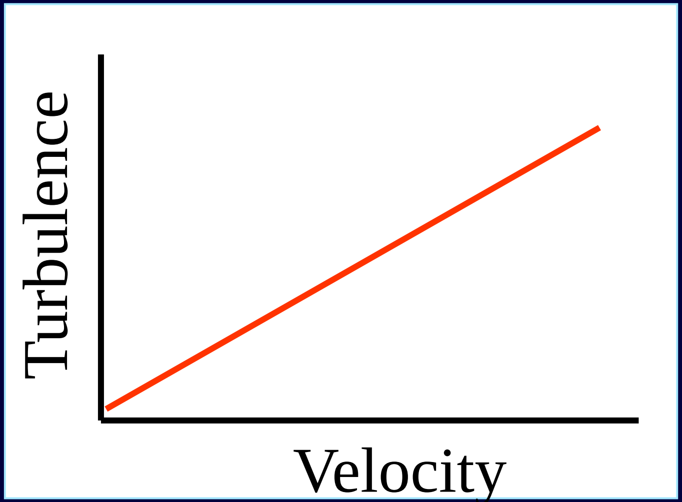
Turbulent
– individual particles follow irregular paths



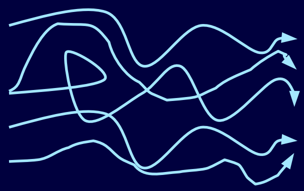
Laminar

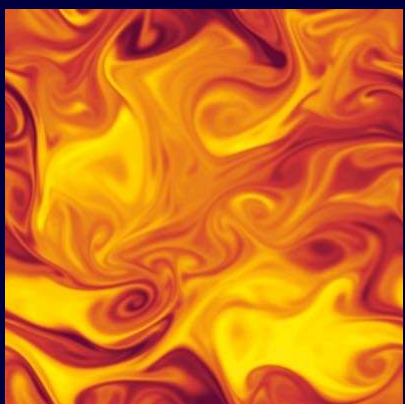
- Particle move in parallel tracks



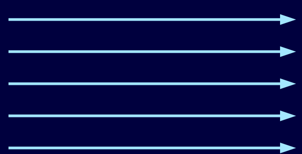


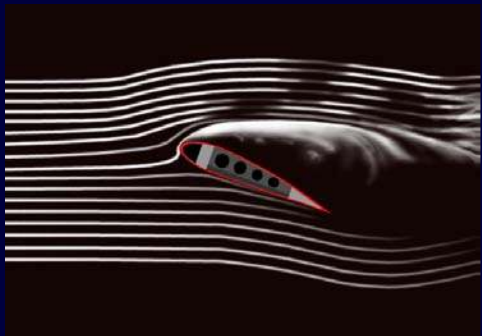
Viscosity → Laminar vs. Turbulent Flow





Turbulent





Laminar

Reynolds number < ~1

Reynolds Number

$$\frac{\text{inertial forces}}{\text{viscous forces}} = Re = \frac{\delta U l}{\mu} = \frac{U l}{\nu}$$

dUl : u

U = m/s = relative speed

l = length in direction of flow

Key variables for living organisms

δ = density of water (depends on temp)

μ = viscosity

ν = kinematic viscosity = $\frac{\mu}{\delta}$ (water = 1×10^{-6} m^2/s @ 20 C)

Reynolds Numbers

$$Re = \frac{\delta U l}{\mu}$$

Speed (U) →

Size (l) →

Density (δ) →

Viscosity (μ) ←

Reynolds Numbers

Whale	150,000,000
Mike Phelps	5,000,000
Trout	400,000
Daphnia	25
Protist	0.1
Filtering setae	0.001

R_e is large, turbulence prevails

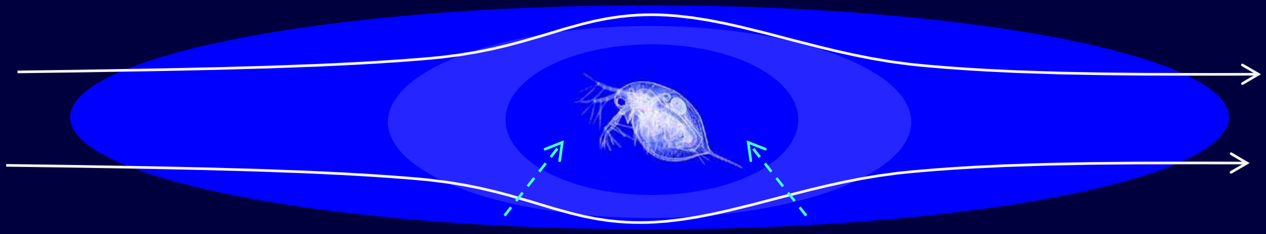
R_e is small, laminar flow


1 mm

Biotic importance: Reynolds Numbers

Small organisms surrounded by boundary layer
diffusion needed to transport
slow, limiting process

Turbulence effective transporter



Today:

Hydrology of lakes
Human effects on hydrology
Water has many properties conducive to aquatic living
Reynold's numbers

NO CLASS TUESDAY
Thursday: Physical and chemical limnology

Lab – Room 179, zooplankton ID
Bring laptops with wireless