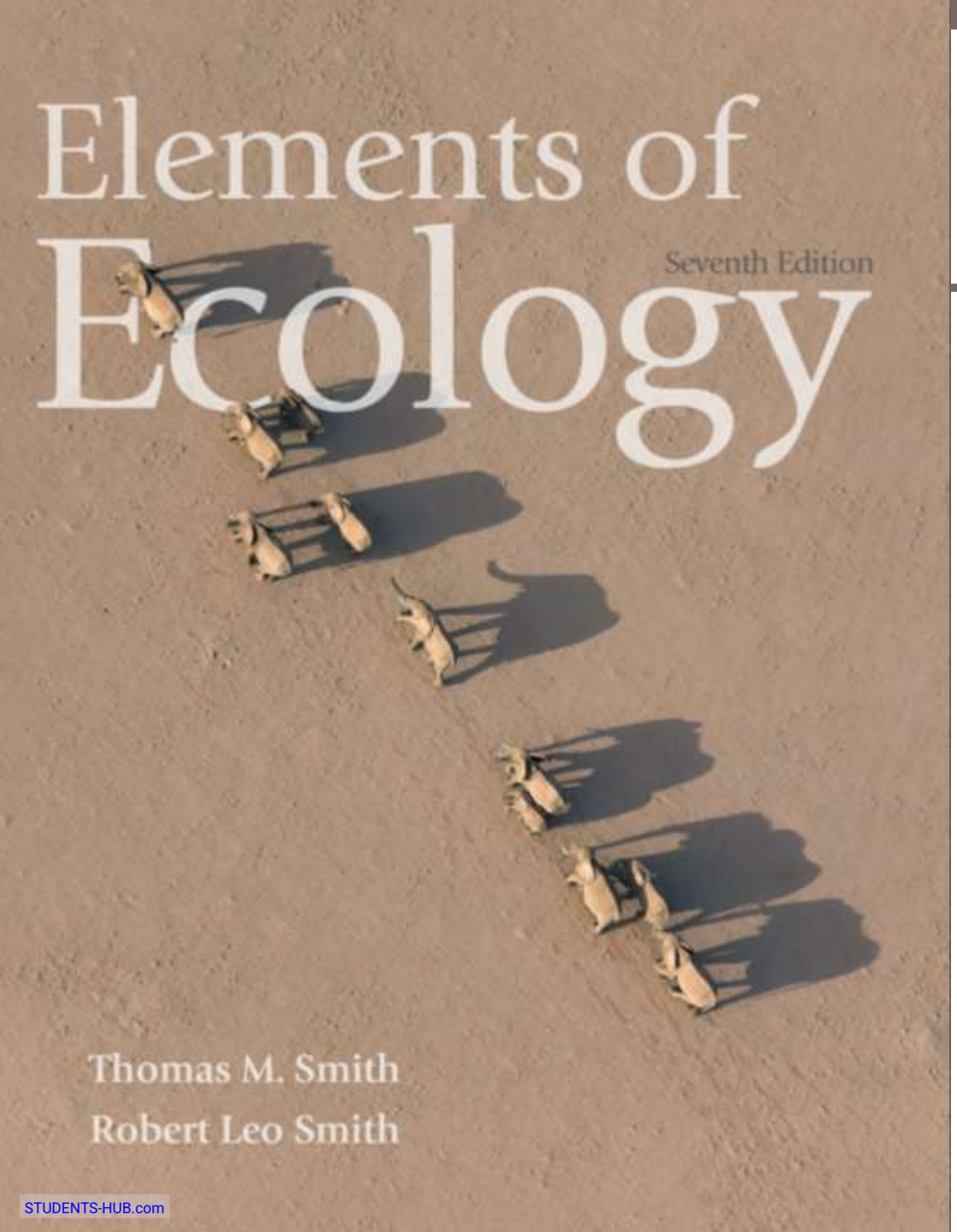


Chapter 3

The Aquatic Environment

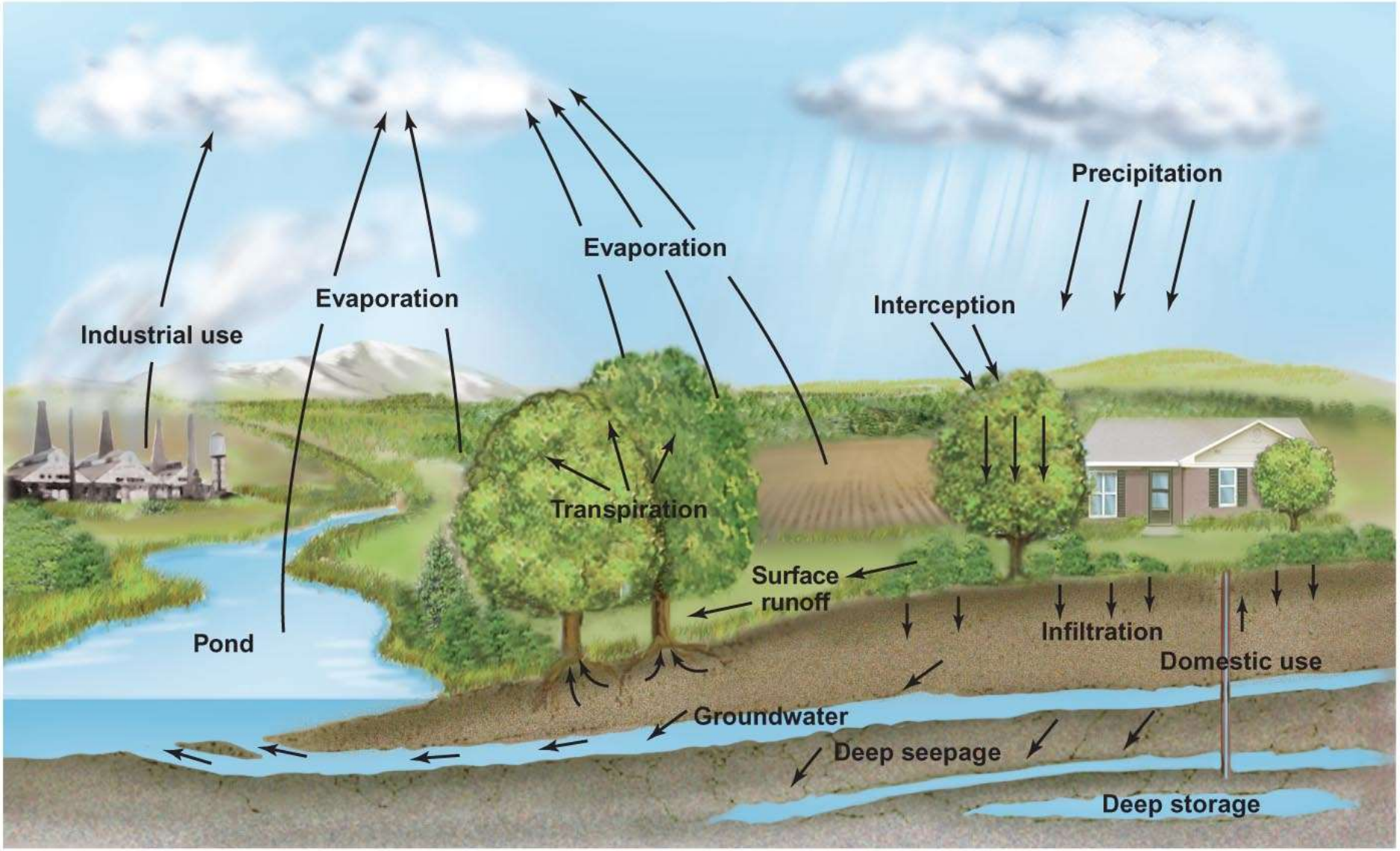
Lecture prepared by
Aimee C. Wyrick

Chapter 3: The Aquatic Environment

- Water is the essential substance of life
- 75 to 95 percent of the weight of all living cells is water.
- Water **covers 75 percent** of the planet's surface and is the dominant environment on Earth
- Aquatic environment includes:
  - **a) Saltwater (marine)**
  - **b) Freshwater**

3.1 Water Cycles between Earth and the Atmosphere

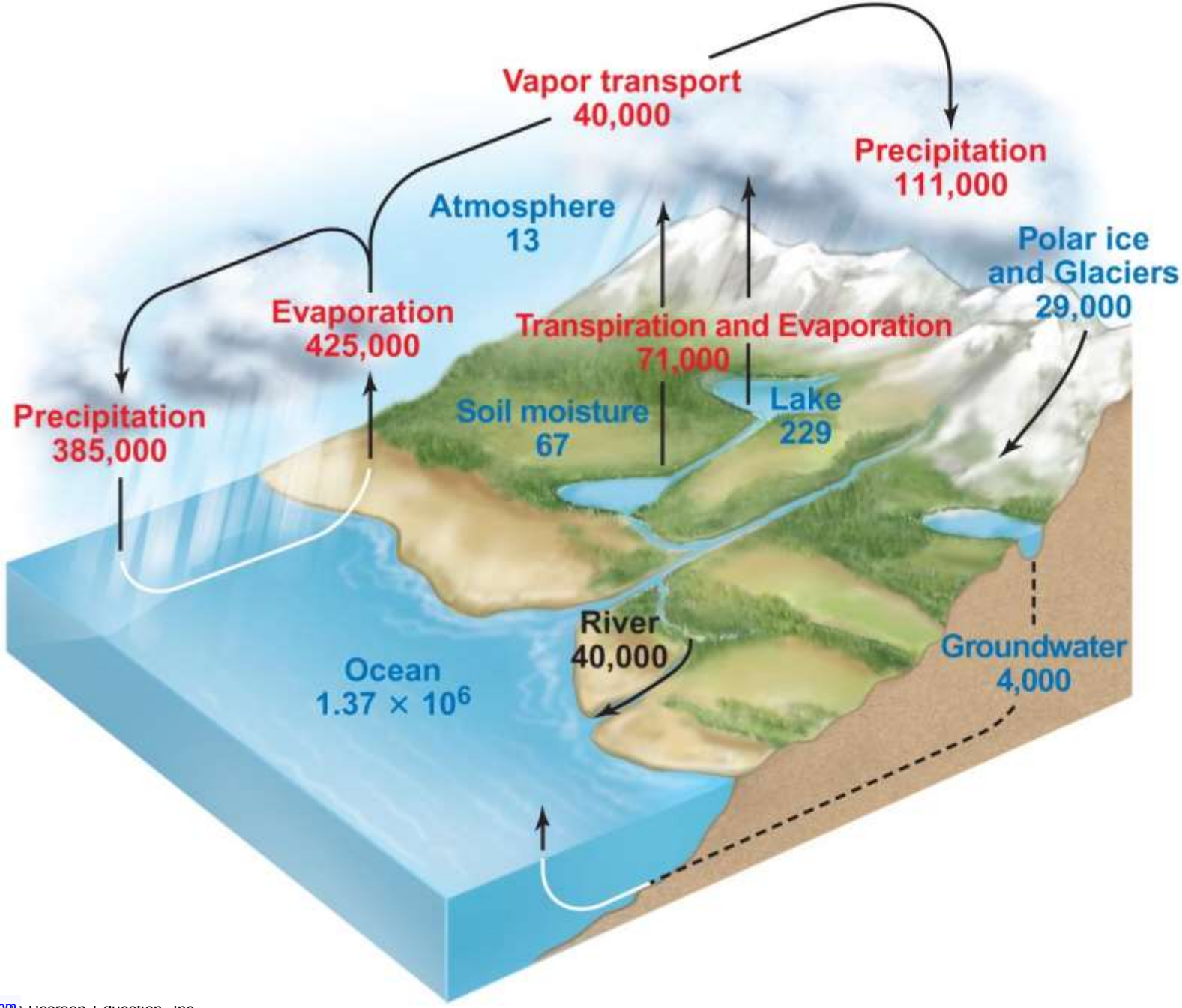
- The **water** (or **hydrologic**) **cycle** *is the process by which water travels in a sequence from the air to Earth and returns to the atmosphere.*
- **Solar radiation** is **the driving force** behind the water cycle because it provides energy for the evaporation of water.



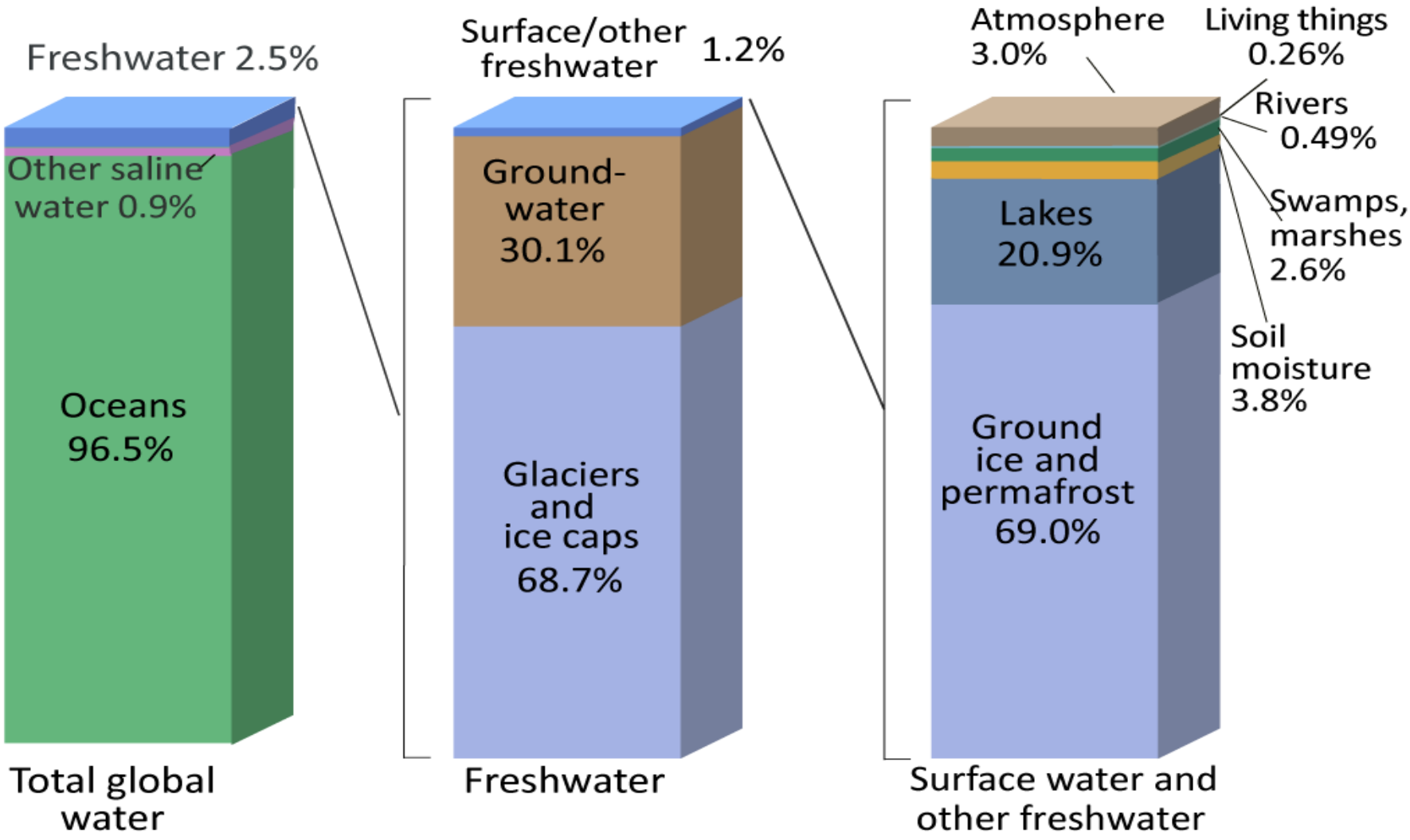
- **Water vapor** in the atmosphere eventually falls in some form of **precipitation.**
- **Interception** occurs when precipitation falls onto vegetation, dead organic matter, and urban structures or streets.
- This water **evaporates directly** back to the atmosphere

- Precipitation that reaches the soil moves into the ground by **infiltration.**
- **Surface runoff** of this water occurs when the soil is saturated.
- The water that seeps down to an impervious layer of rock collects as **groundwater.**

- **Evapotranspiration** *is the total amount of evaporating water.*
  - Surficial water in terrestrial and aquatic environments returns to the atmosphere **by evaporation**.
  - **Transpiration** is the evaporation of water from the internal surfaces of plants



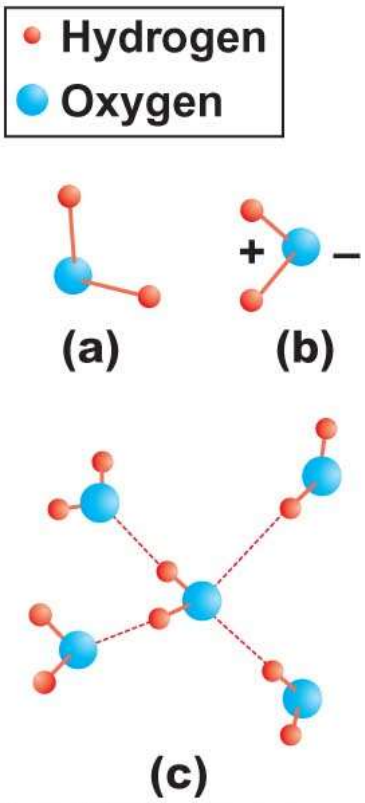
Where is Earth's Water?



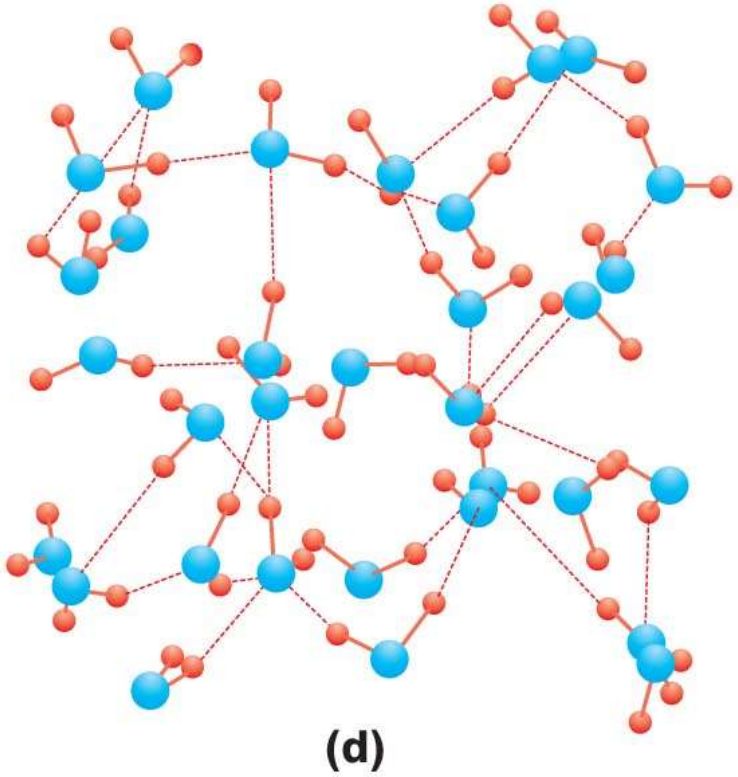
Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources. (Numbers are rounded).

3.2 Water Has Important Physical Properties

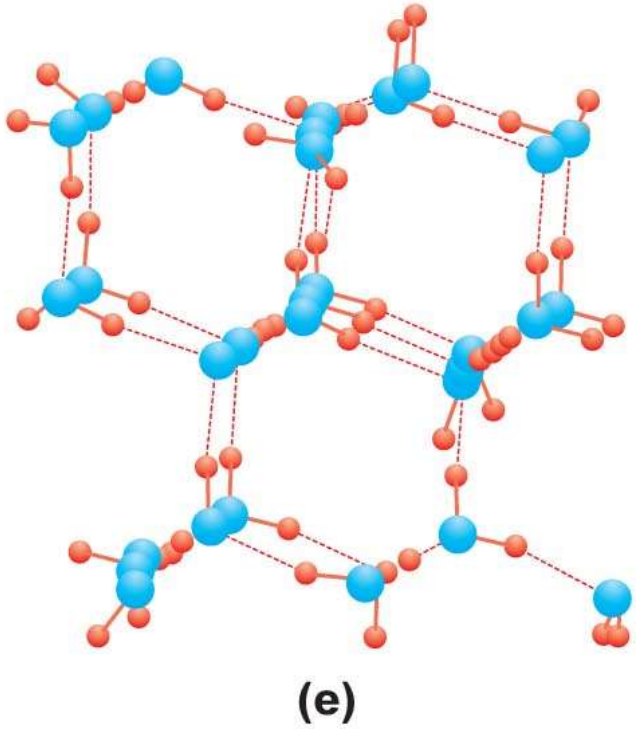
- In water (H_2O), the atoms are asymmetrically bound to one another.
- The hydrogen atoms share an electron with the oxygen atom through a **covalent bond.**
  - Because electrons are unequally shared and spend more time around oxygen, water is considered a **polar** molecule.
- Because of their polarity, water molecules bond with one another due to hydrogen bonding.



hydrogen Bonding



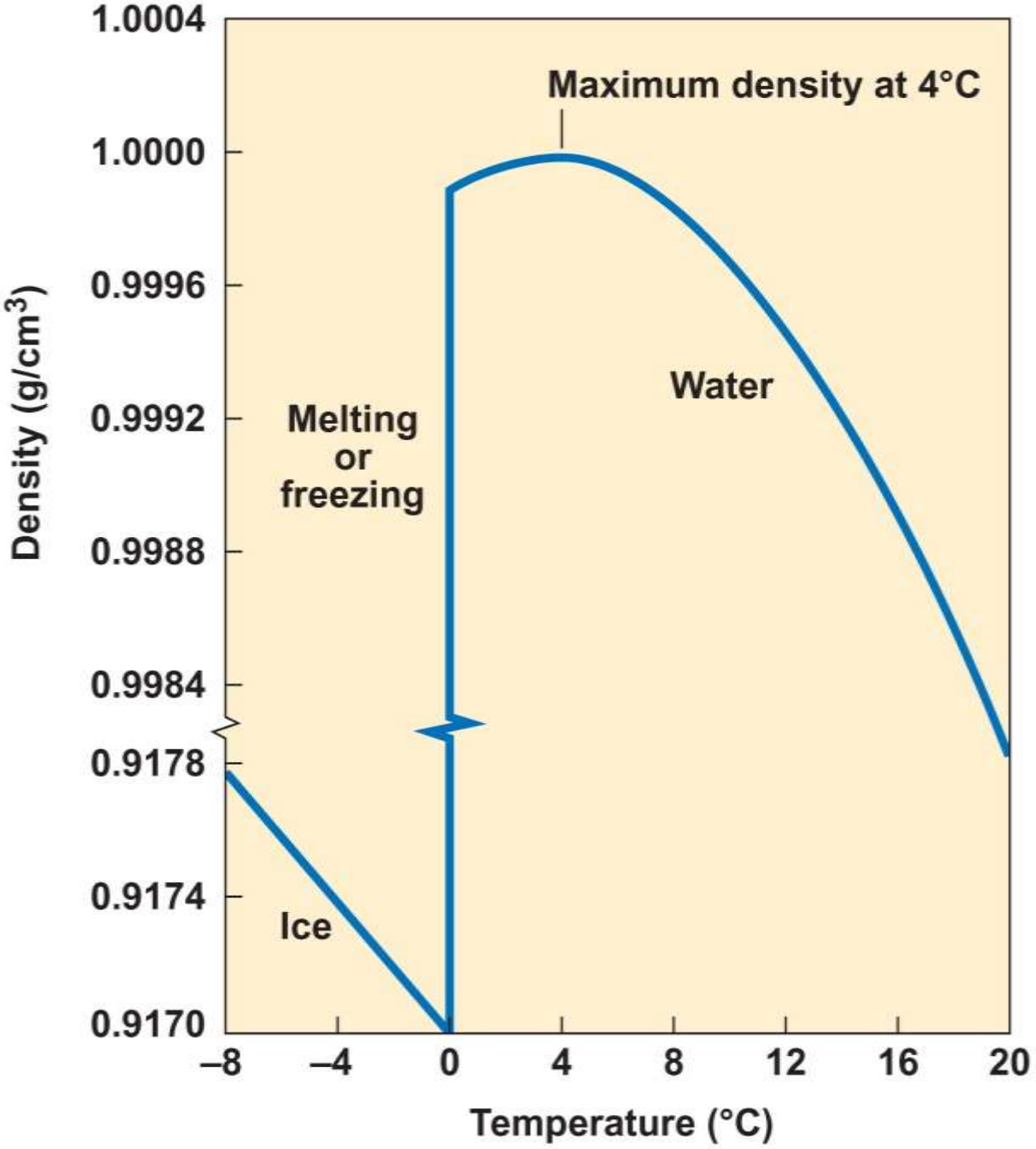
Liquid water



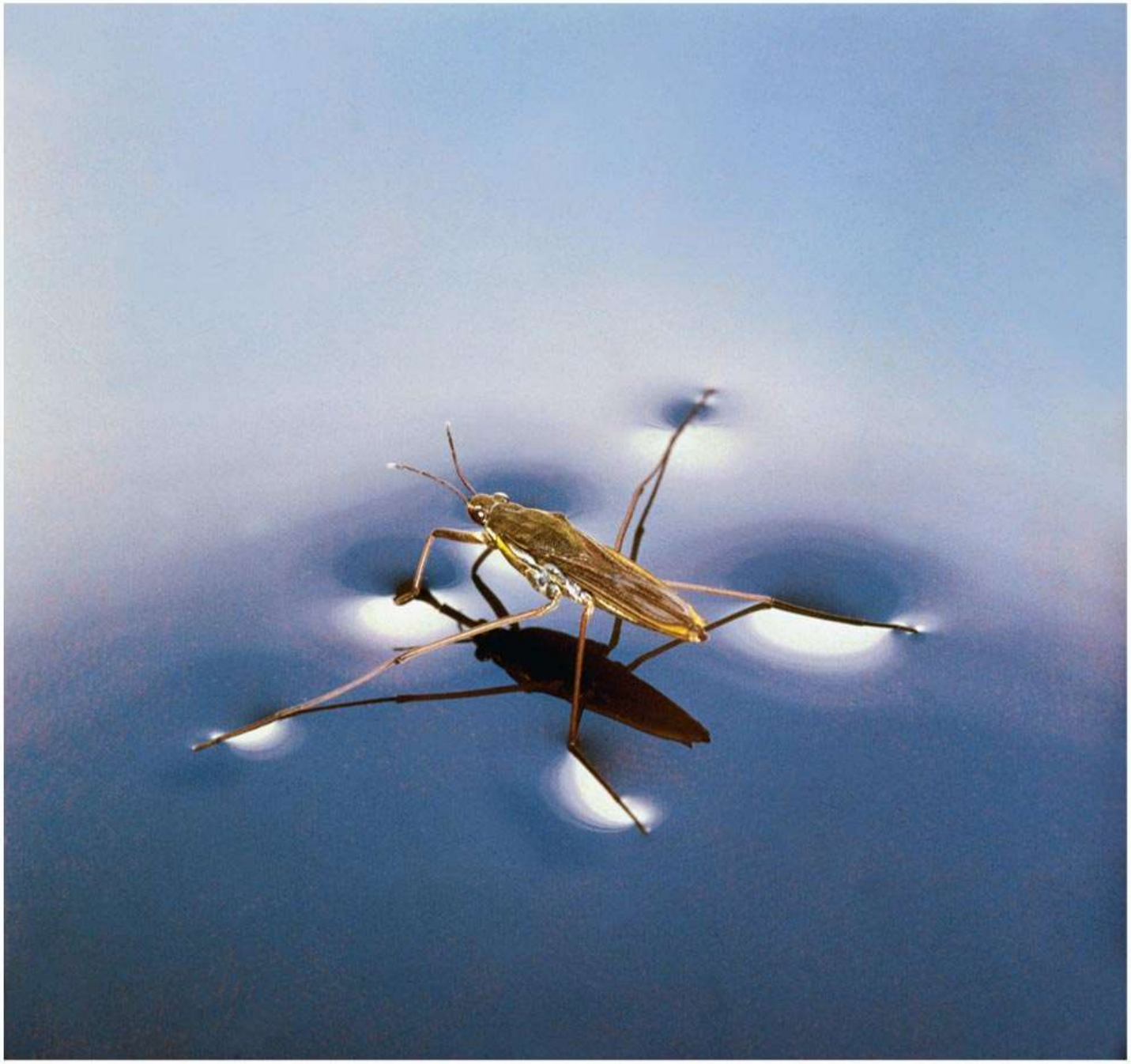
Ice Crystals

- Water has **unique properties** that are related to the hydrogen bonding between and among water molecules.
- **Specific heat** of water = **1**
  - **Specific heat** *is the energy (measured in calories) required to raise 1 gram of water 1°C.*
- Water must absorb (or lose) great quantities of heat to change its temperature.
  - This helps to buffer aquatic habitats and is important for thermal regulation within living organisms

- Water molecules in solid form (ice) are spaced farther apart (have more space) than water molecules in liquid.
- Therefore, water becomes less dense as it converts from liquid to solid.
  - This allows for **insulation of water bodies** so that they do not freeze solid.



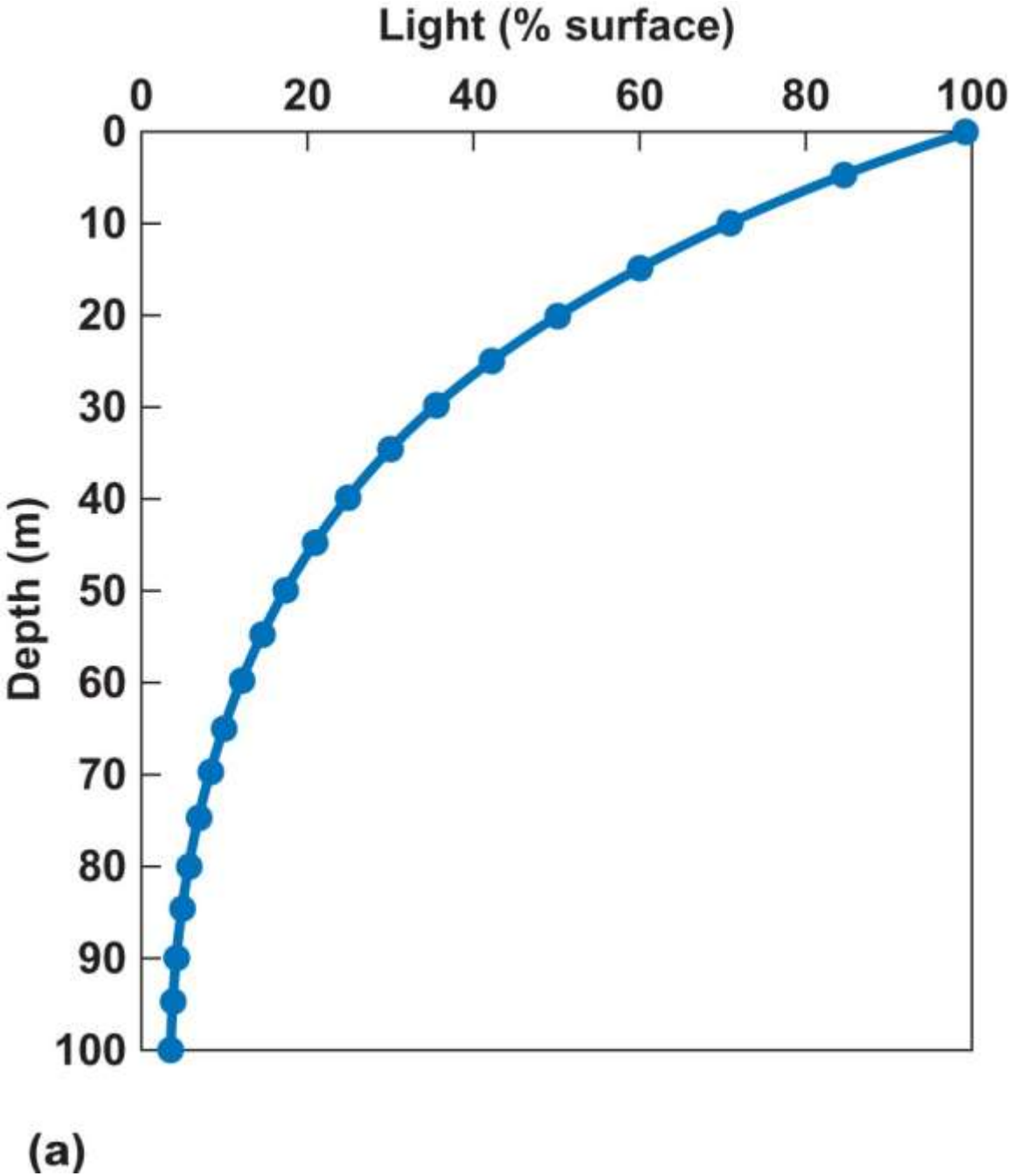
- **Cohesion** *is the linkage between and among water molecules due to hydrogen bonding*
- **Surface tension** *of water is the result of differences in attraction among water molecules between the surface of the water and air*
  - The surface of water is able to support small organisms



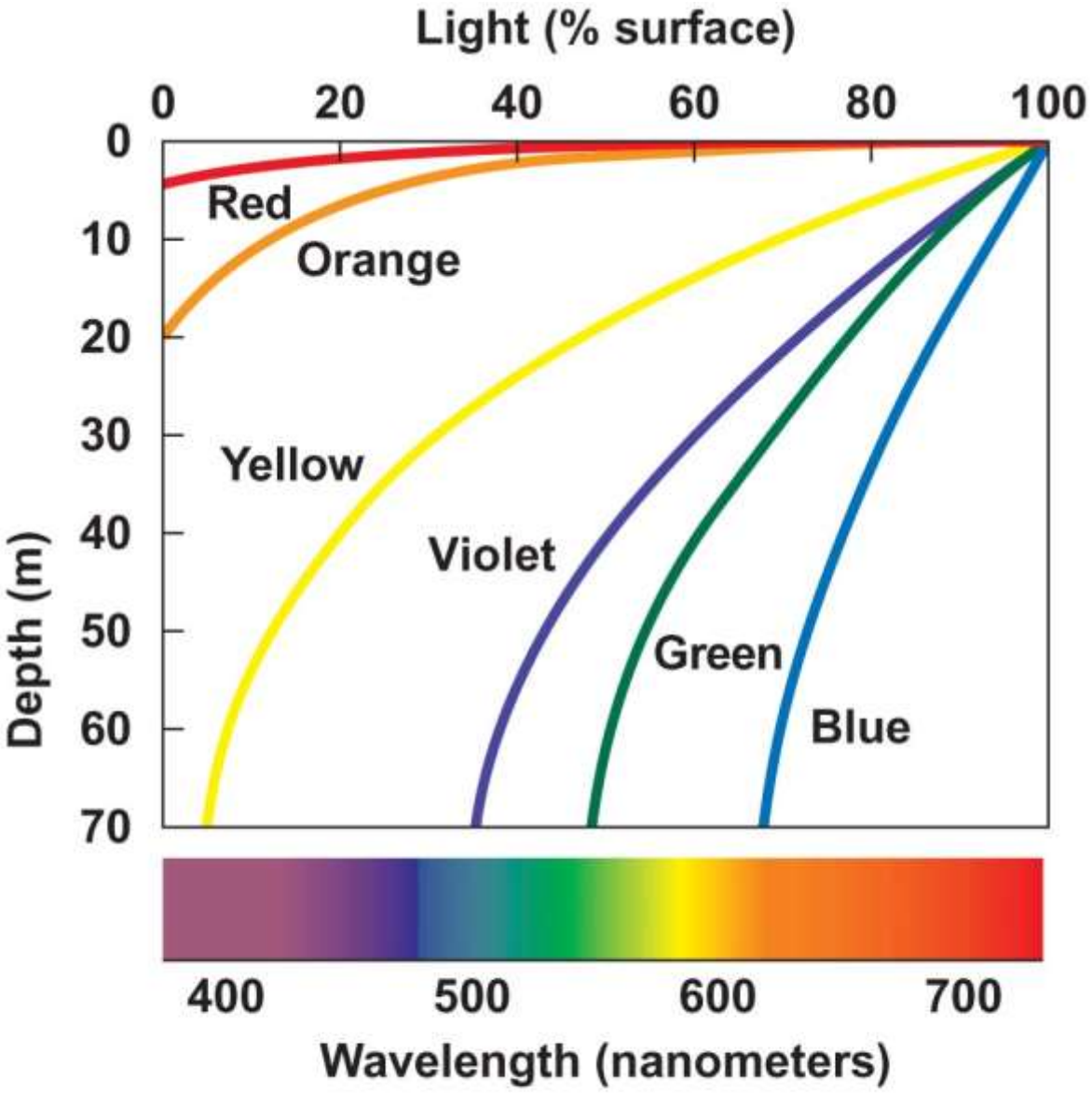
- **Viscosity** *is the property that measures the force necessary to separate the molecules. For water it is related to cohesion.*
- Aquatic organisms must cope with the frictional resistance of water and overcome viscosity
  - The frictional resistance of water is 100 times greater than air!
- Water has a high viscosity due largely to its greater density (860 times that of air!)
  - Aquatic organisms experience **buoyancy** in water because of the upward force of water acting on the less dense object

3.3 Light Varies with Depth in Aquatic Environments

- Some of the **light** that strikes the **surface of water is reflected**; the amount of light reflected is related to the angle of light.
- As **light enters the water** surface, it is intercepted and subsequently **absorbed** or **scattered** by suspended particles and water.



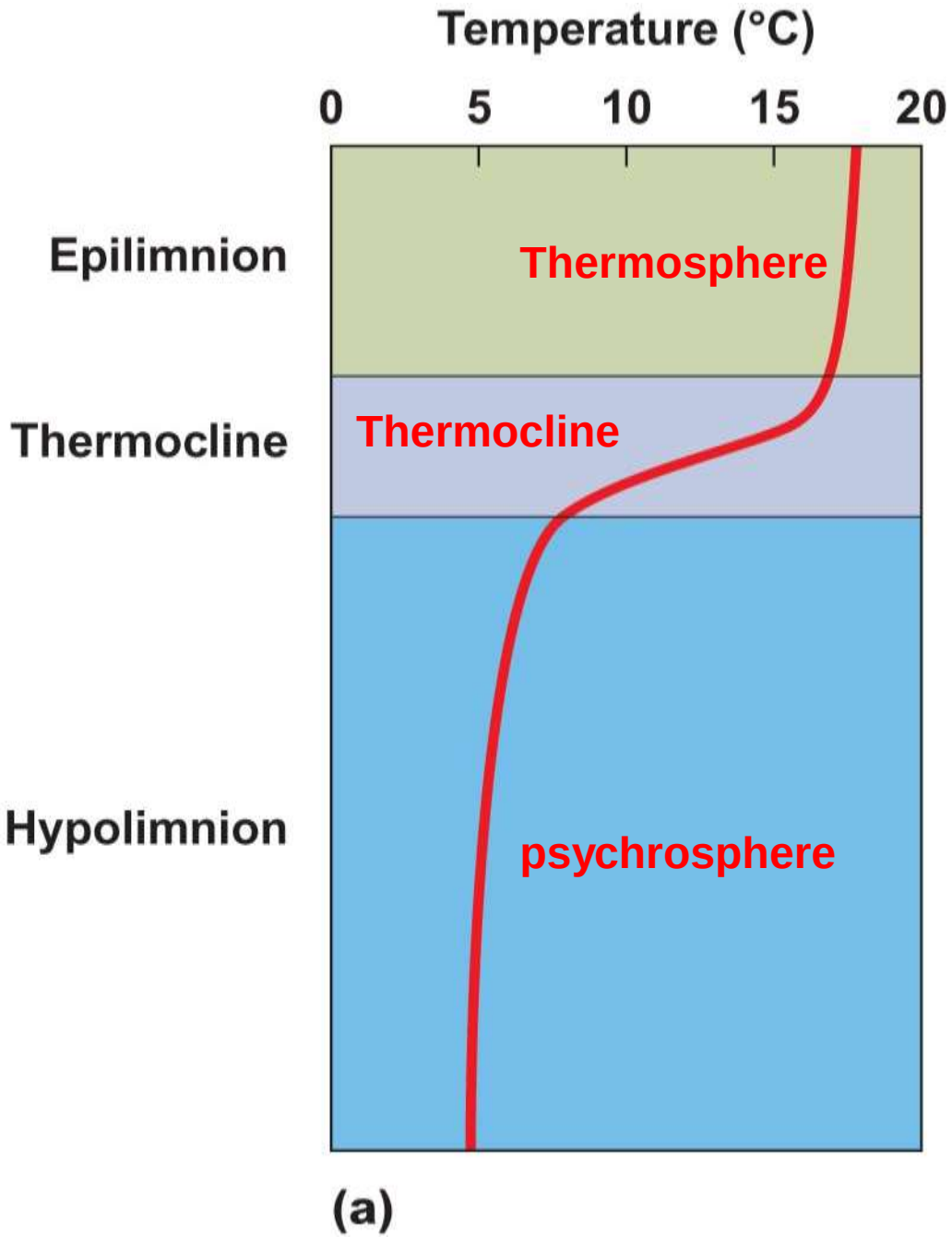
- Water absorbs some wavelengths of visible light more than others.
- Longer wavelengths (red light) are absorbed first. Blue wavelengths alone penetrate the depths.
- The pattern of light absorption in water gives rise to unique adaptations in aquatic organisms:
  - *Body color or lack of pigmentation.*
  - *Large eyes.*
  - *Bioluminescence*.

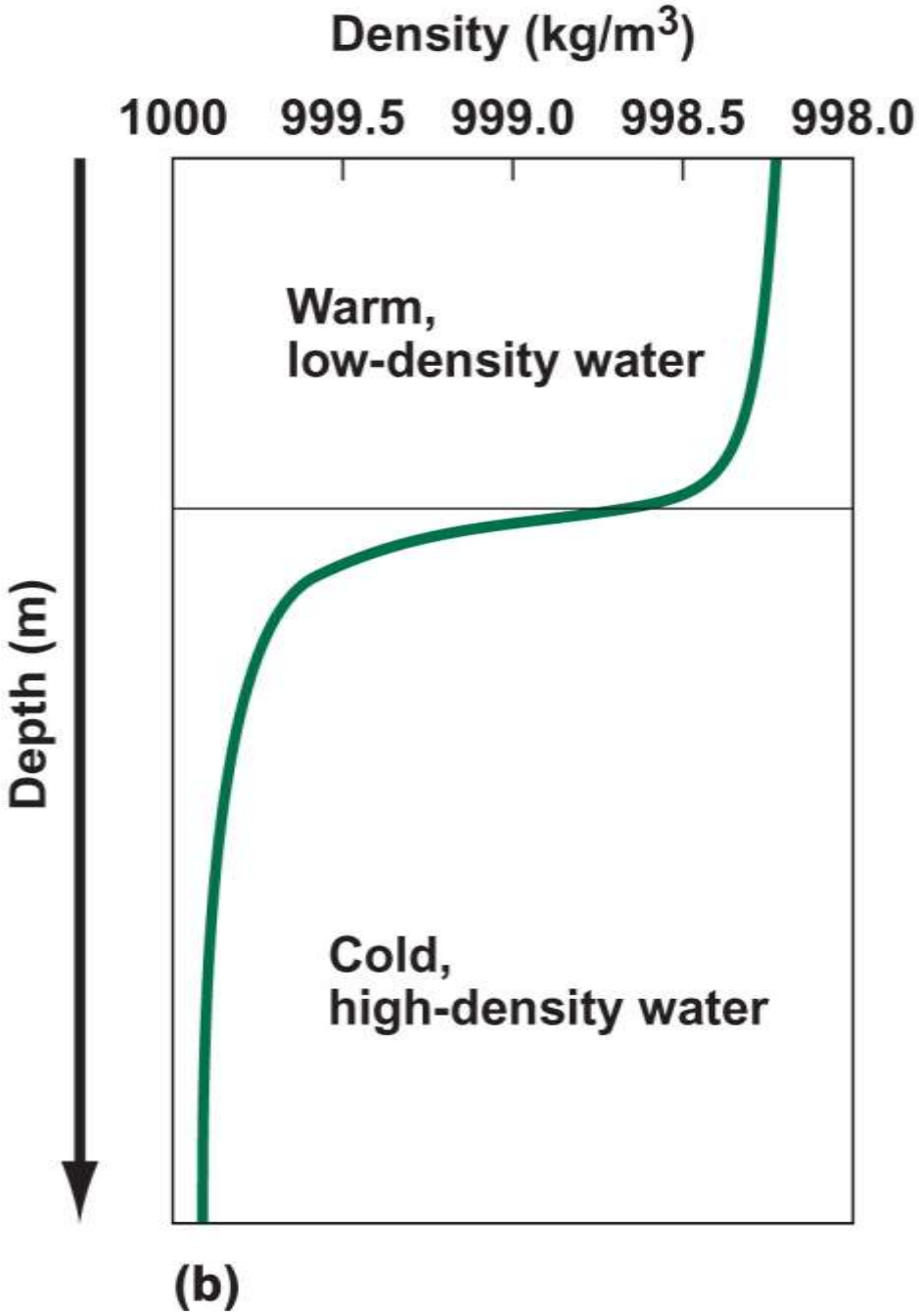


(b)

3.4 Temperature Varies with Water Depth

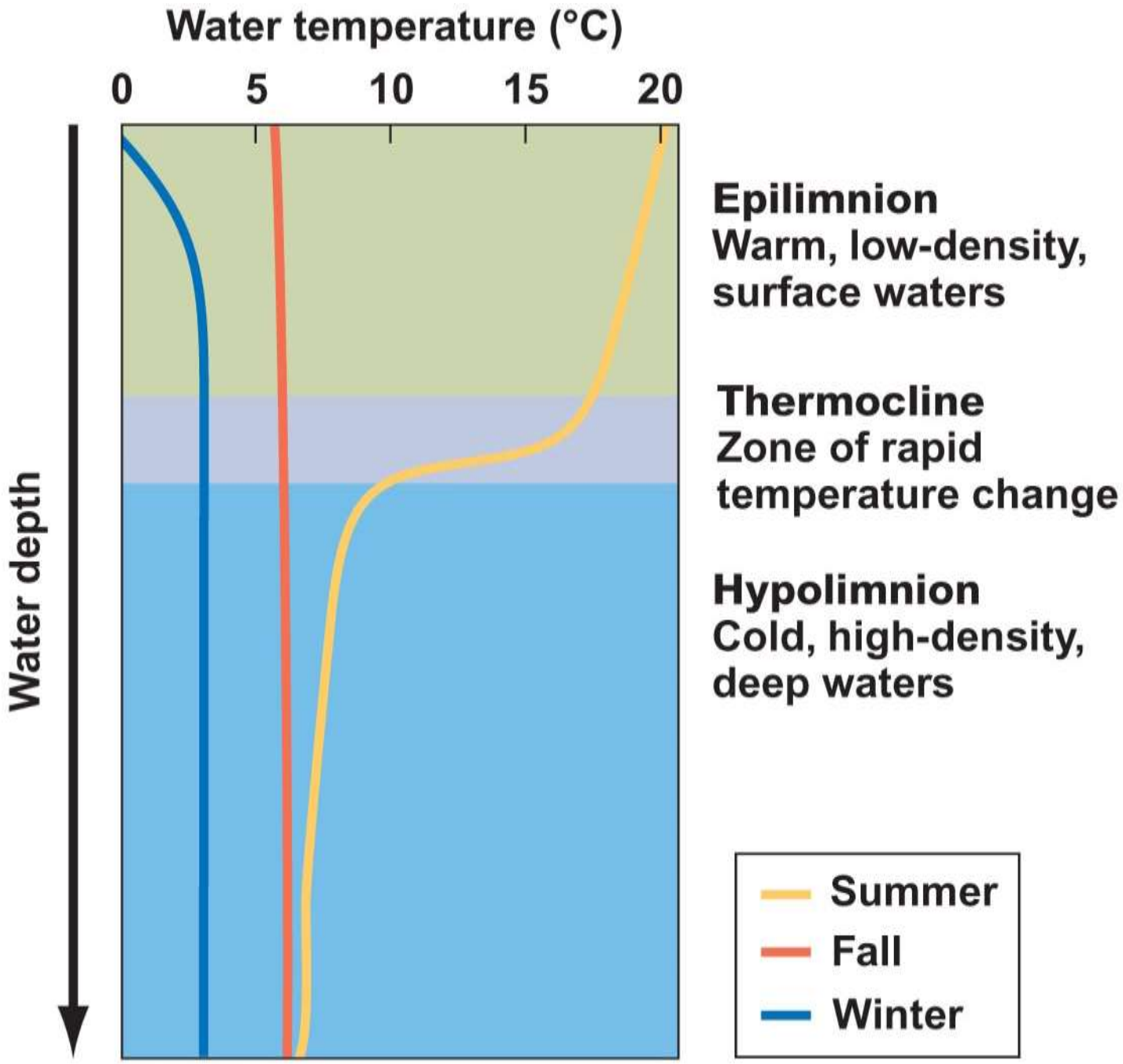
- As sunlight is absorbed in the surface waters, it heats up.
- **Heat is distributed** vertically as winds and surface waves mix.
- The decrease in water temperature as one moves from the surface into the depths does not follow the same pattern as light attenuation





- The **thermocline** *is the region of the vertical depth profile where water temperature declines most rapidly.*
  - The thermocline depth depends on solar radiation input and level of mixing.
- The thermocline is located between the **epilimnion** (warm, lighter water above) and the **hypolimnion** (cold, denser water below).

- **Seasonal changes** in the input of **solar radiation** give rise to changes in the vertical depth profile of water temperature
- The position of the **thermocline is permanent in tropical waters**
- In temperate zones, many larger bodies of water experience a mixing of the epilimnion and hypolimnion in the **fall** and **spring (spring and Fall Overturns)**



3.5 Water Functions as a Solvent

- A **solution** *is a liquid with a homogeneous mixture of two or more substance.*
- The **solvent** is the dissolving agent and **solute** is the substance dissolved.
  - An **aqueous solution** has water as the solvent
- Water can dissolve more substances than any other liquid. This is crucial to biological systems.

- Water's **dissolving "power"** is a result of its polarity.
- Every water molecule has a positive and negative side so it is attracted to other charged atoms and molecules (**ions**).
- Water dissolves other **polar substances**.

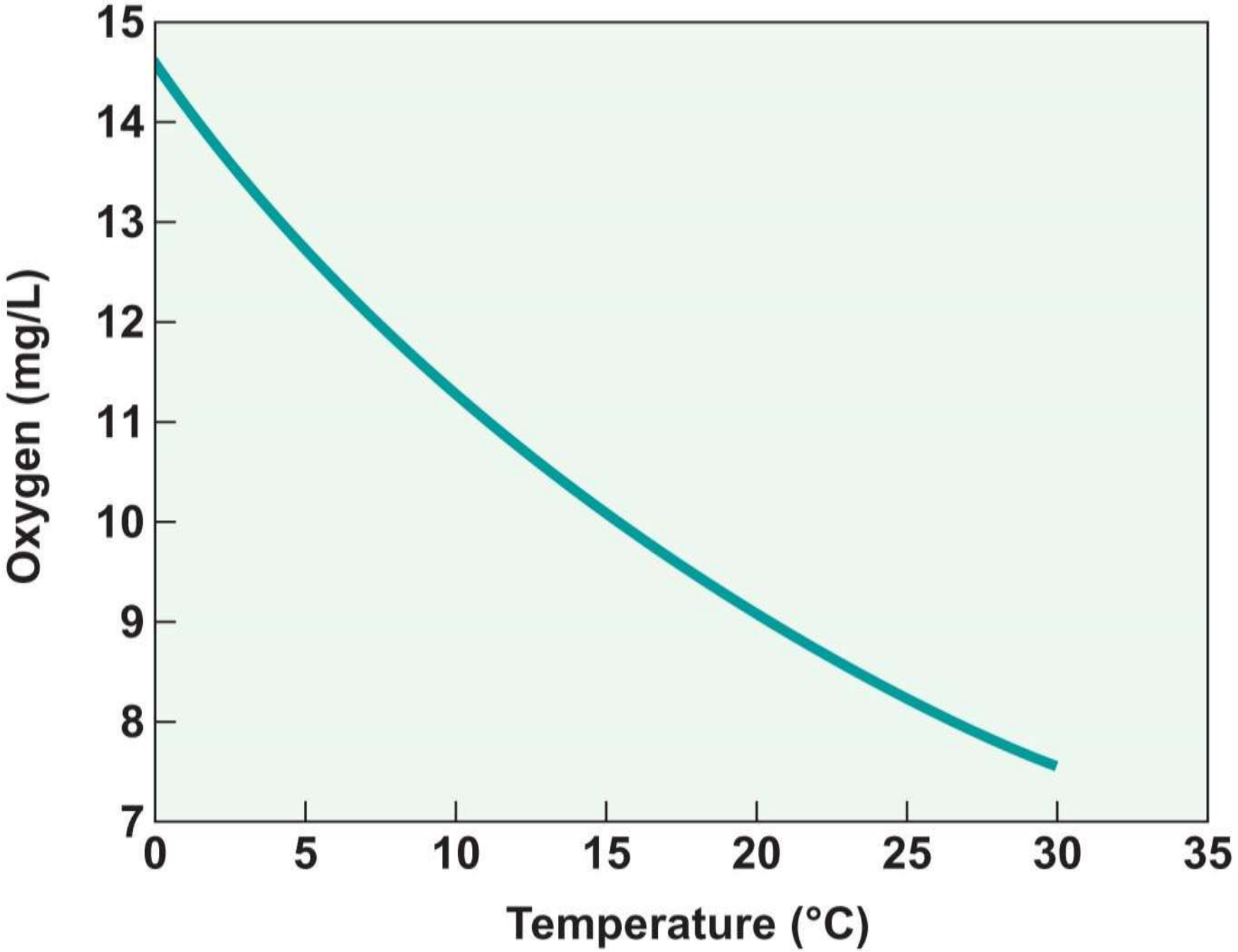
- The solubility of sodium chloride (NaCl) is very high and accounts for **most of the *solutes* (ions or salts) in seawater.**
- Salinity is determined by an **index of chlorine** (the most abundant *element* in seawater)
- Salinity is expressed in **practical salinity units (psu)** and represented as a percentage
  - Freshwater = 0.065 ‰ to 0.30 ‰
  - Open sea = 35 ‰

Table 3.1 | Composition of Seawater of 35 Practical Salinity Units (psu)

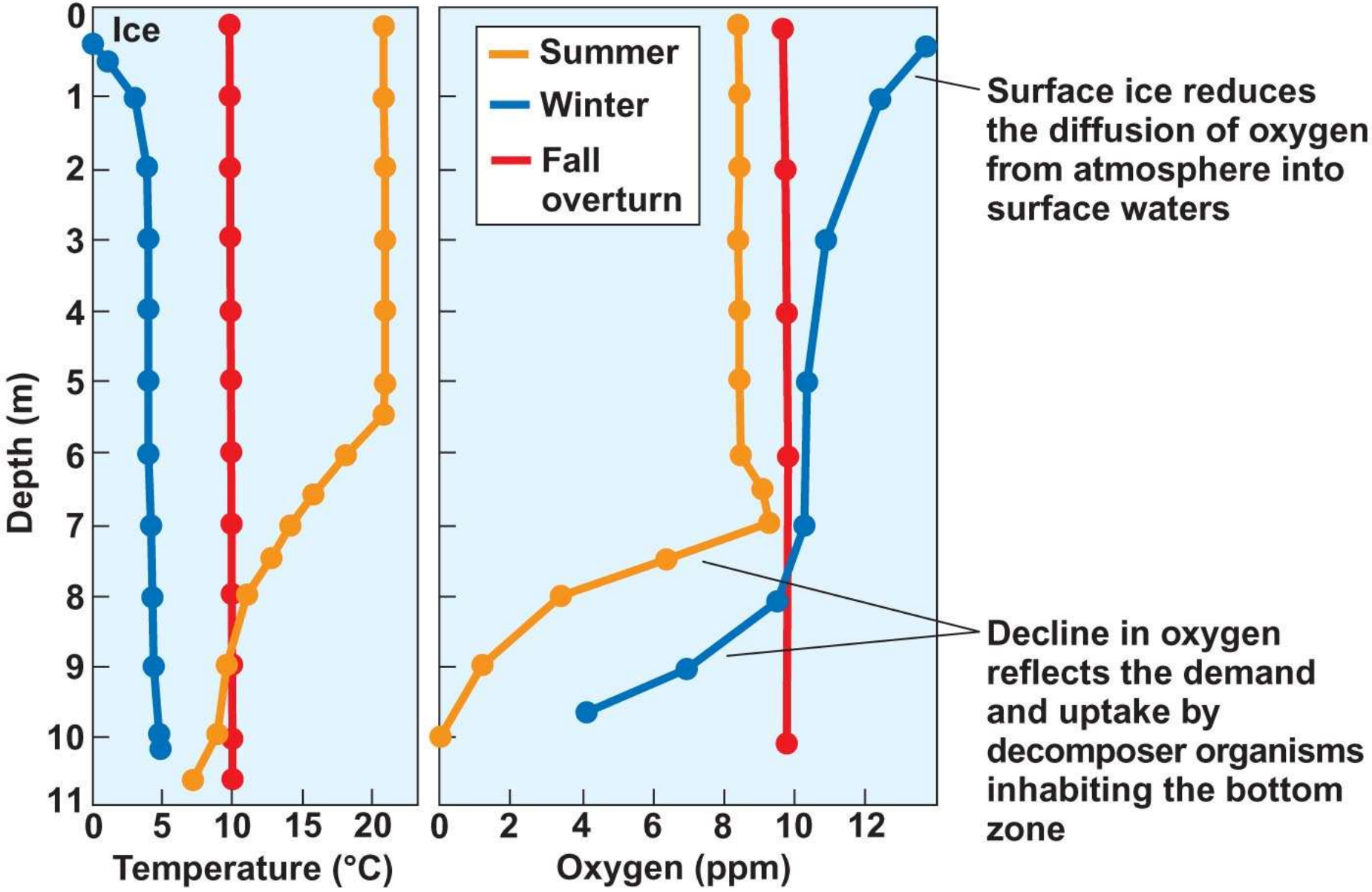
Elements	g/kg	Milli-moles/kg	Milli-equivalents/kg
Cations			
Sodium	10.752	467.56	467.56
Potassium	0.395	10.10	10.10
Magnesium	1.295	53.25	106.50
Calcium	0.416	10.38	20.76
Strontium	0.008	0.09	0.18
			605.10
Anions			
Chlorine	19.345	545.59	545.59
Bromine	0.066	0.83	0.83
Fluorine	0.0013	0.07	0.07
Sulfate	2.701	28.12	56.23
Bicarbonate	0.145	2.38	—
Boric acid	0.027	0.44	—
			602.72

3.6 Oxygen Diffuses from the Atmosphere to the Surface Waters

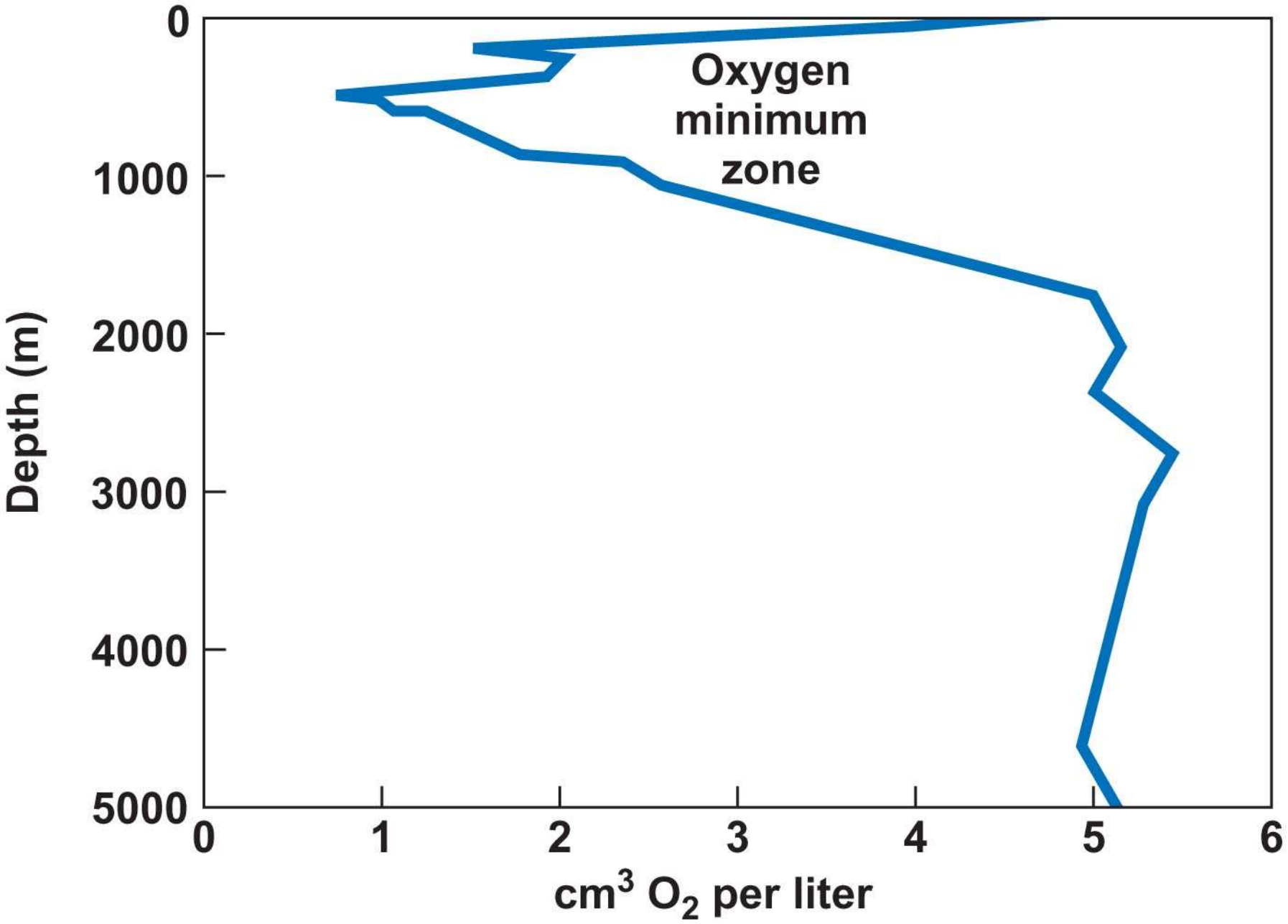
- **Diffusion** *is the general tendency of molecules to move from a region of high concentration to one of lower concentration.*
- Oxygen (and carbon dioxide) diffuse from the atmosphere into the surface waters of aquatic environments.
  - The rate of diffusion is dependent on the solubility of oxygen (greater in cold water) and the diffusion gradient



- Oxygen diffuses from the surface to the waters below.
- Oxygen may become **stratified** in lakes and ponds during the summer:
  - Warm water holds less oxygen
  - Both the atmosphere and aquatic plants are oxygen sources
  - Winds mix oxygen-rich water with oxygen-poor water
  - Oxygen demand by organisms decreases with depth



- **Oxygen is not distributed uniformly** within the depths of the ocean:
  - ***Maximum oxygen levels are found in the upper 10 to 20 meters***



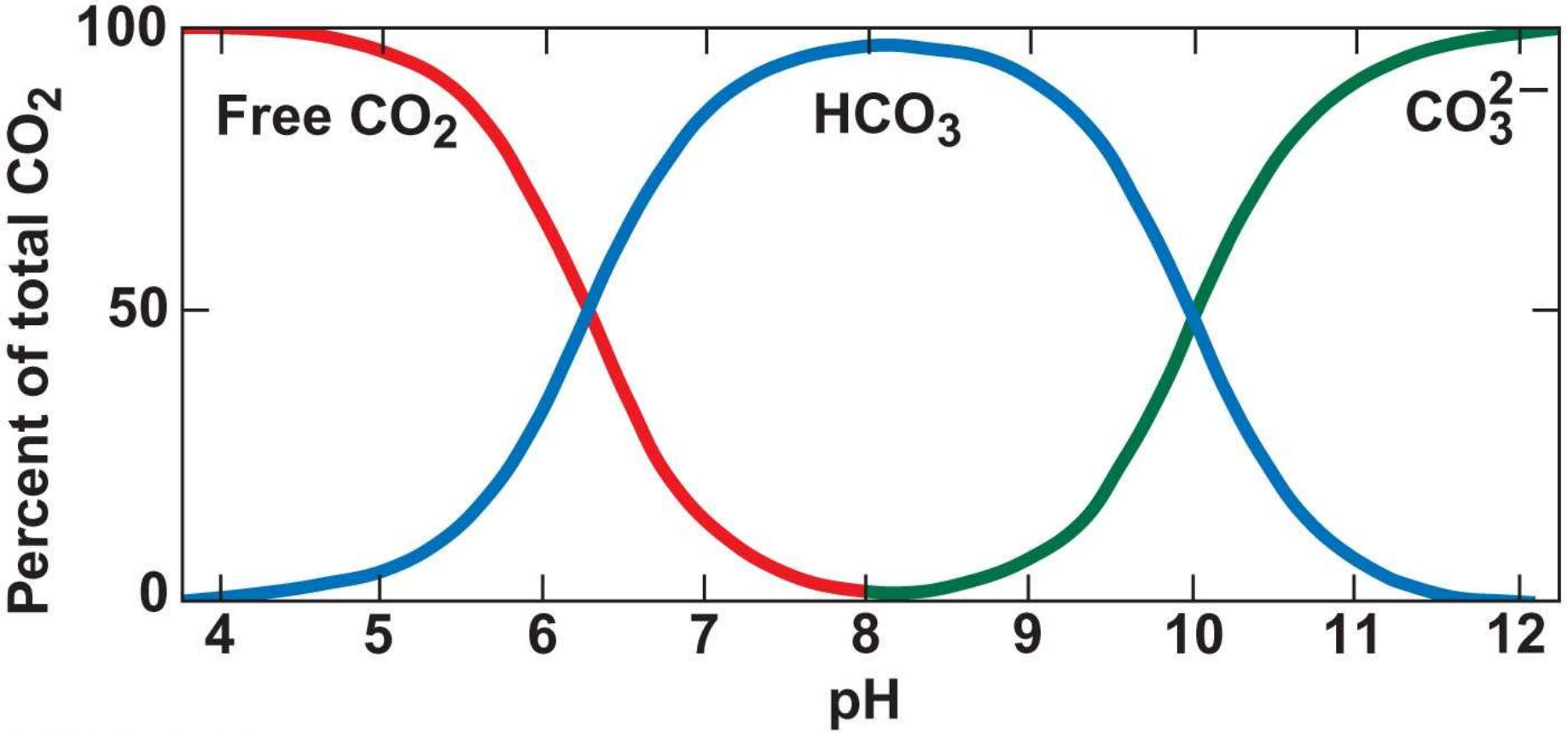
- The oxygen content of flowing water is high due to the greater contact of water with the atmosphere.
- Even at saturation levels, the supply of oxygen in aquatic environments is meager when compared with the supply in the atmosphere.
- Concentration of oxygen is a **limiting factor for aquatic organisms.**

3.7 Acidity Has a Widespread Influence on Aquatic Environments

- Water has a considerable capacity to absorb carbon dioxide:
  - **CO_2** (carbon dioxide) + **H_2O** (water) ↔ **H_2CO_3 (carbonic acid)**
  - H_2CO_3 ↔ **HCO_3^- (bicarbonate)** + H^+ (hydrogen ion)
  - HCO_3^- ↔ + H^+ + **CO_3^{2-} (carbonate)**
- The carbon dioxide–carbonic acid–bicarbonate system tends to stay in equilibrium.
- These reactions result in the production and absorption of H^+.

- The abundance of hydrogen ions in solution is a measure of acidity
  - *The greater the number of H^+ ions, the more acidic the solution*
- Alkaline solutions have a high concentration of **hydroxyl ions (OH^-)** and **few H^+ ions**
- **$pH = -\log_{10} [H^+]$**
  - The pH scales ranges from **1 (acidic) to 14 (alkaline).**
  - A **neutral pH (7)** results when $[H^+] = [OH^-]$

- The dynamics of the carbon dioxide–carbonic acid–bicarbonate system directly affects the pH of aquatic ecosystems.
  - This system generally acts as a buffer and keeps the pH of water within a narrow range.
- **The pH of natural waters = 2 to 12**
  - pH is higher in watersheds dominated by limestone (supplies CO_3^{2-})



- **The pH** of aquatic environments influences distribution and abundance of organisms by affecting:
  - **Physiological processes.**
  - **Concentration of toxic metals**
    - *Aluminum dissolves as pH decreases and becomes more concentrated in aquatic environments*

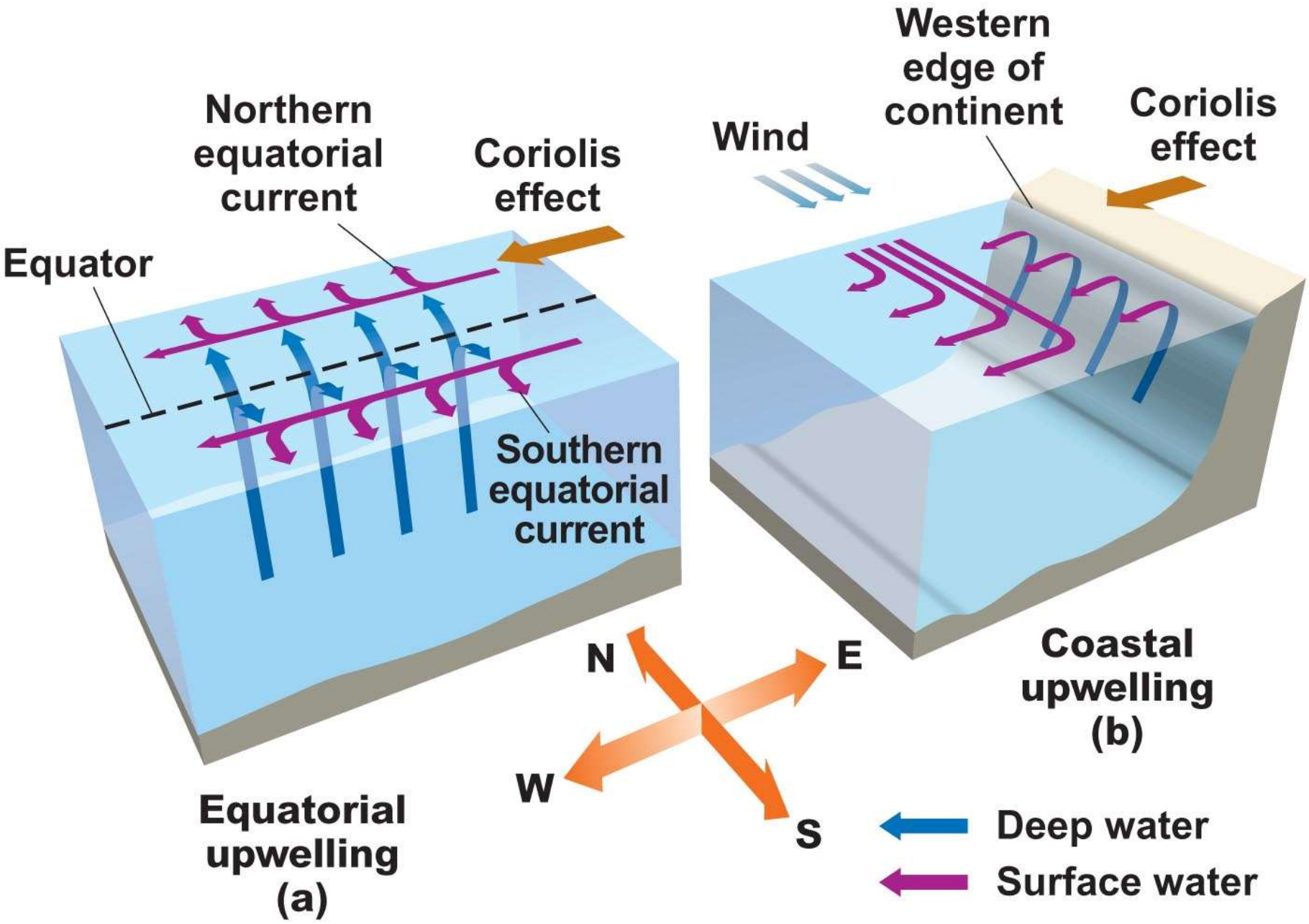
3.8 Water Movements Shape Freshwater and Marine Environments

- Water movements (**currents, waves**) determine the nature of many aquatic environments
- The velocity of a current molds the character and structure of a stream

(a)

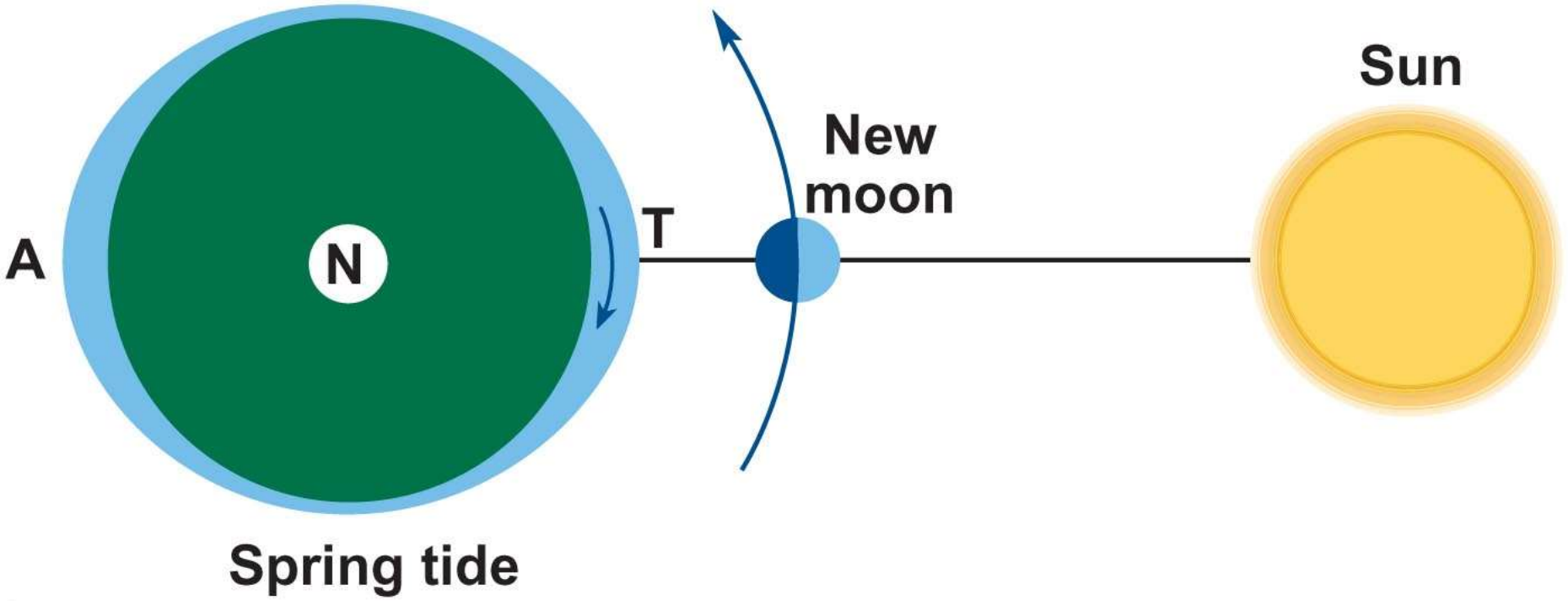
(b)

- **Surface waves are generated by wind**
  - As waves approach land, they encounter increasingly shallow water and eventually break onshore
  - The force of waves removes and deposits substrates (rocks, sand)
- **Deep-water currents result from changes in seawater density, temperature, and salinity**
  - **Upwelling** occurs where deep waters move up to the surface



3.9 Tides Dominate the Marine Coastal Environment

- Tides result from the gravitational pulls of the **Sun and the Moon**, each of which causes two tides in ocean waters.

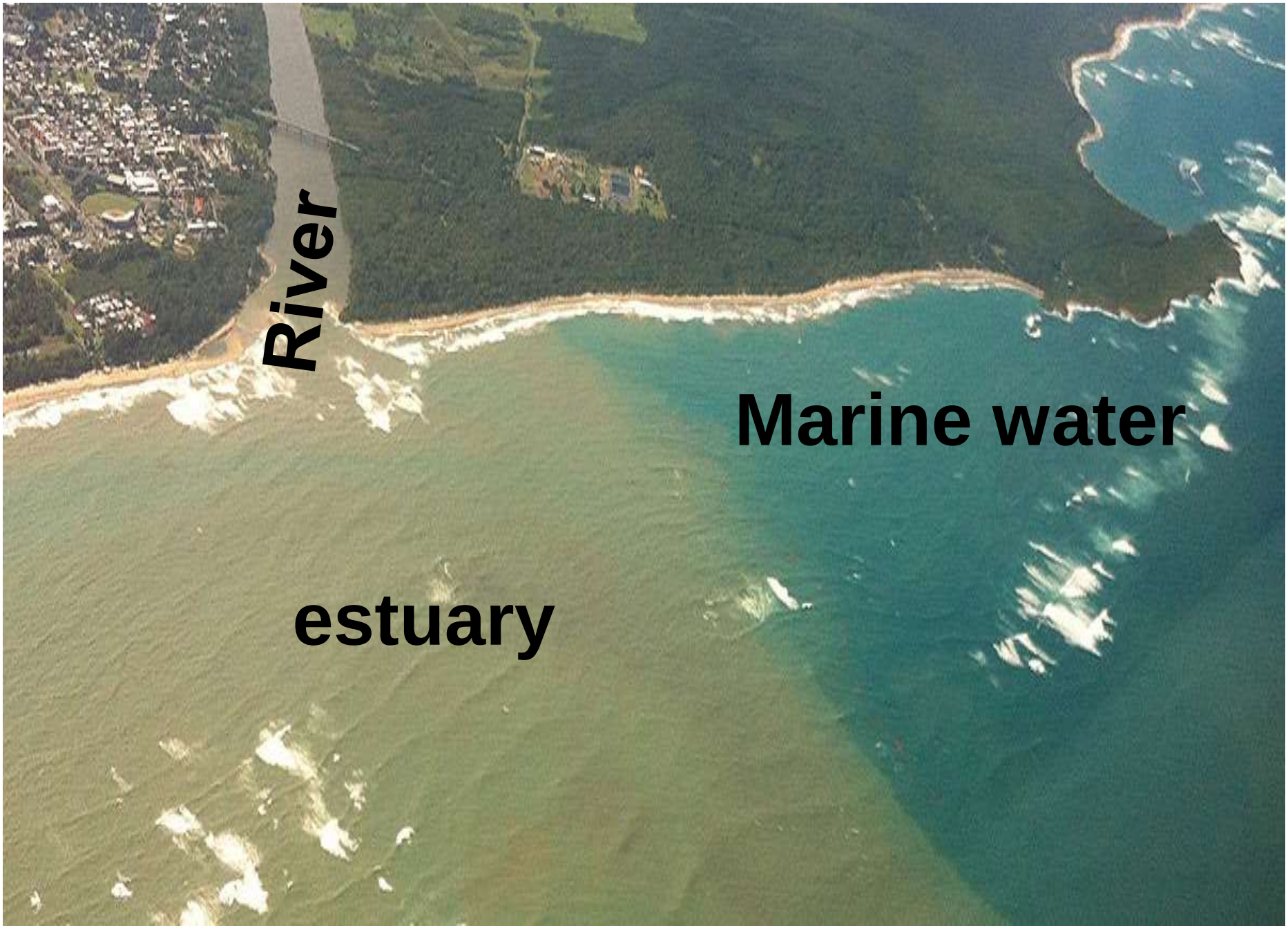


- Interactions between the gravitational pull of the Sun and the Moon on Earth cause differences in the **strength (height) of tides:**
  - **Spring tides**: large difference between high and low tides
  - **Neap tides**: very small difference between high and low tides
- Tides are variable from day to day and around the Earth.

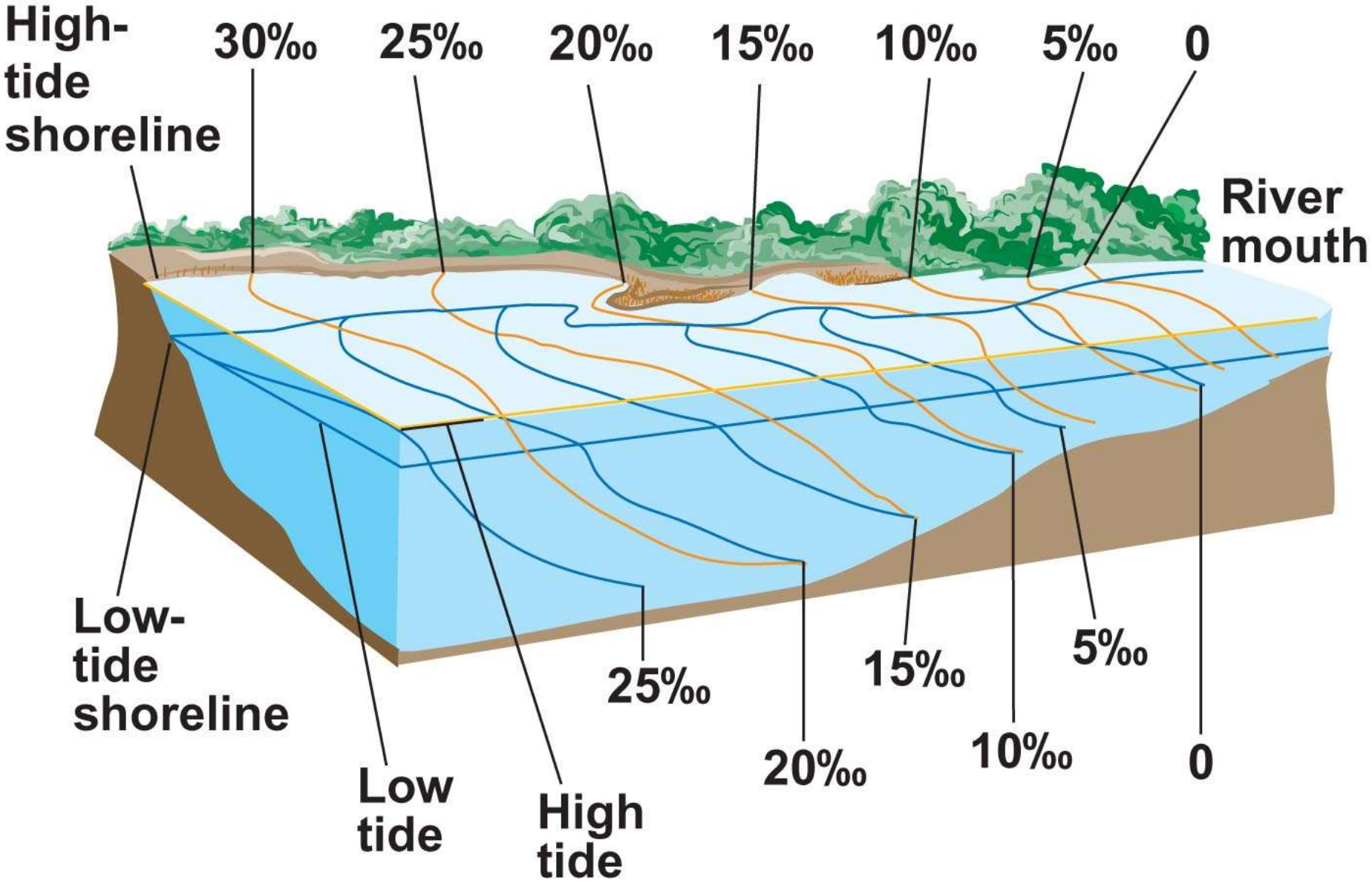
- The **intertidal zone** *is the area lying between the water lines of high and low tide.*
  - This area undergoes dramatic daily shifts in conditions (temperature, solar radiation, etc.) related to the inundation by water and exposure to air
- Organisms that live in the sand and mud do not experience the same wide fluctuations as those living on rocky shores

3.10 The Transition Zone between Freshwater and Saltwater Environments Presents Unique Constraints

- An **estuary** *is the place where freshwater joins and mixes with saltwater.*
- The estuary is strongly influenced by tides and so experiences *wide fluctuations in temperature as tidal water advances and recedes.*
- Inflowing freshwater and tidal saltwater influence the salinity of the estuary.
  - **Estuarine salinity varies vertically and horizontally.**



- **Tidal overmixing** *occurs when heavier seawater sinks as lighter freshwater rises.*
  - *This mixing takes place from the surface to the bottom (vertical).*
- Horizontally, the least saline waters are at a river's mouth



- Organisms that live in estuaries must have special **adaptations to survive.**
- Estuaries are areas of low organism diversity but high productivity.

End of Chapter 3