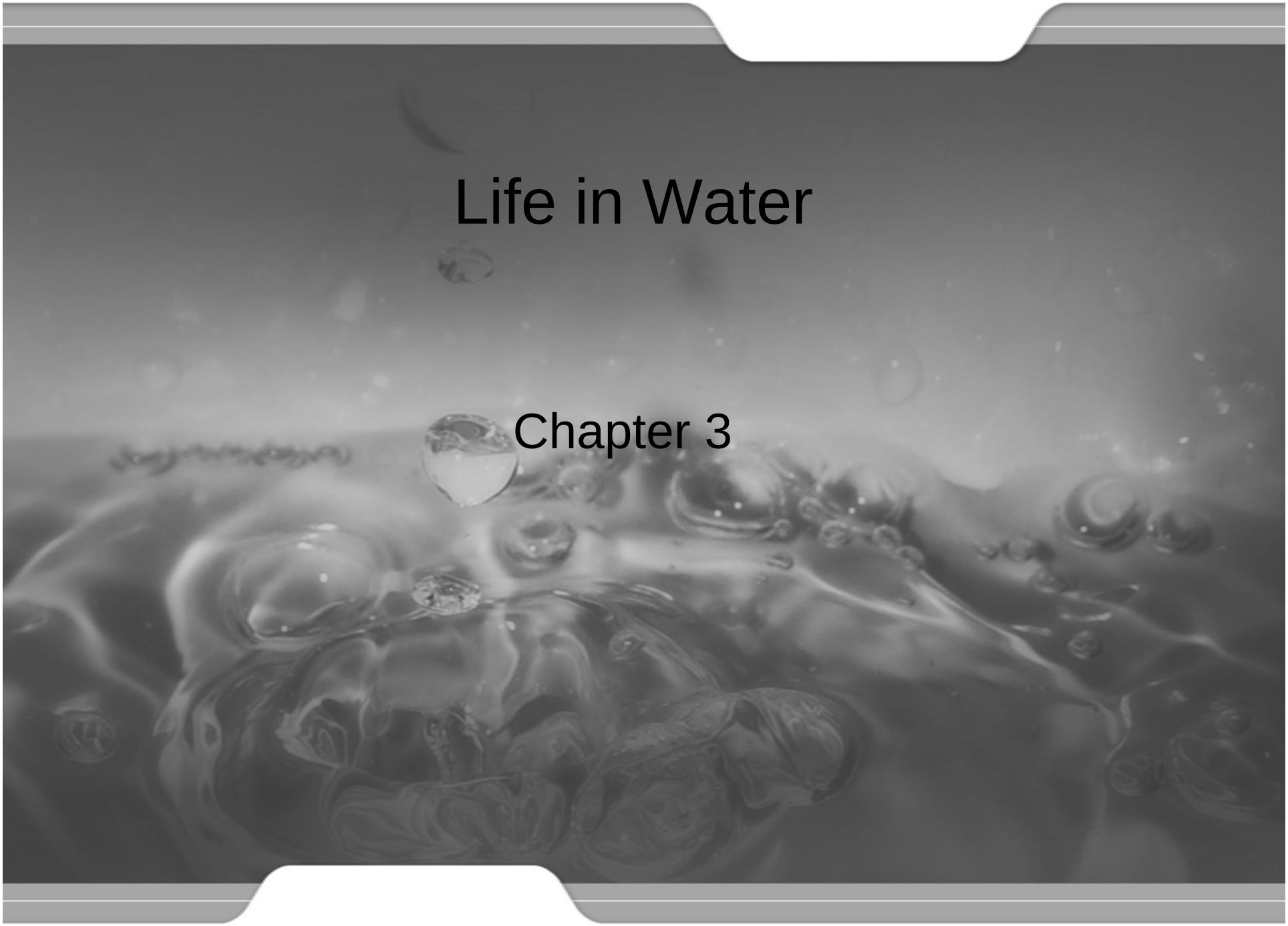


Life in Water

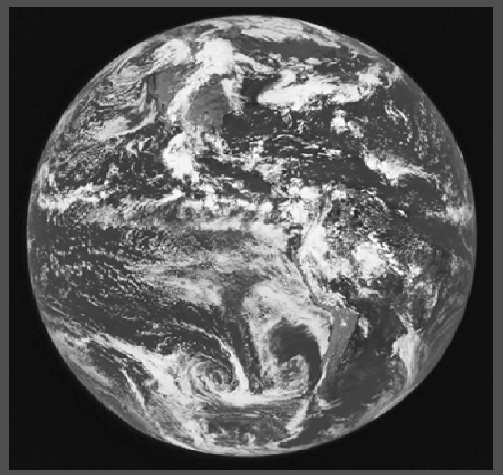
Chapter 3

Outline

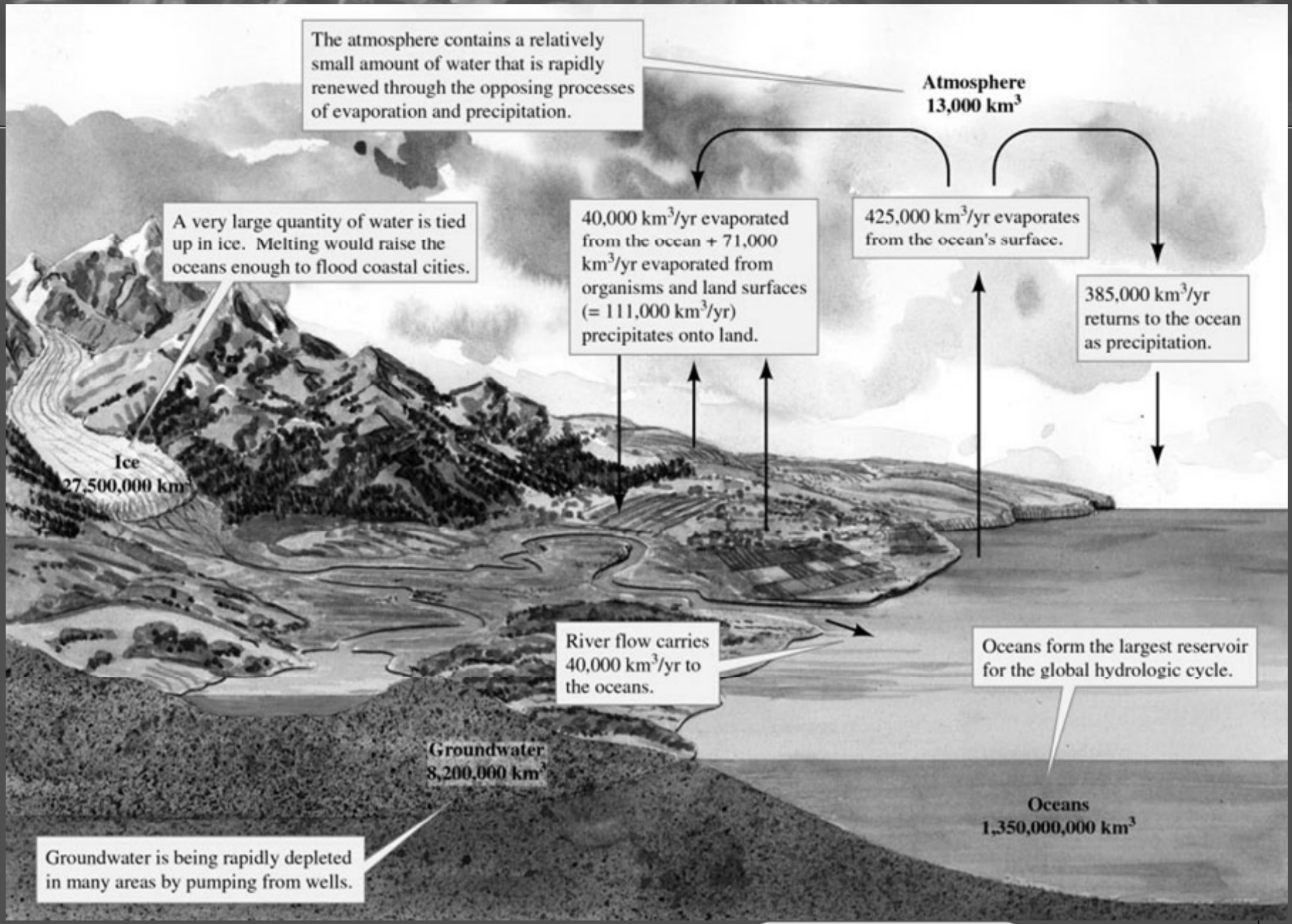
- Hydrologic Cycle
- Oceans
- Shallow Marine Waters
- Marine Shores
- Estuaries, Salt Marshes, and Mangrove Forests
- Rivers and Streams
- Lakes

The Hydrologic Cycle

- Over 71% of the earth's surface is covered by water:
  - Oceans contain 97%.
  - Polar ice caps and glaciers contain 2%.
  - Freshwater in lakes, streams, and ground water make up less than 1%.



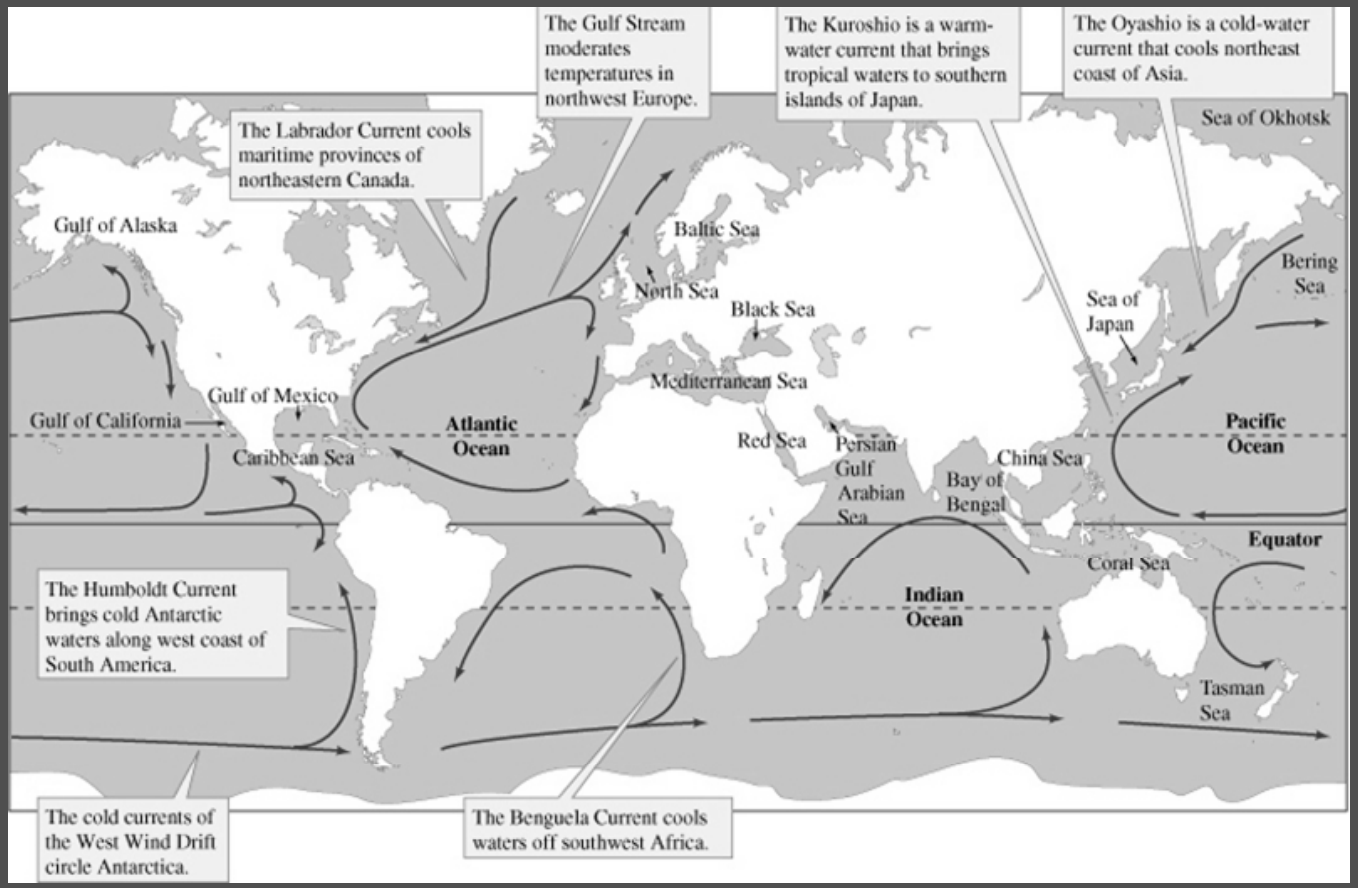
- Reservoir = storage for nutrient/molecule
  - H2O enters
    - Precipitation
    - Surface or subsurface flow
  - H20 leaves
    - Evaporation
    - Flow
- Cycle powered by solar energy


The atmosphere contains a relatively small amount of water that is rapidly renewed through the opposing processes of evaporation and precipitation.
Atmosphere
13,000 km3
A very large quantity of water is tied up in ice. Melting would raise the oceans enough to flood coastal cities.
40,000 km3/yr evaporated from the ocean + 71,000 km3/yr evaporated from organisms and land surfaces (= 111,000 km3/yr) precipitates onto land.
425,000 km3/yr evaporates from the ocean's surface.
385,000 km3/yr returns to the ocean as precipitation.
Ice
27,500,000 km3
River flow carries 40,000 km3/yr to the oceans.
Oceans form the largest reservoir for the global hydrologic cycle.
Groundwater
8,200,000 km3
Oceans
1,350,000,000 km3
Groundwater is being rapidly depleted in many areas by pumping from wells.

The Hydrologic Cycle

- Turnover time is the time required for the entire volume of a reservoir to be renewed.
  - Atmosphere 9 days
  - Rivers 12-20 days
  - Oceans 3,100 years

Oceanic Circulation



- Driven by prevailing winds
- Moderates earth's climate

Oceans - Geography

- The Pacific is the largest ocean basin with a total area of nearly 180 million km^2.
  - Gulf of California
  - Gulf of Alaska
  - Bering Sea
  - Sea of Okhotsk
  - Sea of Japan
  - China Sea
  - Tasman Sea
  - Coral Sea

Oceans - Geography

- The Atlantic is the second largest basin with a total area of over 106 million km^2.
  - Mediterranean
  - Black Sea
  - North Sea
  - Baltic Sea
  - Gulf of Mexico
  - Caribbean Sea

Oceans - Geography

- The Indian is the smallest basin with an area of just under 75 million km^2.
  - Bay of Bengal
  - Arabian Sea
  - Persian Gulf
  - Red Sea

Oceans - Geography

- Average Depth
  - Pacific - 4,000 m
  - Atlantic - 3,900 m
  - Indian - 3,900 m
- Undersea Trenches
  - Marianas - 10,000 m deep
    - Would engulf Mt. Everest with 2 km to spare.

Oceans - Structure

- Littoral Zone (intertidal zone): Shallow shoreline (under influence of tides).
- Neritic Zone: Coast to margin of continental shelf.

Oceans - Structure

- Oceanic Zone: Beyond continental shelf.
  - Epipelagic 0 - 200 m
  - Mesopelagic 200 - 1,000 m
  - Bathypelagic 1,000 - 4,000 m
  - Abyssal 4,000 - 6,000 m
  - Hadal 6,000 $^{+}$ m
- Benthic: Habitat on bottom of ocean.
- Pelagic: Habitat off the bottom of the ocean.

Oceans - Physical Conditions

- Light
  - Approximately 80% of solar energy striking the ocean is absorbed in first 10 m.
    - Very little, if any penetrates past 600 m.
      - Leaves approximately 3,400 m of deep black water with only light produced by bioluminescence.

Oceans - Physical Conditions

- Temperature
  - Sunlight increases velocity of water.
    - Rapid motion decreases density, thus warm water floats on top of cooler water.
  - Thermocline: Layer of water through which temperature changes rapidly with depth.
    - Creates thermal stratification.

Oceans - Physical Conditions

- Water Movements
  - Oceans are never still.
    - Wind-driven surface currents across open ocean create gyres that move right in the Northern Hemisphere and left in the Southern Hemisphere.
    - Deepwater currents cause upwelling.

Oceans - Chemical Conditions

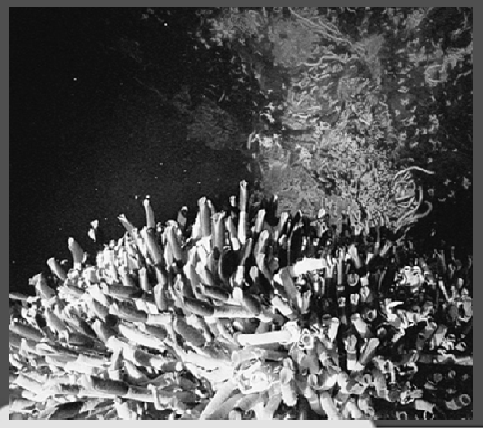
- Salinity
  - In the open ocean, salinity varies from about 34 ppt to 36.5 ppt.
    - Lowest salinity occurs near equator where precipitation exceeds evaporation.
    - Highest salinity occurs in subtropics where evaporation exceeds precipitation.
  - GSL = 50 – 270 ppt!

Oceans - Chemical Conditions

- Oxygen
  - A liter of air contains about 200 ml of oxygen at sea level, while a liter of seawater contains a maximum of 9 ml of oxygen.
    - Typically concentration is highest near ocean surface, and decreases with depth.
      - Minimum usually < 1,000m.

Oceans - Biology

- Photosynthetic organisms are limited to upper epipelagic zone (euphotic zone).
  - Phytoplankton and zooplankton.
  - Due to size, oceans contribute ¼ of total photosynthesis in the bioshpere.
- Chemosynthesis occurs near undersea hot springs.



Oceans - Human Influences

- For most of human history, vastness of oceans has acted as a buffer against human intrusion.
- New human-induced threats:
  - Overharvesting
  - Dumping

Shallow Marine Waters

- Reef Categories
  - Fringing reefs: Hug shore of continents.
  - Barrier reefs: Stands between open sea and lagoon.
  - Coral atolls: Coral inlets built up from submerged ocean island.
- Kelp Beds
  - Structure similar to terrestrial forests.
    - Canopy at water's surface.

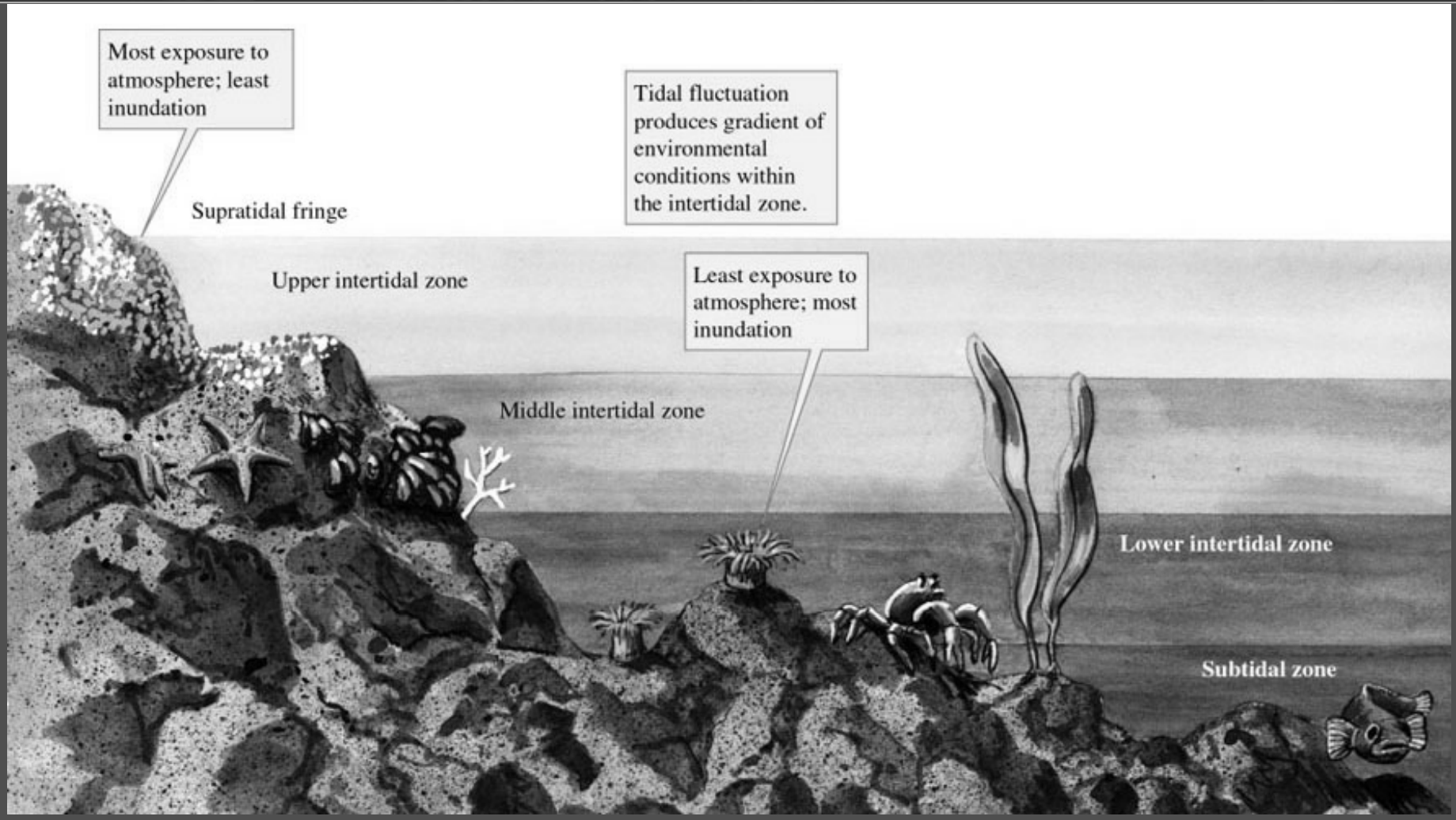
Shallow Marine Waters

- Reefs and kelp beds both grow in surface waters with sufficient light for photosynthesis.
  - Both limited by temperature.
- Currents deliver oxygen and nutrients, and remove waste products.
  - Biological productivity may depend on flushing action.
- Reefs and kelp beds among most productive and diverse ecosystems.

Marine Shores

- Inhabitants of intertidal zone are adapted to amphibious existence.
  - Differential tolerances to periodicity of air exposure leads to zonation of species.
- Due to increased accessibility, intertidal zones are experiencing increasing human exploitation.

Intertidal Zonation



Estuaries, Salt Marshes, and Mangrove Forests

- Estuaries are found where rivers meet the sea.
- Salt Marshes and Mangrove Forests are concentrated along low-lying coasts.
  - All driven by ocean tides and river flow.
    - Transport organisms, nutrients, oxygen, and remove wastes.
  - Extremely vulnerable to human intrusion.

Rivers and Streams

- Rivers and streams can be divided along three dimensions:
  - Length: Pools, runs, riffles, rapids
  - Width : Wetted / active channels
  - Vertical: Water surface, column
- Riparian zone is a transition area between the aquatic and upland terrestrial environments.

Rivers and Streams

- Rivers and streams are vertically divided into water surface, water column, and bottom (benthic).
  - Hyporheic Zone: Transition between surface water and groundwater.
    - Phreatic Zone: Groundwater

Rivers and Streams - Physical Conditions

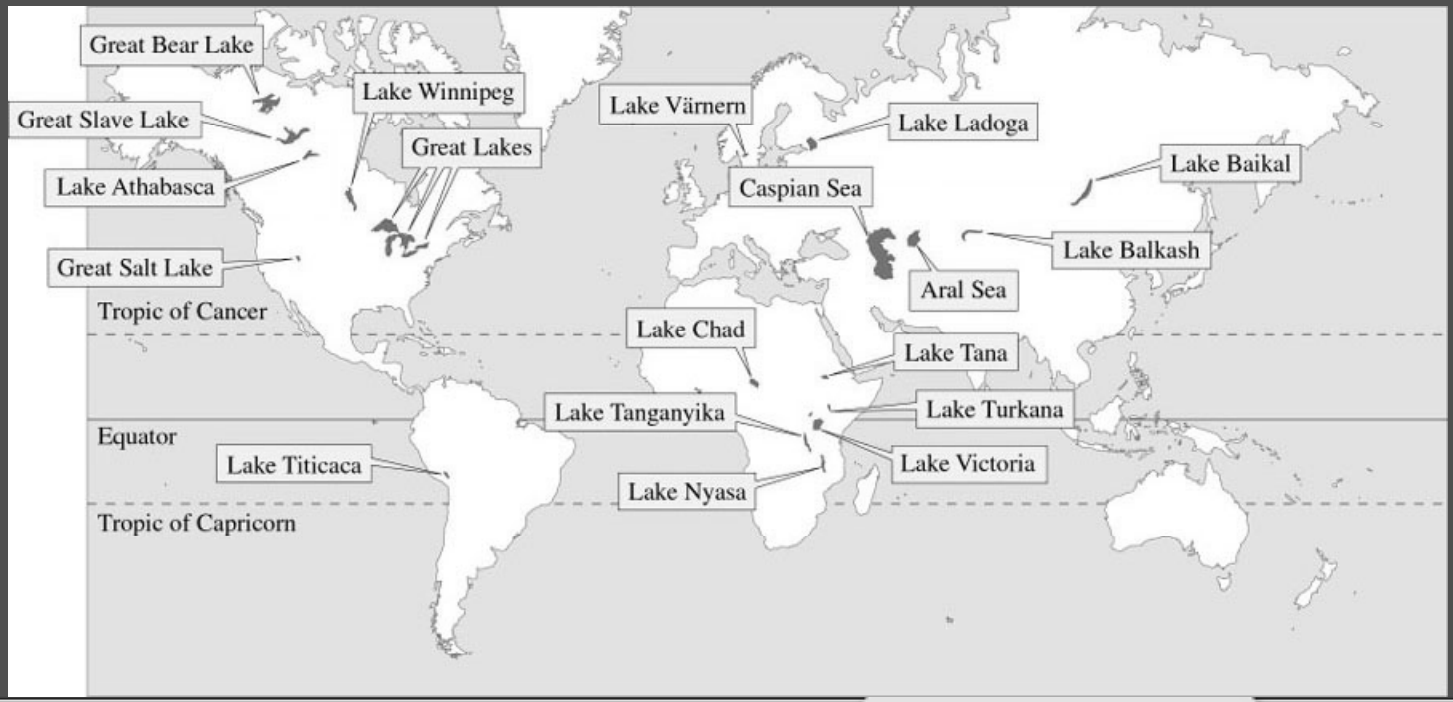
- Light Principles
  - How much light shines on the surface.
  - How far light penetrates the water column.
- Water Movements
  - Erosion from land.
  - Suspended bottom sediments.
- Temperature
  - Closely tracks air temperature.

Rivers and Streams

- Chemical Conditions
  - Salinity
    - Reflects history of leaching in the basin.
  - Oxygen
    - Inversely correlated with temperature.
      - Usually not limiting in river systems.
- Human Influence
  - Long, intense history of human use.
    - Transportation, Irrigation, Waste Disposal.

Lakes

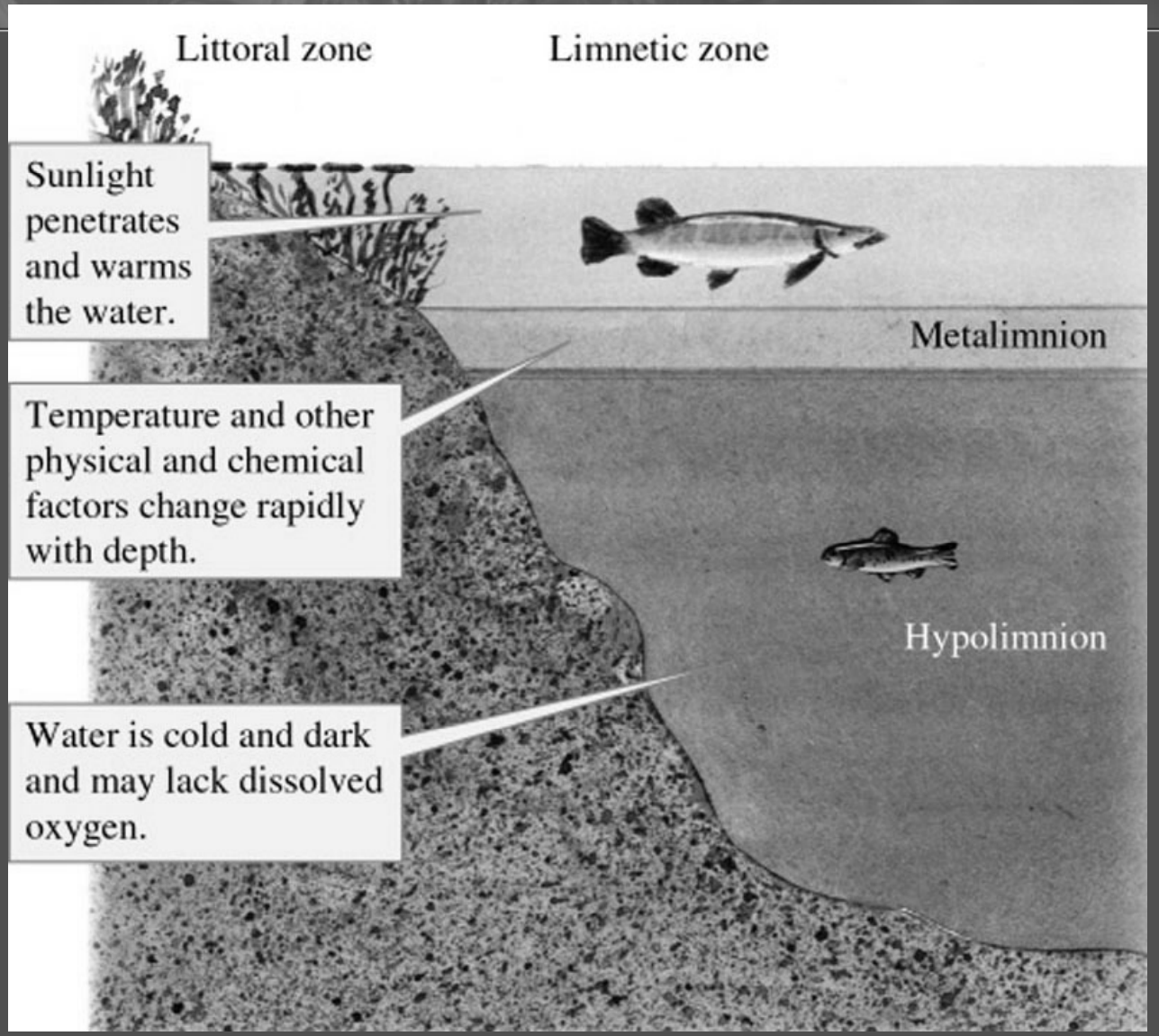
- Most of the world's freshwater resides in a few large lakes.
  - Great Lakes of North America contain 20% of freshwater in the world.



Lakes - Structure

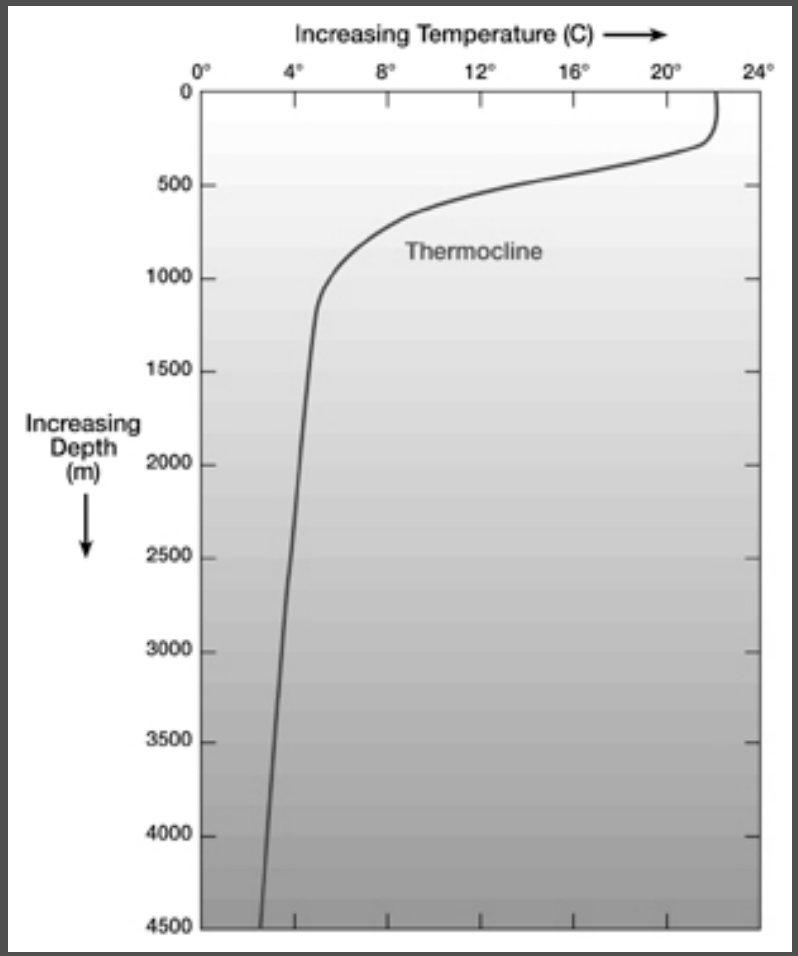
- Structure
  - Littoral zone: Shallows
  - Limnetic zone: Open lake
    - Epilimnion: Warm surface layers.
    - Metalimnion: Temperature changes with depth.
    - Hypolimnion: Cold dark waters.

Lake Structure

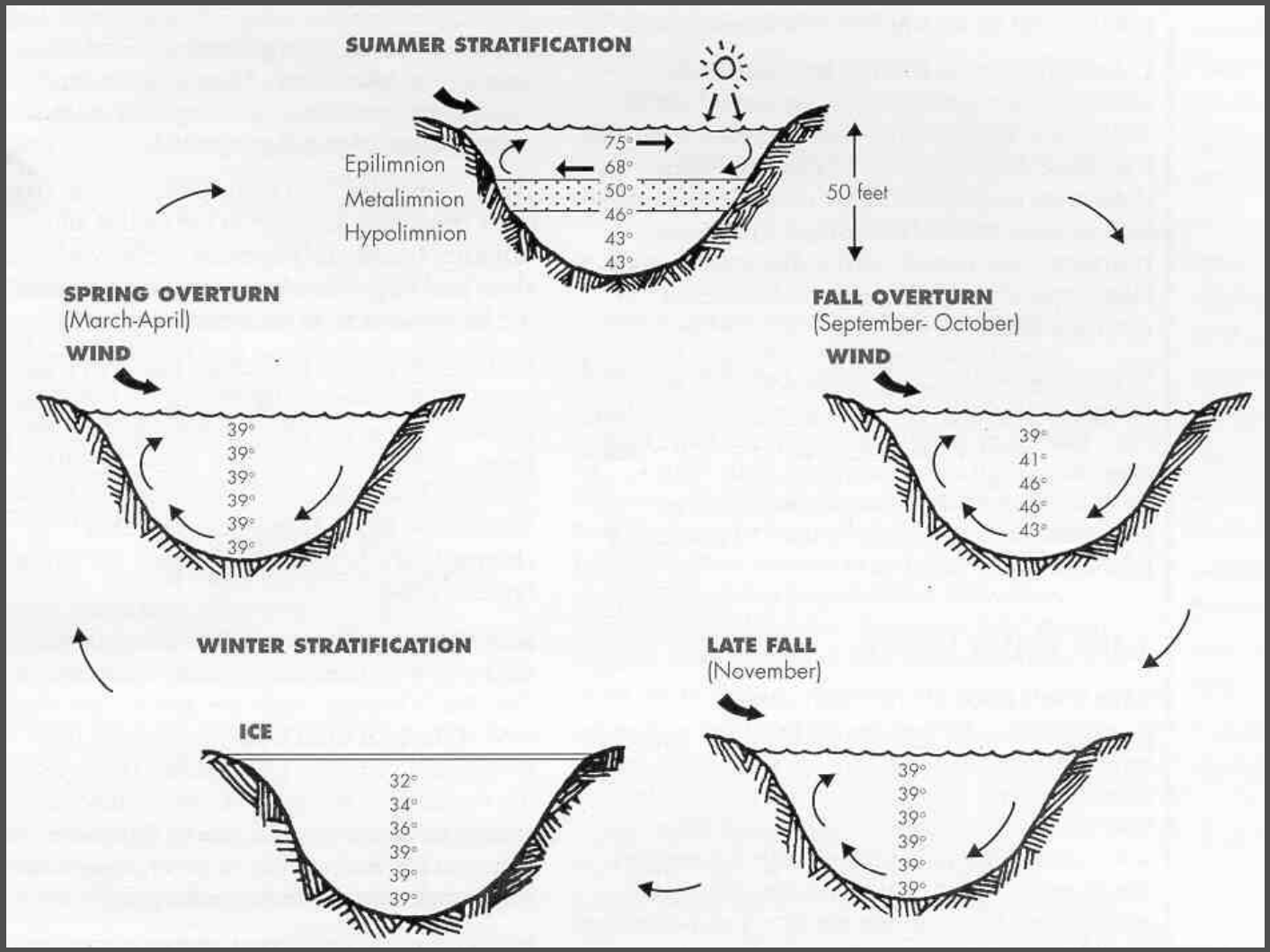


Lakes - Physical Conditions

- Light
  - Lake color depends on light absorption and biological activity.
- Temperature
  - Lakes become thermally stratified as they warm.
- Water Movement
  - Wind-driven mixing of the water column is ecologically important.


Increasing Temperature (C)
0°
4°
8°
12°
16°
20°
24°
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Thermocline
Increasing Depth (m)

Seasonal Temperature Changes



Lakes - Chemical Conditions

- Oxygen
  - Oligotrophic: Low biological production, although often well oxygenated.
  - Eutrophic: High biological production, but may be depleted of oxygen.