OCEANOGRAPHY

5. Water and Seawater

part II

notes from textbook, integrated with original contributions

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5.3 – How Salty is Seawater?

- Total amount of dissolved solids in water, including dissolved gases
  - Excludes dissolved organics
  - Excludes solid materials like clay minerals
- Ratio of mass of dissolved substances to mass of water sample
- Expressed in parts per thousand (ppt)
- Typical ocean salinity is 35 ppt ($^{o}/_{oo}$) or parts per thousands

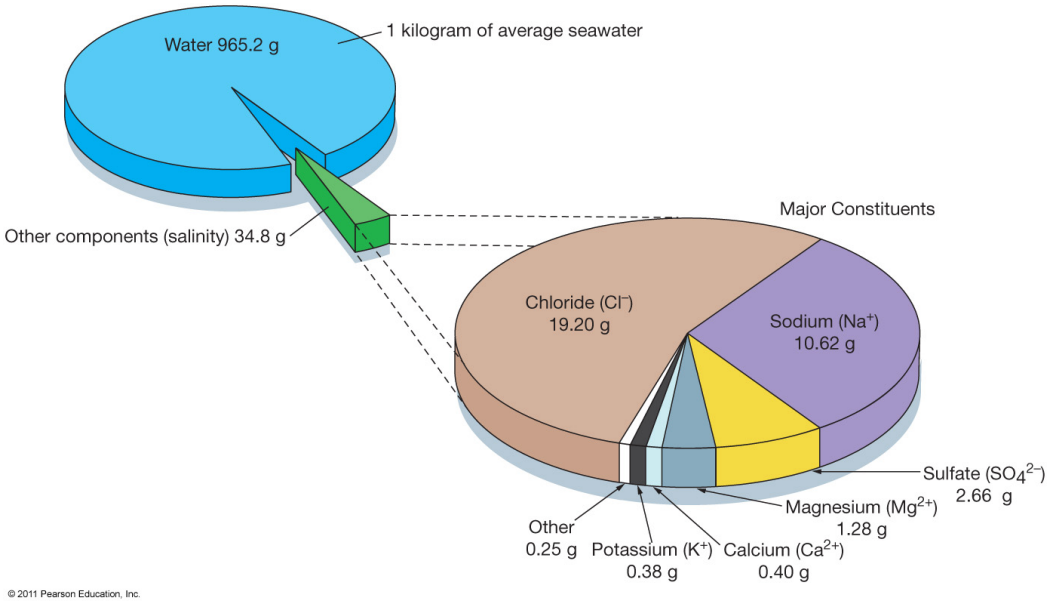


TABLE 5.1 SELECTED DISSOLVED MATERIALS IN 35‰ SEAWATER

1. Major Constituents (in parts per thousand, ‰)

Constituent	Concentration (‰)	Ratio of constituent/total salts (%)
Chloride (Cl^-)	19.2	55.04
Sodium (Na^+)	10.6	30.61
Sulfate (SO_4^{2-})	2.7	7.68
Magnesium (Mg^{2+})	1.3	3.69
Calcium (Ca^{2+})	0.40	1.16
Potassium (K^+)	0.38	1.10
Total	**34.58‰**	**99.28%**

2. Minor Constituents (in parts per million, ppm[a])

Gases		Nutrients		Others	
Constituent	Concentration (ppm)	Constituent	Concentration (ppm)	Constituent	Concentration (ppm)
Carbon dioxide (CO_2)	90	Silicon (Si)	3.0	Bromide (Br^-)	65.0
Nitrogen (N_2)	14	Nitrogen (N)	0.5	Carbon (C)	28.0
Oxygen (O_2)	6	Phosphorus (P)	0.07	Strontium (Sr)	8.0
		Iron (Fe)	0.002	Boron (B)	4.6

3. Trace Constituents (in parts per billion, ppb[b])

Constituent	Concentration (ppb)	Constituent	Concentration (ppb)	Constituent	Concentration (ppb)
Lithium (Li)	185	Zinc (Zn)	10	Lead (Pb)	0.03
Rubidium (Rb)	120	Aluminum (Al)	2	Mercury (Hg)	0.03
Iodine (I)	60	Manganese (Mn)	2	Gold (Au)	0.005

[a]Note that 1000 ppm = 1‰.

[b]Note that 1000 ppb = 1 ppm.

Determining Salinity

- Evaporation
- Chemical analysis–*titration*
  - Principle of constant proportions: “Major dissolved constituents in same proportion regardless of total salinity”
  - Measure amount of halogens (Cl, Br, I, F) (chlorinity)
  - Salinity = 1.80655 * Chlorinity *(ppt)*
  - $1.80655 * 19.2^{o}/_{oo} = 34.7^{o}/_{oo}$
- Electrical conductivity
  - Salinometer

TABLE 5.2 COMPARISON OF SELECTED PROPERTIES OF PURE WATER AND SEAWATER

Property	Pure water	35‰ Seawater
Color (light transmission)		
• Small quantities of water	Clear (high transparency)	Same as for pure water
• Large quantities of water	Blue-green because water molecules scatter blue and green wavelengths best	Same as for pure water
Odor	Odorless	Distinctly marine
Taste	Tasteless	Distinctly salty
pH	7.0 (neutral)	Surface waters range = 8.0–8.3; average = 8.1 (slightly alkaline)
Density at 4°C (39°F)	1.000 g/cm^3	1.028 g/cm^3
Freezing point	0°C (32°F)	−1.9°C (28.6°F)
Boiling point	100°C (212°F)	100.6°C (213.1°F)

5.4 – Why Does Seawater Salinity Vary?

- Salinity varies from location to location
- Open-ocean salinity is 33–38 $^{o}/_{oo}$
- In coastal areas salinity varies more widely
  - An influx of freshwater lowers salinity or creates brackish conditions (Baltic Sea)
  - A greater rate of evaporation raises salinity or creates hypersaline conditions (Red Sea)
  - Salinity may vary with seasons (dry/rain)
    - Miami FL, Astoria OR

Processes Affecting Salinity

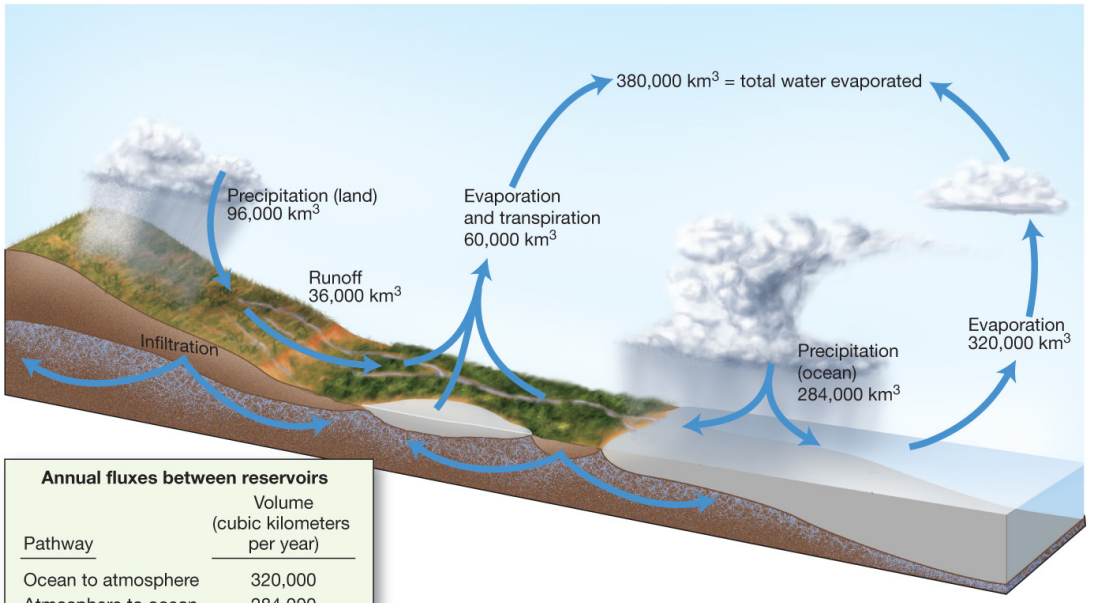
- Decreasing salinity – adding fresh water to ocean
  - Runoff, melting icebergs, melting sea ice
  - Precipitation
- Increasing salinity – removing water from ocean
  - Sea ice formation
  - Evaporation

TABLE 5.3 PROCESSES AFFECTING SEAWATER SALINITY

Process	How accomplished	Adds or removes	Effect on salt in seawater	Effect on H_2O in seawater	Salinity increase or decrease?	Source of freshwater from the sea?
Precipitation	Rain, sleet, hail, or snow falls directly on the ocean	Adds very fresh water	None	More H_2O	Decrease	N/A
Runoff	Streams carry water to the ocean	Adds mostly fresh water	Negligible addition of salt	More H_2O	Decrease	N/A
Icebergs melting	Glacial ice calves into the ocean and melts	Adds very fresh water	None	More H_2O	Decrease	Yes, icebergs from Antarctic have been towed to South America
Sea ice melting	Sea ice melts in the ocean	Adds mostly fresh water and some salt	Adds a small amount of salt	More H_2O	Decrease	Yes, sea ice can be melted and is better than drinking seawater
Sea ice forming	Seawater freezes in cold ocean areas	Removes mostly fresh water	30% of salts in seawater are retained in ice	Less H_2O	Increase	Yes, through multiple freezings, called *freeze separation*
Evaporation	Seawater evaporates in hot climates	Removes very pure water	None (essentially all salts are left behind)	Less H_2O	Increase	Yes, through evaporation of seawater and condensation of water vapor, called *distillation*

Earth's Water: the hydrologic cycle

- 97.2% in the world ocean
- 2.15% frozen in glaciers and ice caps
- 0.62% in groundwater and soil moisture
- 0.02% in streams and lakes
- 0.001% as water vapor in the atmosphere



Annual fluxes between reservoirs

Pathway	Volume (cubic kilometers per year)
Ocean to atmosphere	320,000
Atmosphere to ocean	284,000
Atmosphere to continent	96,000
Continent to atmosphere	60,000
Continent to ocean	36,000

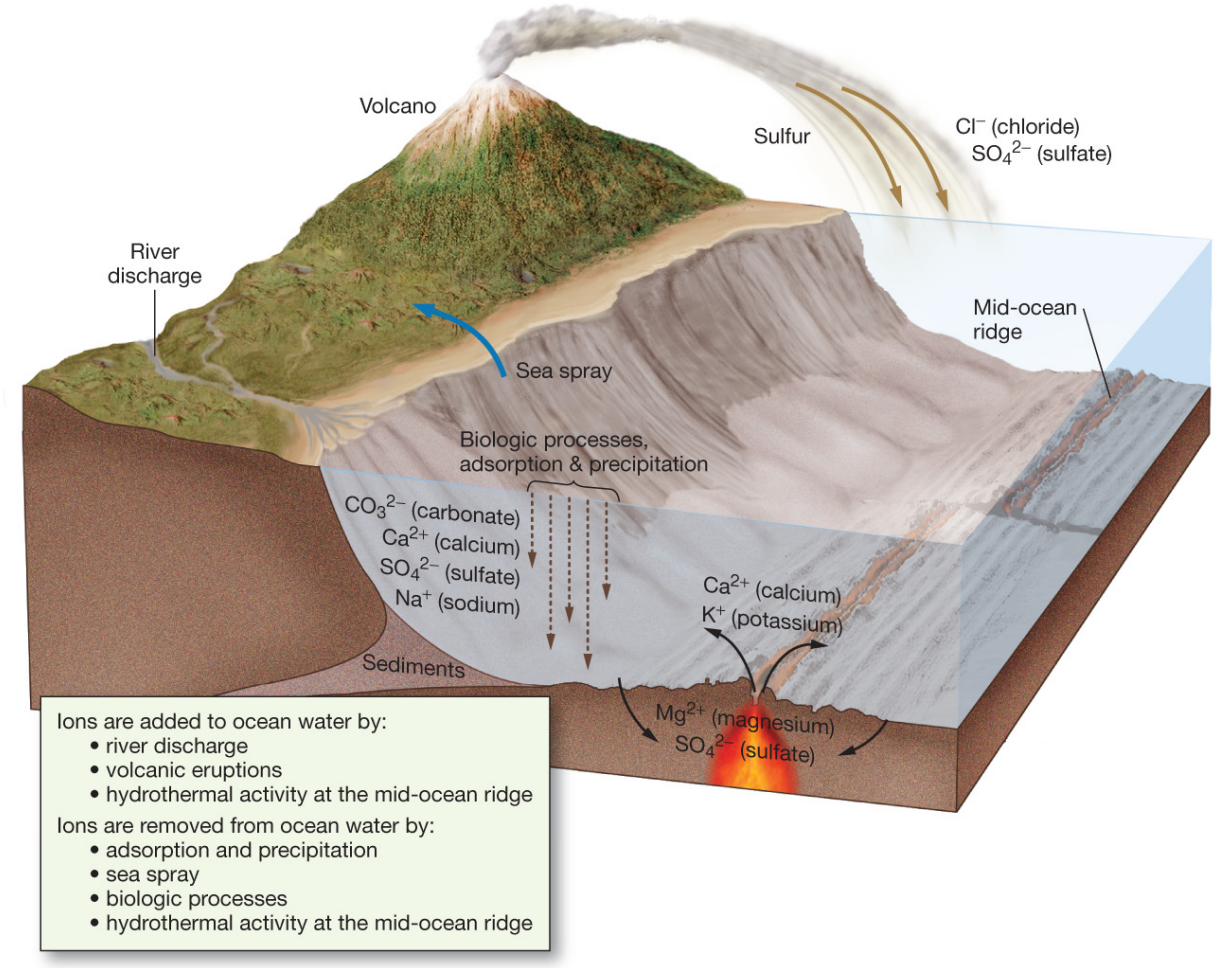
Residence Time

- Average length of time a substance remains dissolved in seawater
- Ions with long residence time are in high concentration in seawater.
- Ions with short residence time are in low concentration in seawater.
- Steady state condition
  - the rate at which an element is added to the ocean is equivalent to the rate at which it is removed: the average amounts of various elements remain constant

loss of salt from the ocean

- ocean spray
- ocean water circulation at mid-ocean ridges
- deposition of shells
- formation of evaporites

Processes that Add/Subtract Dissolved Substances



5.5 – Is Seawater Acidic or Basic?

- Acid releases a hydrogen ion (H+) when dissolved in water
- Alkaline (or base) releases a hydroxide ion (OH-) in water
- The pH scale is used to measure hydrogen ion concentration
  - Low pH value, acid
  - High pH value, alkaline (basic)
  - pH 7 = neutral
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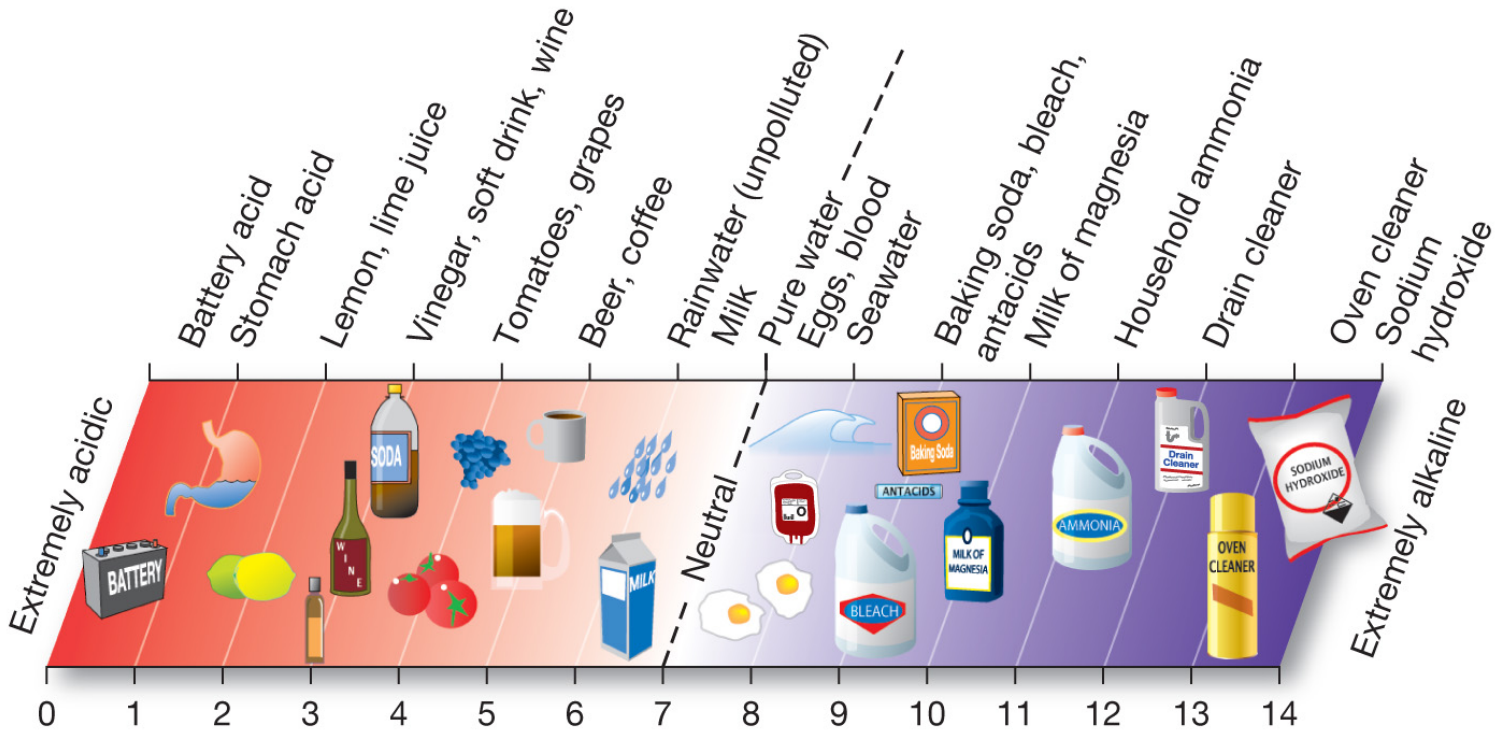
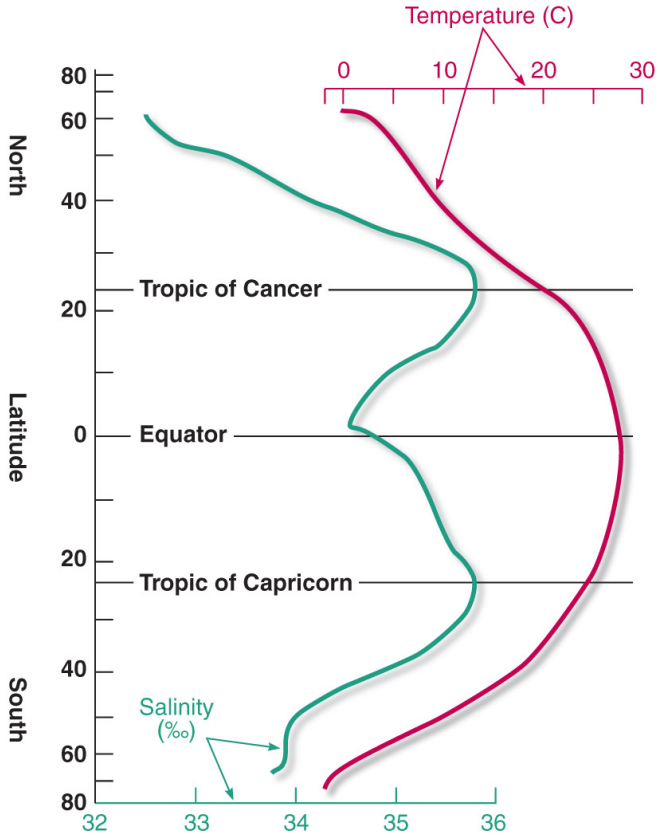


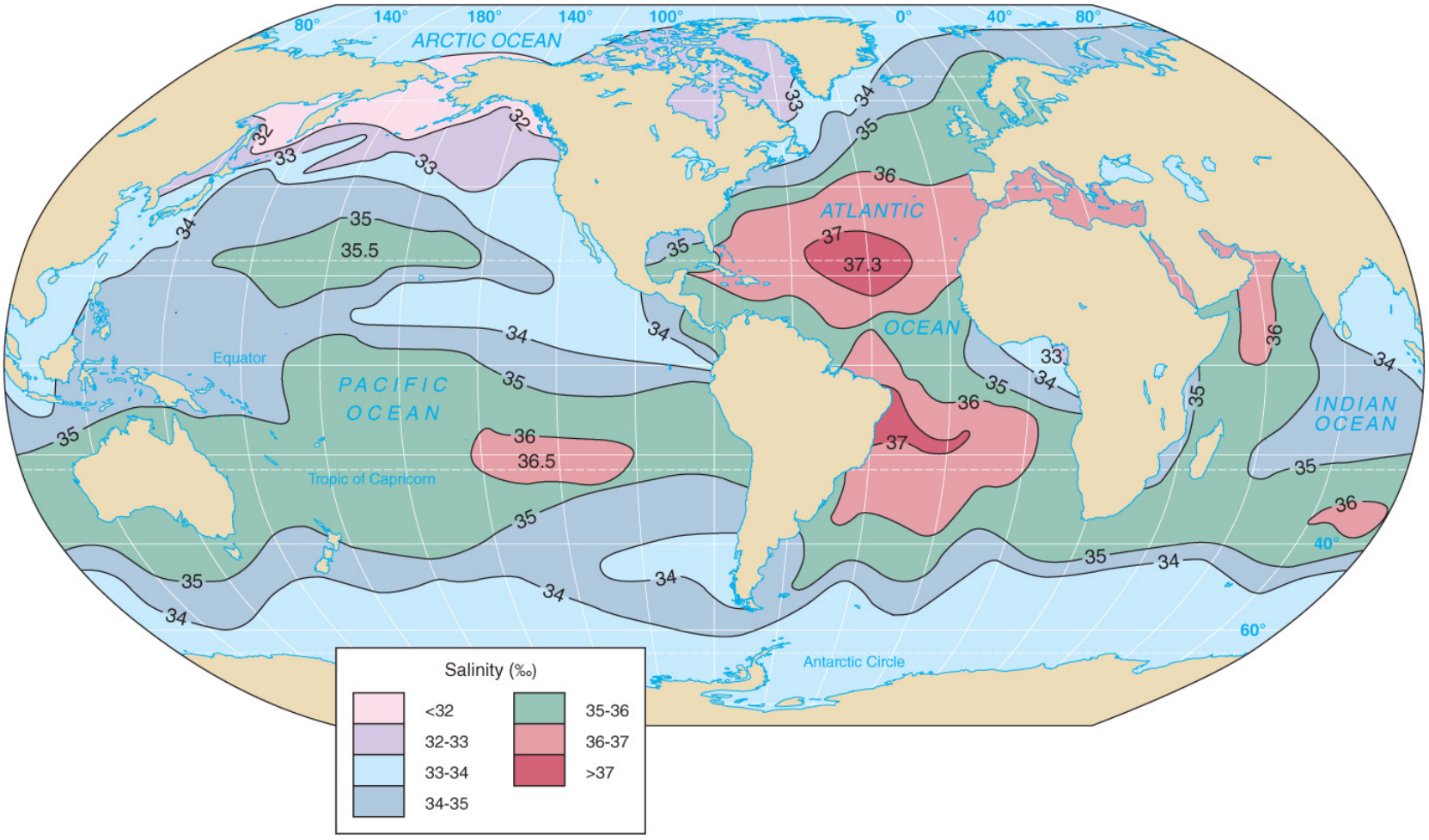
5.6 – How Does Seawater Salinity Vary at the Surface and with Depth?

- Surface Salinity Variation

- High latitudes
  - Low salinity
  - Abundant sea ice melting, precipitation, and runoff
- Low latitudes near equator
  - Low salinity
  - High precipitation and runoff
- Mid latitudes
  - High salinity
  - Warm, dry, descending air increases evaporation

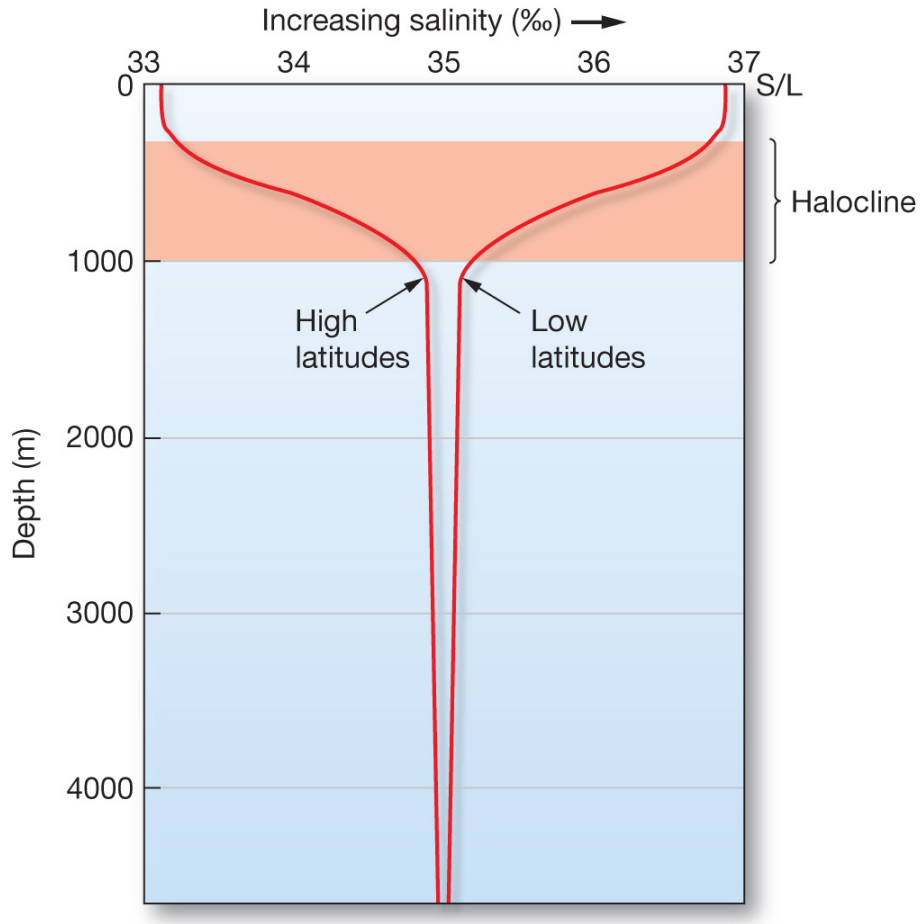


Global Salinity



Salinity Variation with Depth

- Low latitudes – salinity decreases with depth
- High latitudes – salinity increases with depth
- Deep ocean salinity fairly consistent globally
- Halocline – separates ocean layers of different salinity



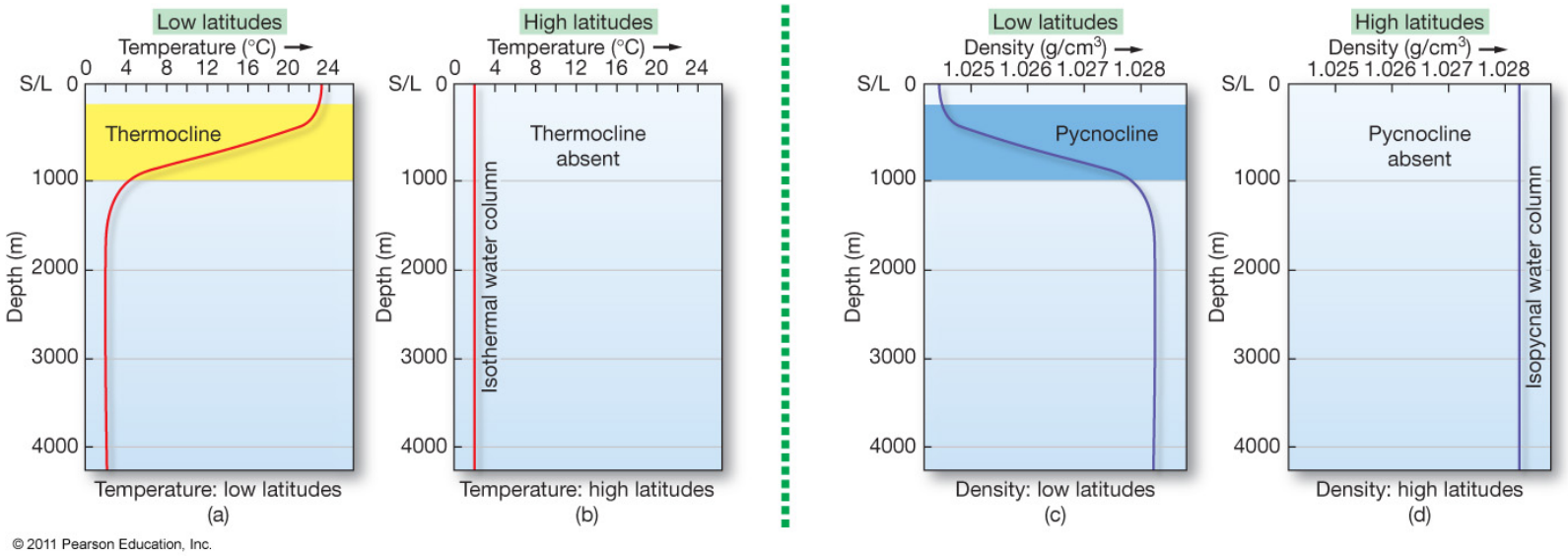
5.7 – How Does Seawater Density Vary with Depth?

- Freshwater density = 1.000 g/cm^3
- Ocean surface water =1.022 to 1.030 g/cm^3
- Ocean layered according to density

- Density increases with decreasing temperature
  - Greatest influence on density
- Density increases with increasing salinity
- Density increases with increasing pressure
  - Does not affect surface waters

Temperature and Density Variation With Depth

- Pycnocline – abrupt change of density with depth
- Thermocline – abrupt change of temperature with depth



Layered Ocean

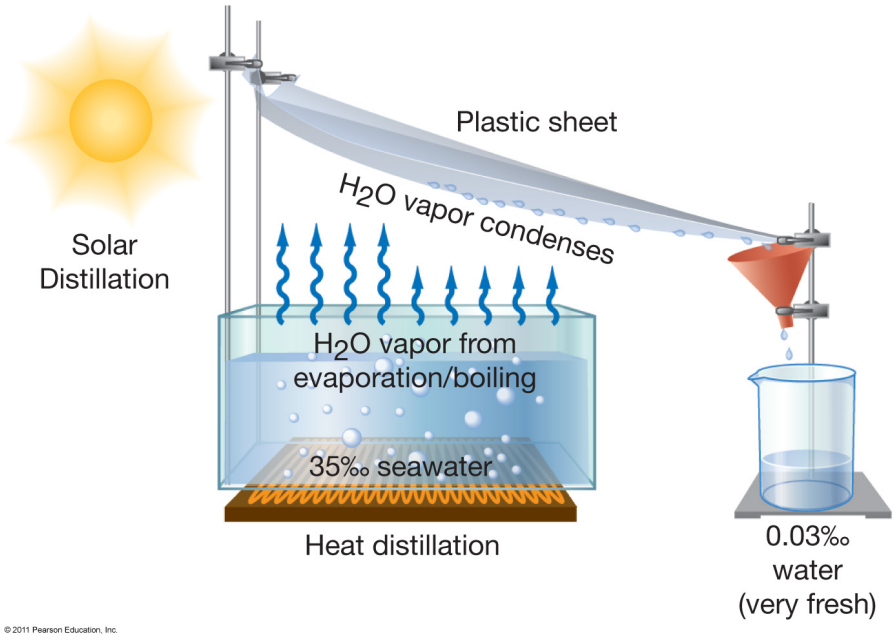
Three distinct water masses based on density:

- Mixed surface layer – above thermocline
- Upper water – thermocline and pycnocline
- Deep water – below thermocline to ocean floor
- High latitude oceans – thermocline and pycnocline rarely develop
  - Isothermal
  - Isopycnal

5.8 – What Methods Are Used to Desalinate Seawater?

Desalination: removing salt from seawater

- Distillation
  - Most common process
  - Water boiled and condensed
  - Solar distillation in arid climates
- Electrolysis
  - Electrode-containing freshwater
  - Membrane between fresh and salt water tanks



- Reverse osmosis
  - Salt water forced through membrane into fresh water
- Freeze separation
  - Water frozen and thawed multiple times