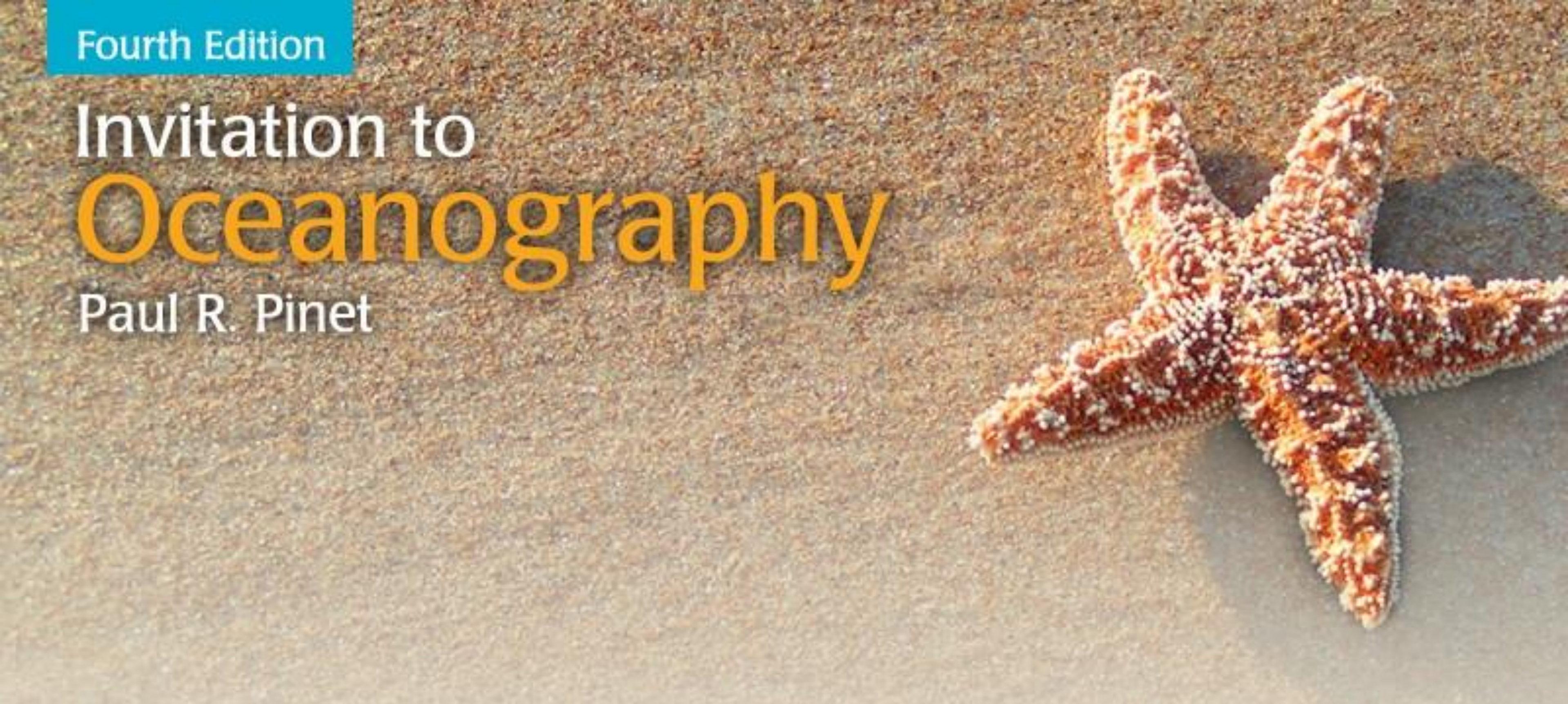
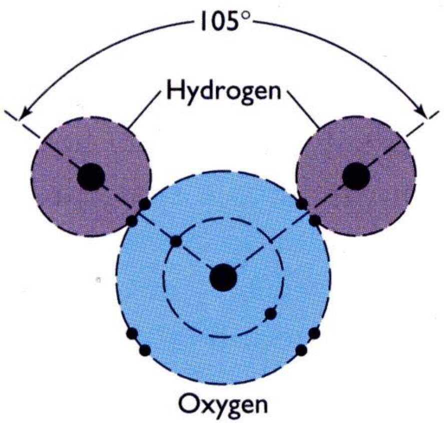
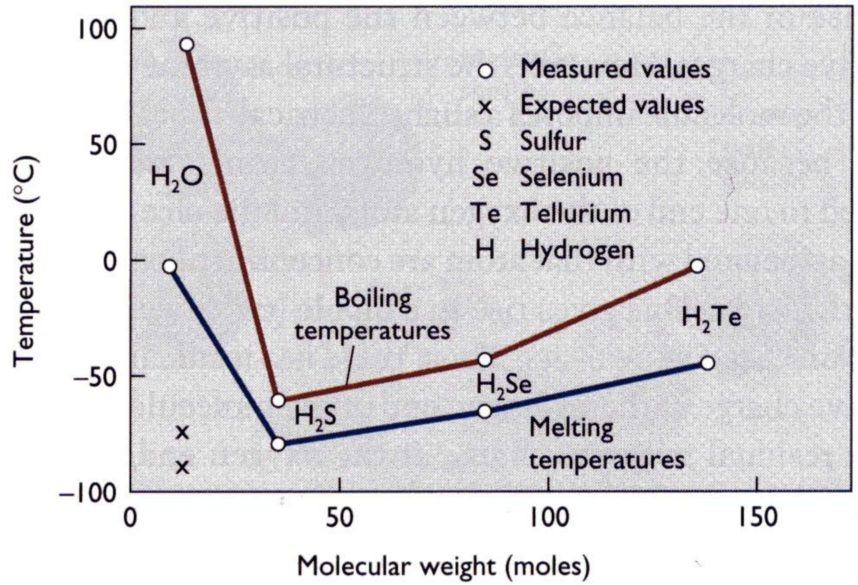


Chapter 5

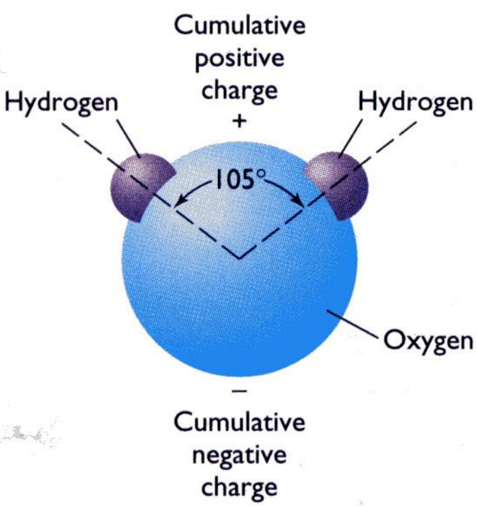
The Properties of Seawater



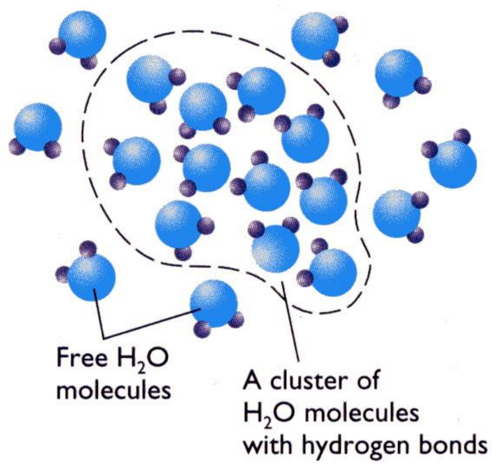
(a) H_2O MOLECULE



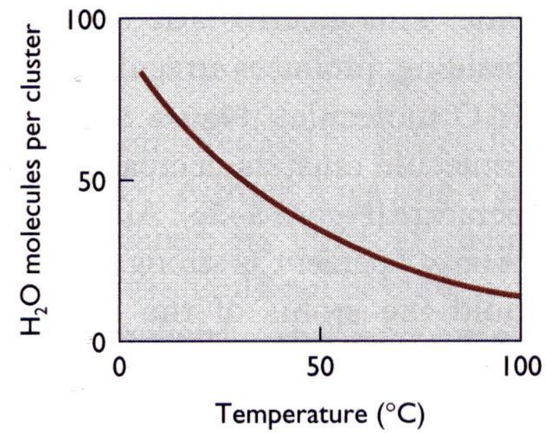
(b) MELTING AND BOILING TEMPERATURES OF WATER



(c) DIPOLE STRUCTURE



(d) CLUSTERS OF WATER



(e) SIZE OF WATER CLUSTERS

- Ice floats in water because all of the molecules in ice are held in hexagons.
  - The center of the hexagon is open space, making ice 8% less dense than water.

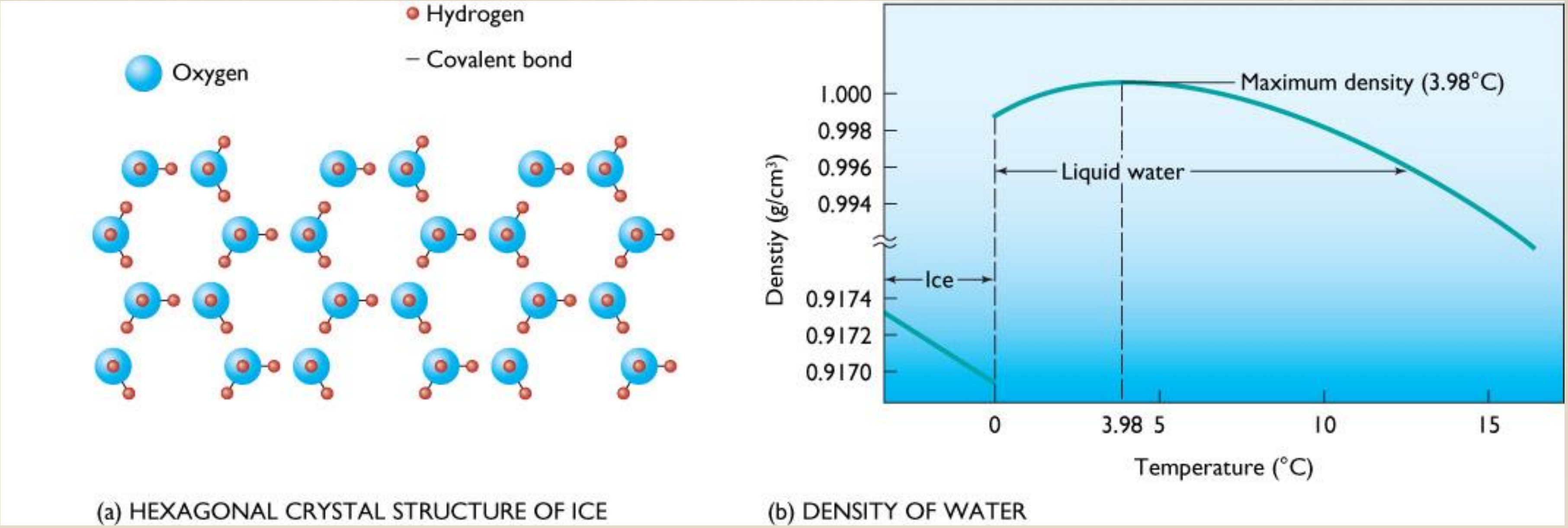


Figure 5-5a Hexagonal Crystal Structure of Ice

Figure 5-5b Density of Water

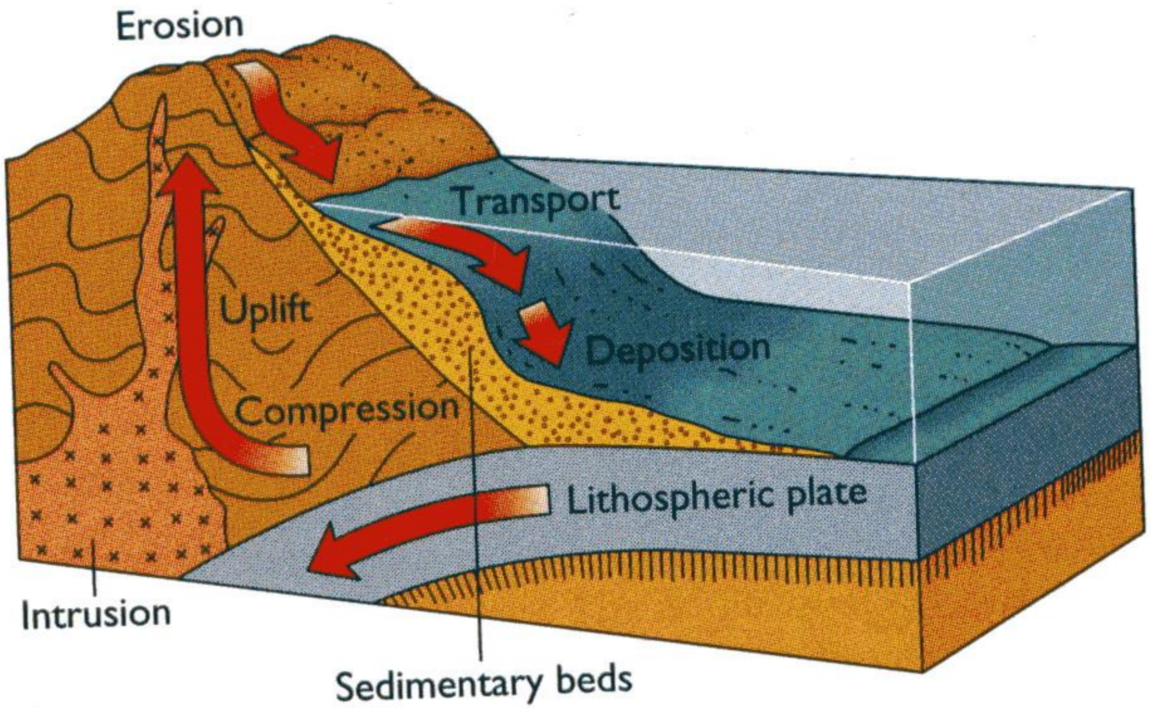


FIGURE 5-6

Sedimentary cycle. Over geologic time, mountains are leveled by rivers. The weathering products are dispersed into the ocean and collect on the sea bottom, forming sedimentary beds. Eventually, these accumulations of sediment are deformed and uplifted into mountain ranges by plate tectonics. Then a new cycle of river erosion begins.

TABLE 5-8

Residence in ocean waters

Substance	Residence Time ($\times 10^6$ yr)
Chloride (Cl^-)	∞
Sodium (Na^+)	260
Lithium (Li^+)	20
Strontium (Sr^{2+})	19
Potassium (K^+)	11
Calcium (Ca^{2+})	8
Zinc (Zn^{2+})	0.18
Barium (Ba^{2+})	0.084
Cobalt (Co^{2+})	0.018
Chromium (Cr)	0.00035
Aluminum (Al)	0.00015

Source: Adapted from C.K. Wentworth, A scale of grade and class terms for clastic sediments, *Journal of Geology* 30, (1922): 377–92.

Effects of Salinity on the Maximum-Density and Freezing-Point Temperatures of Seawater

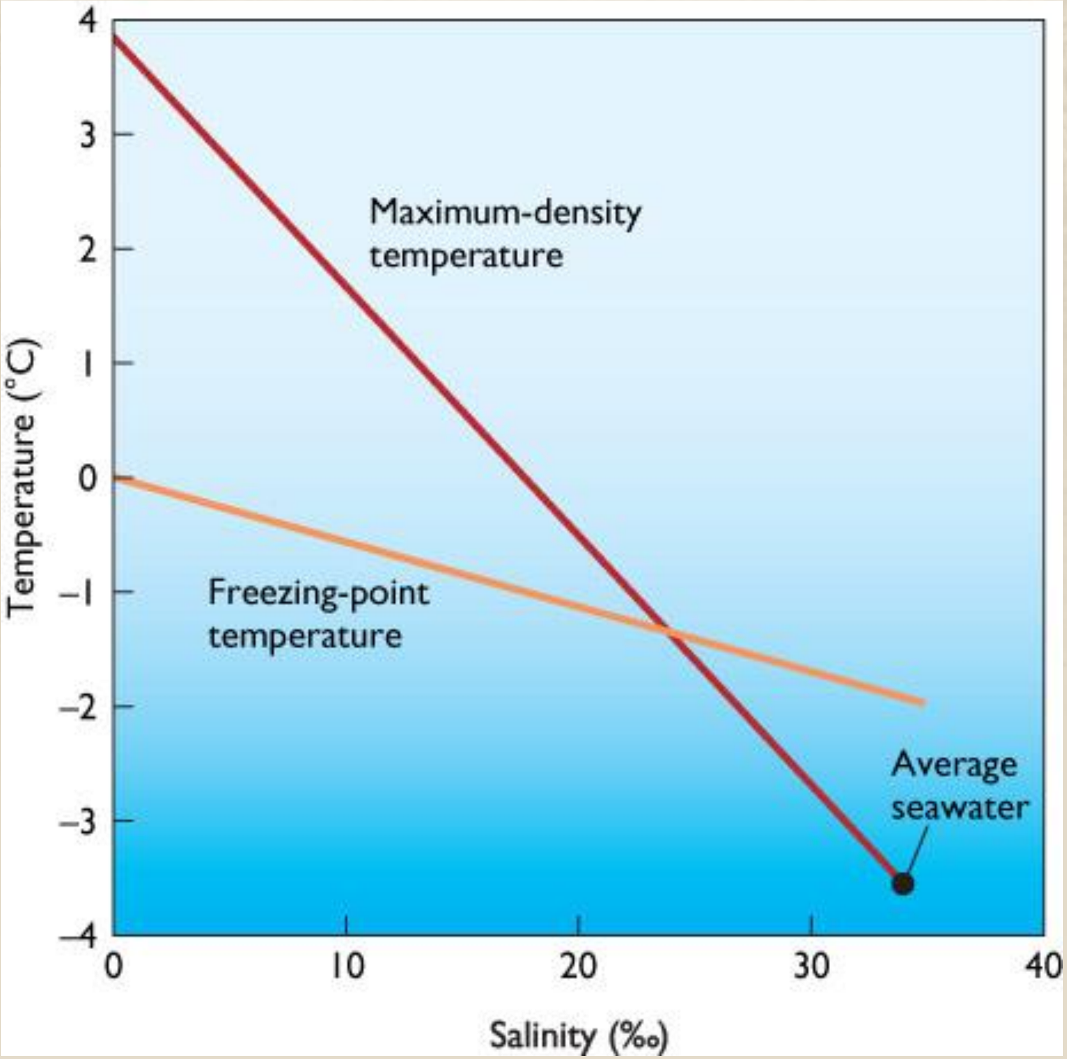


Figure 5-8

Sea Surface Temperatures

- Insolation and ocean-surface water temperature vary with the season.
- Ocean temperature is highest in the tropics (25^{o}C) and decreases poleward.

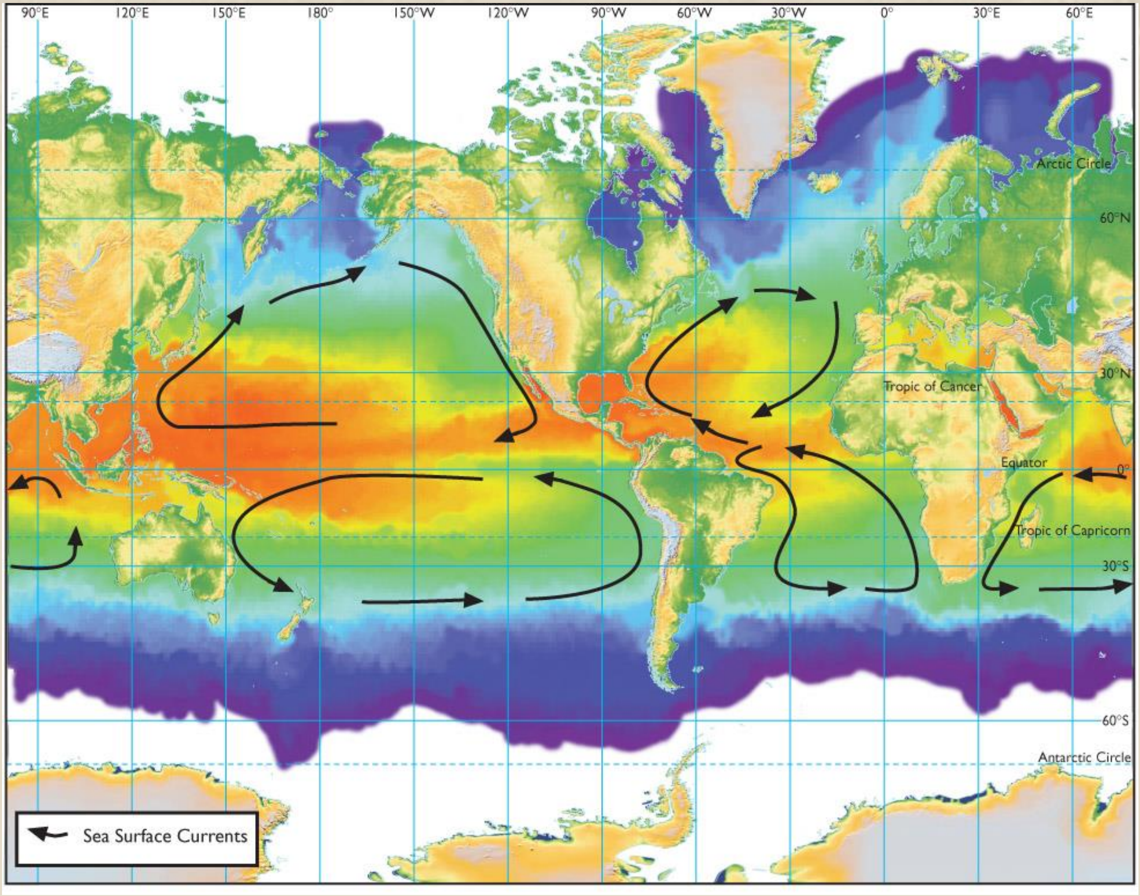
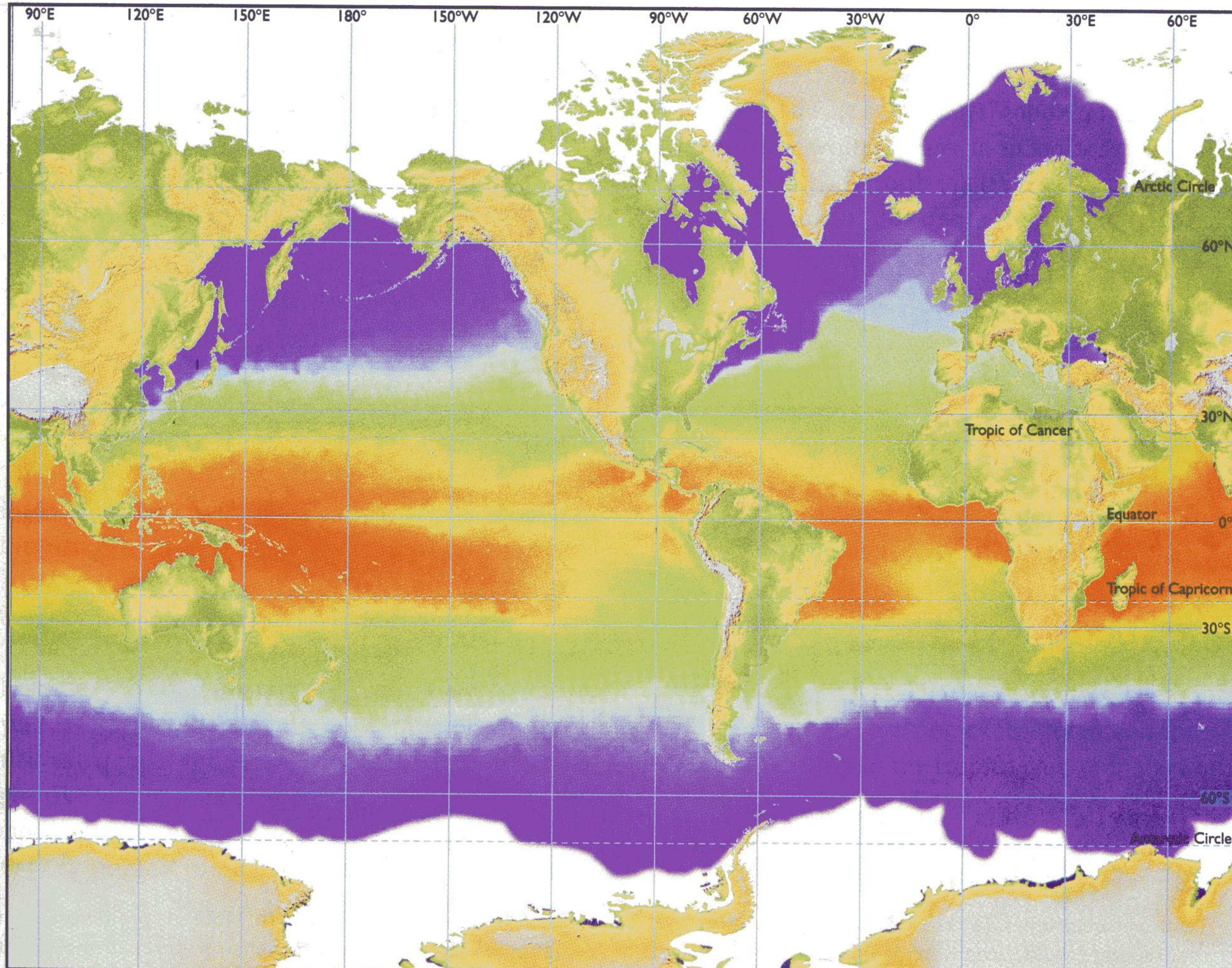
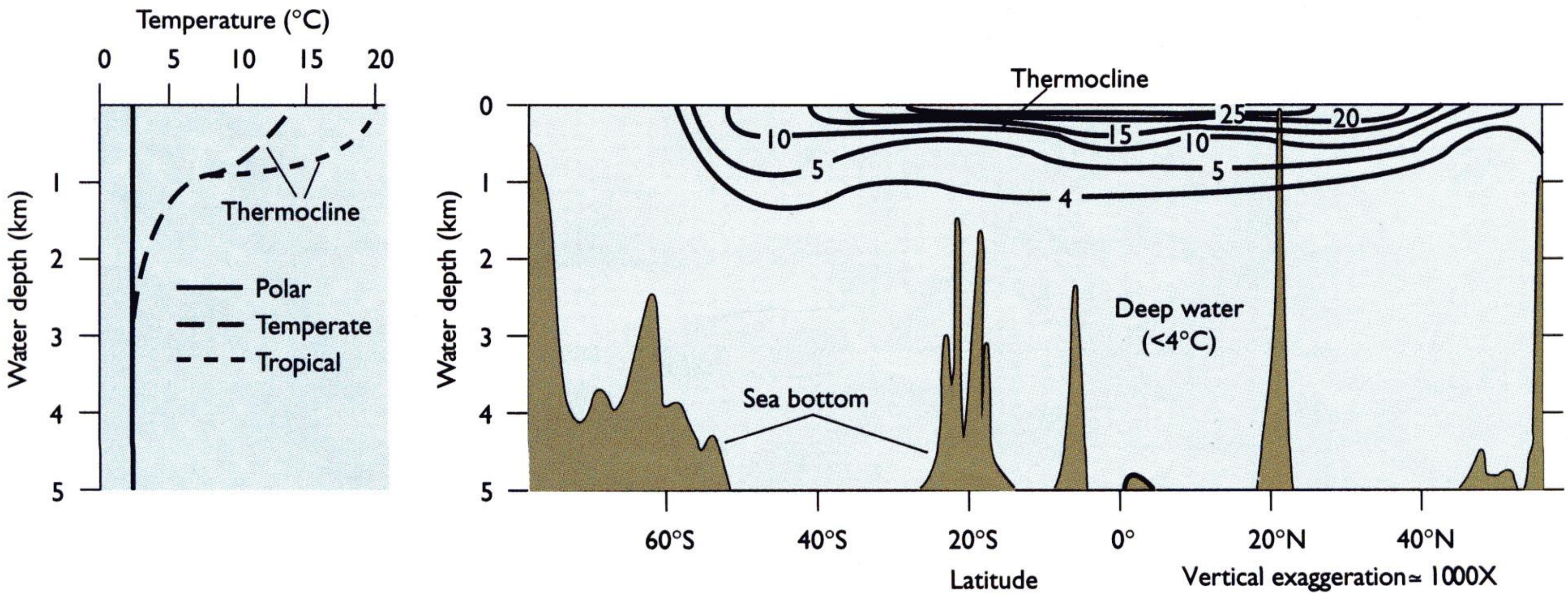


Figure 5-9a Sea-Surface Temperature in August

5-5 Chemical and Physical Structure of the Oceans



(b) SEA-SURFACE TEMPERATURE IN FEBRUARY

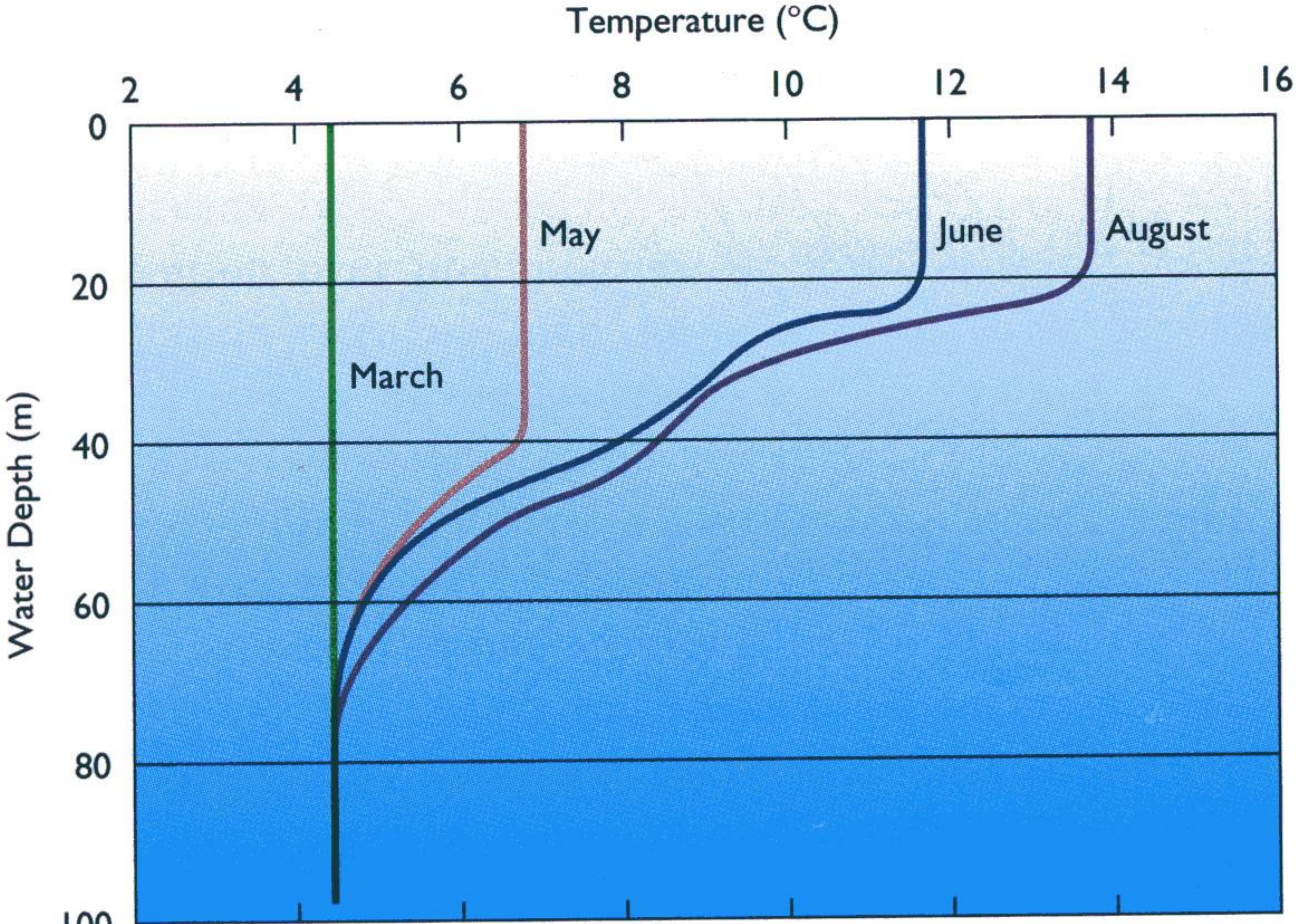


(a) TEMPERATURE PROFILES

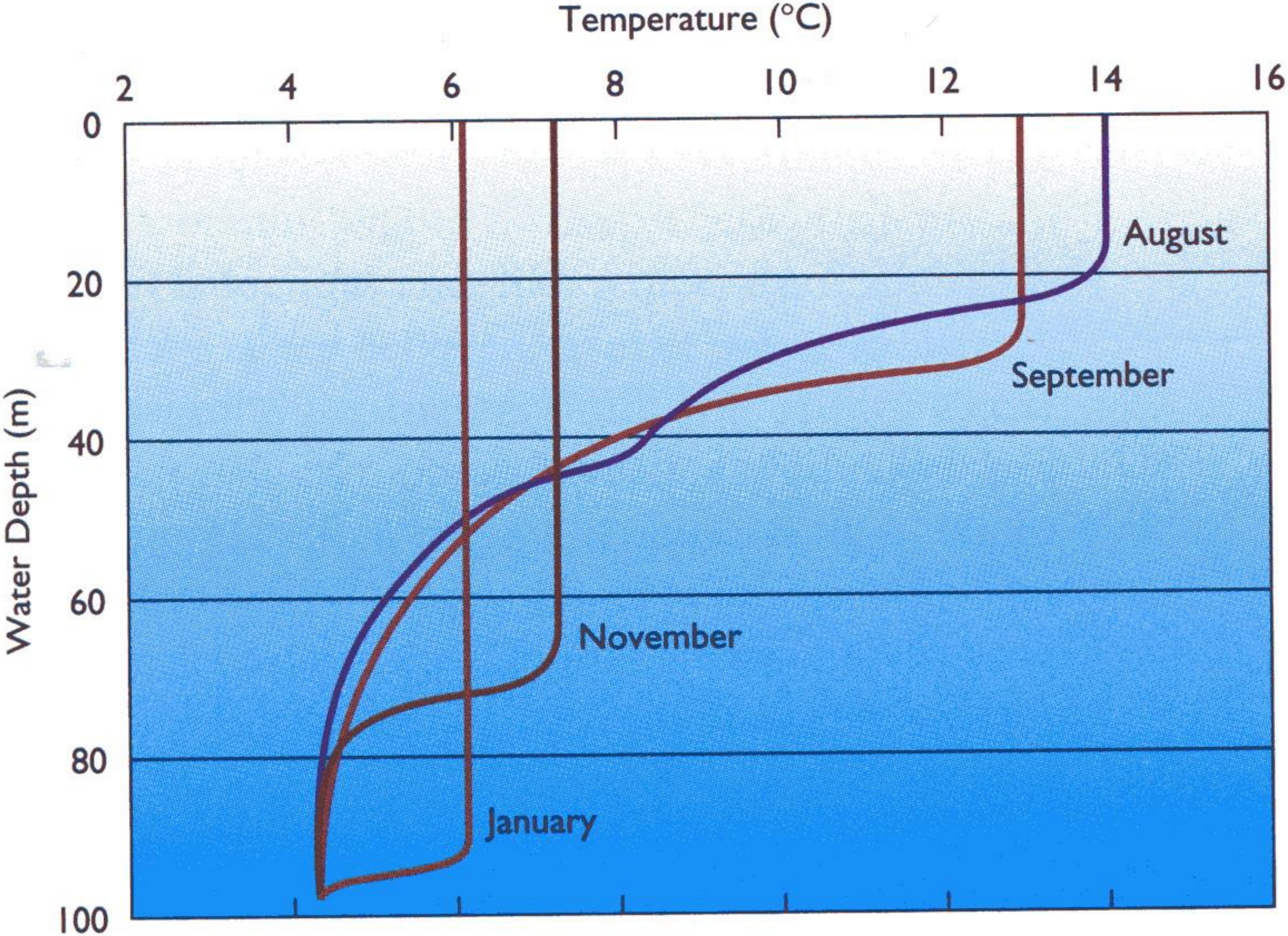
(b) TEMPERATURE DISTRIBUTION (°C) IN CENTRAL PACIFIC OCEAN

FIGURE **5-10**

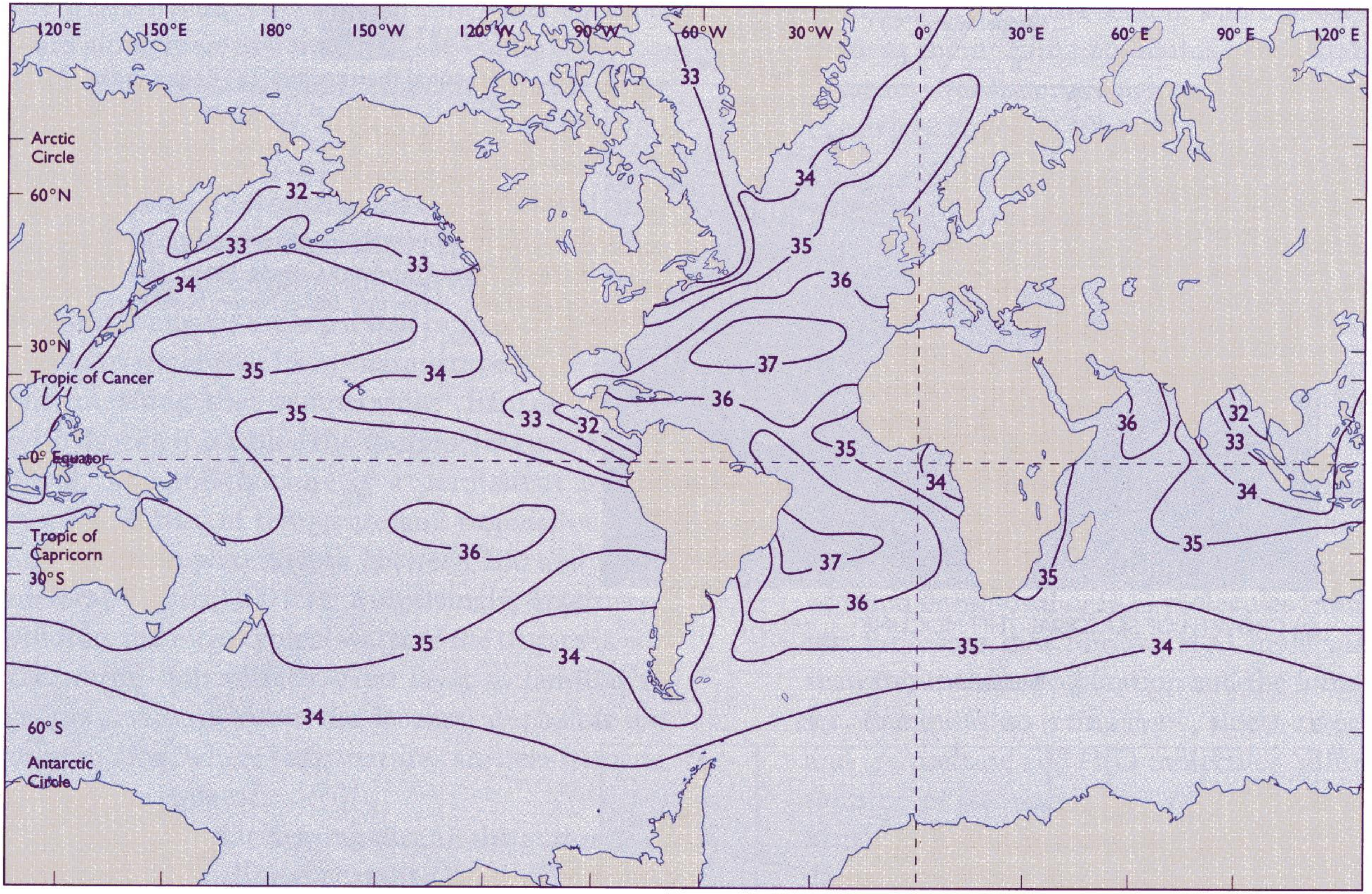
Temperature profiles. (a) These vertical profiles depict variations of temperature with water depth. Note the prominent thermocline that separates cold, deep water from warm surface water. (b) A longitudinal profile of the average temperature distribution in the Pacific Ocean indicates that the bulk of all ocean water is colder than 4° Celsius. [Adapted from J. L. Reid, Jr., *Intermediate Waters of the Pacific Ocean* (Baltimore: Johns Hopkins Press, 1965).]



(a) GROWTH OF SEASONAL THERMOCLINE



(b) DECAY OF SEASONAL THERMOCLINE



(a) SEA-SURFACE SALINITY (o/oo) IN AUGUST

Salinity changes with latitude due to variations in precipitation and evaporation

- Highest ocean salinity is between 20-30^o north and south or the equator, because evaporation exceeds precipitation.

- Salinity at the equator and poleward of 30^o is low because evaporation is less than precipitation.

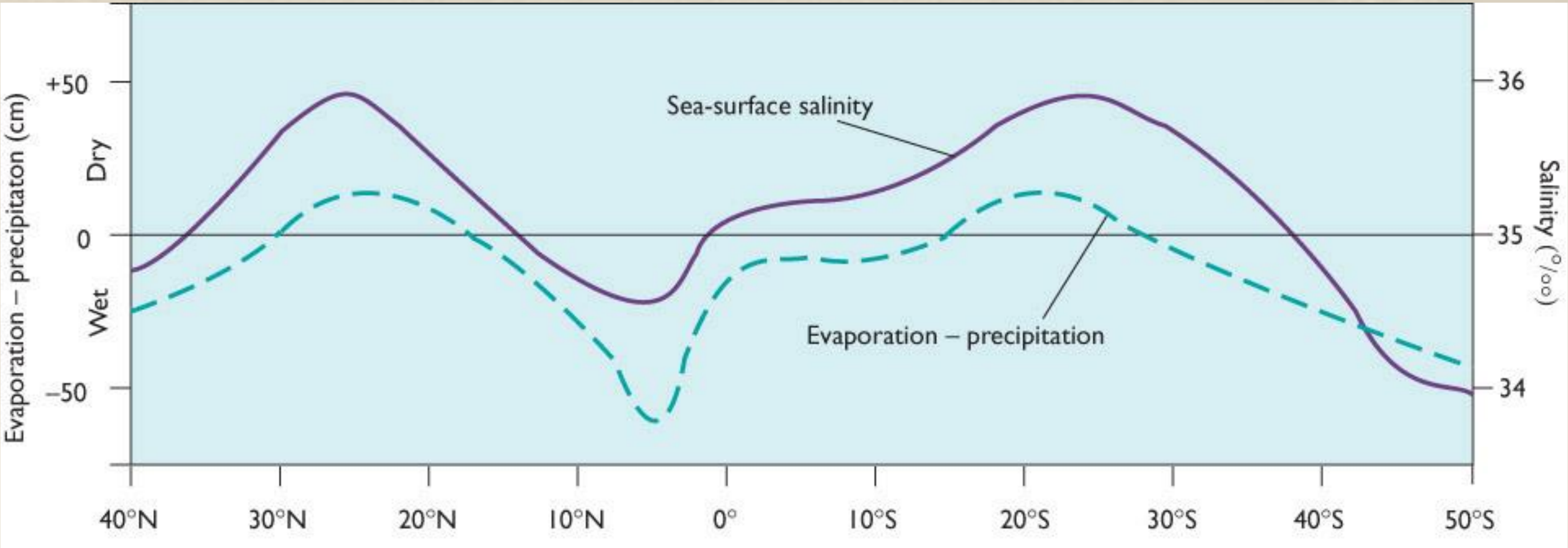


Figure 5-12b Latitudinal Variations in Salinity and “Dryness”

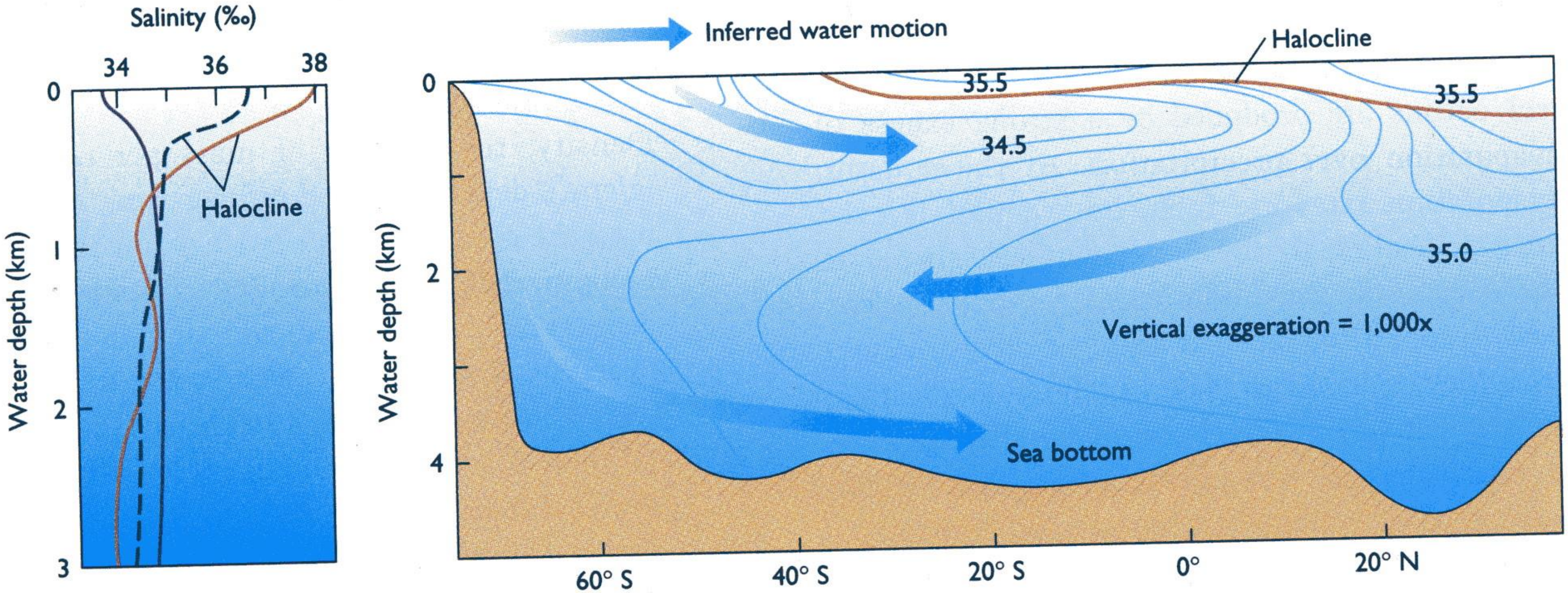


FIGURE **5-13**

Salinity profiles. (a) Vertical profiles of salinity show that sea-surface water may be more or less saline than the water below it. Note the prominent haloclines. (b) Isohalines (lines connecting points of equal salinity) in a longitudinal profile of the western Atlantic Ocean reveal distinct water-mass stratification and a prominent halocline. Below a 2-kilometer depth, the water has a remarkably uniform salinity, ranging between 34.7 and 34.9 ‰. [Adapted from D. Tolmazin, *Elements of Dynamic Oceanography* (Winchester, Mass.: Allen and Unwin, 1985).]

Thermocline, Halocline, and Pycnocline

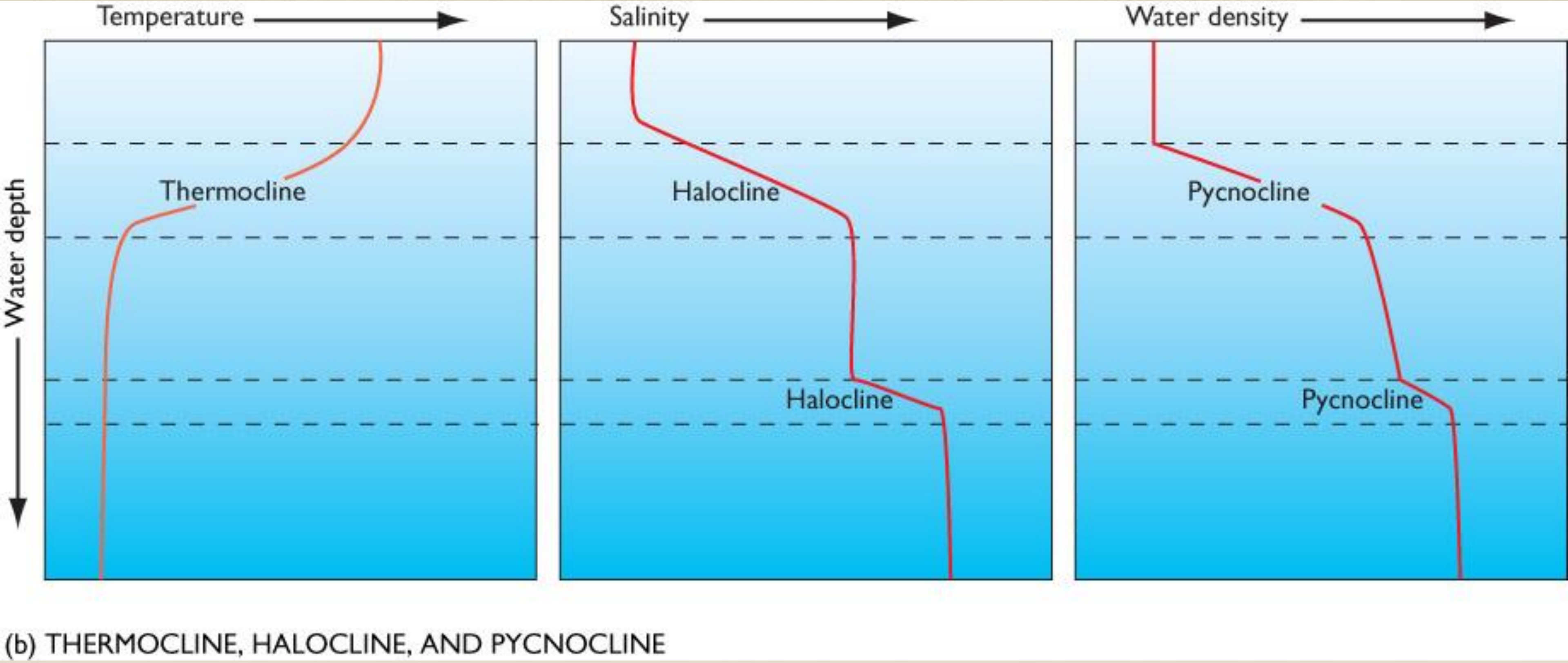


Figure 5-14b

- The water column in the ocean can be divided into the:
  - surface layer
  - pycnocline
  - deep layer

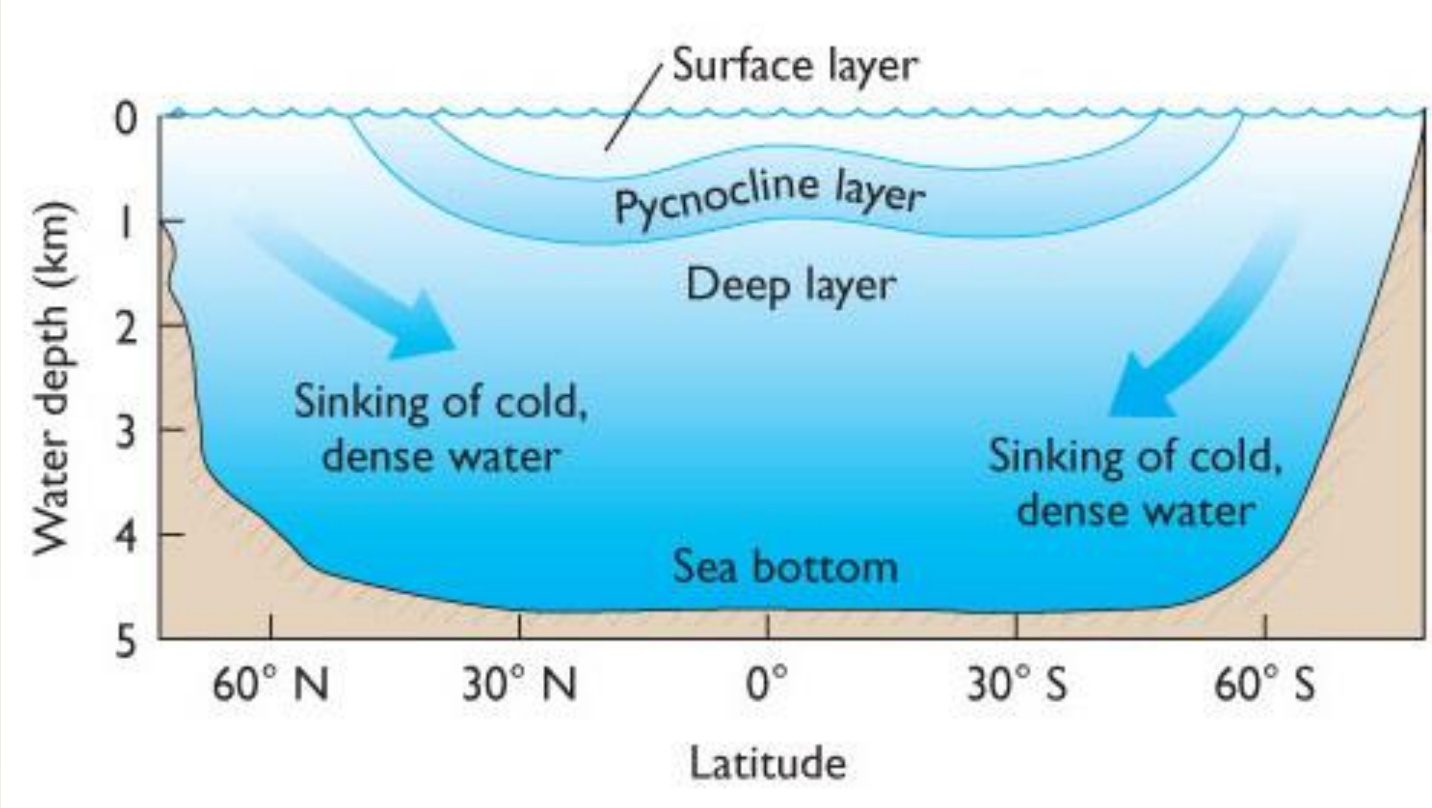
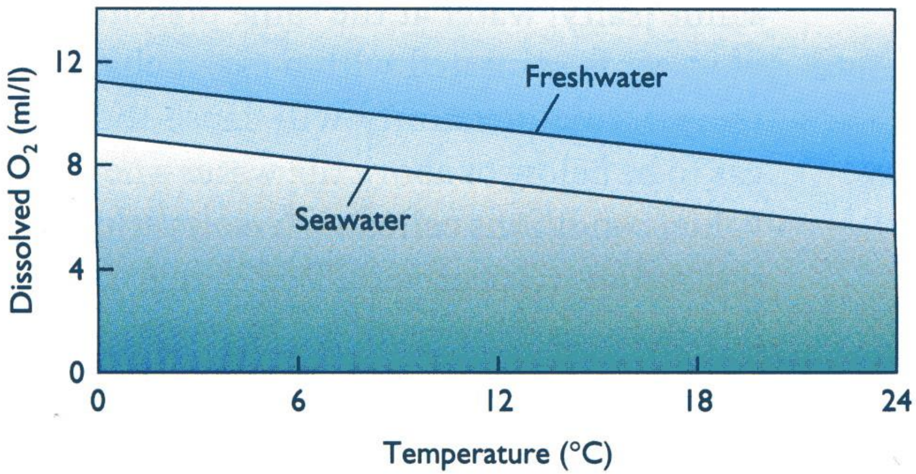
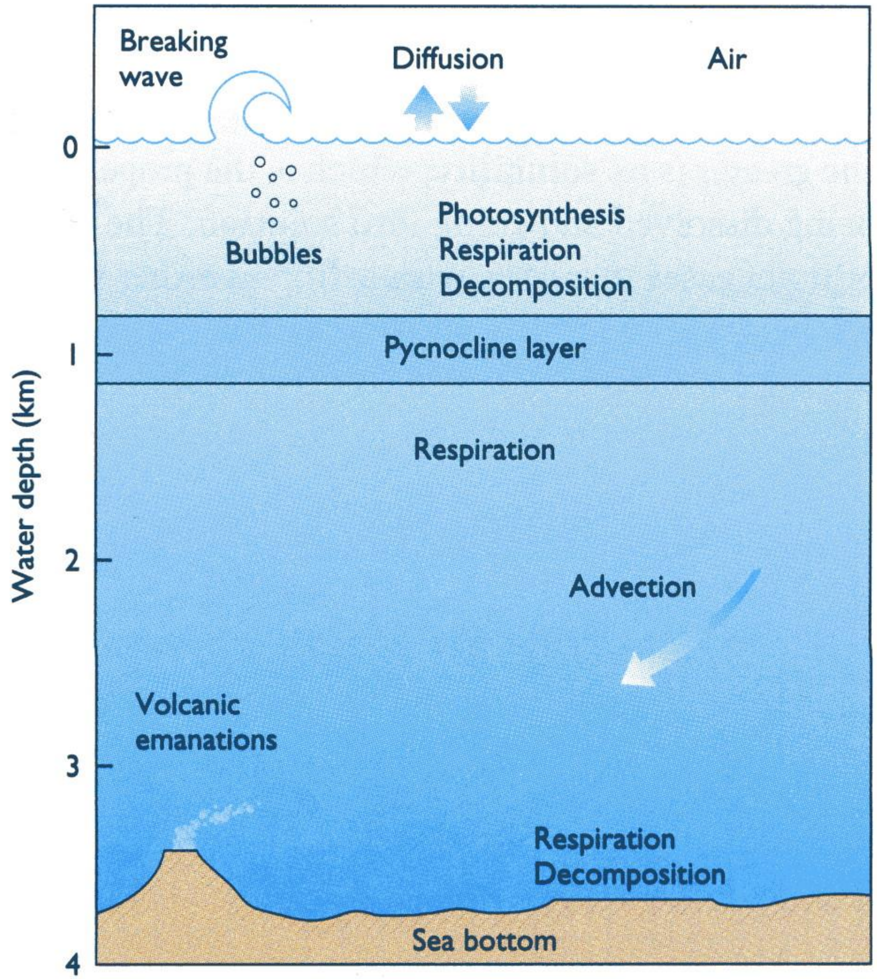


Figure 5-14c Density Structure of the Oceans



(a) SOLUBILITY OF OXYGEN



(b) SOURCES AND SINKS OF GASES

FIGURE **5-15**

Gases in seawater. (a) The solubility of oxygen decreases as water temperature and salinity rise. (b) Dissolved gases in the oceans are derived from both external and internal sources and organic and inorganic processes.

Helium-3

Volcanic emissions from the East Pacific Rise cause this large plume of helium-3.

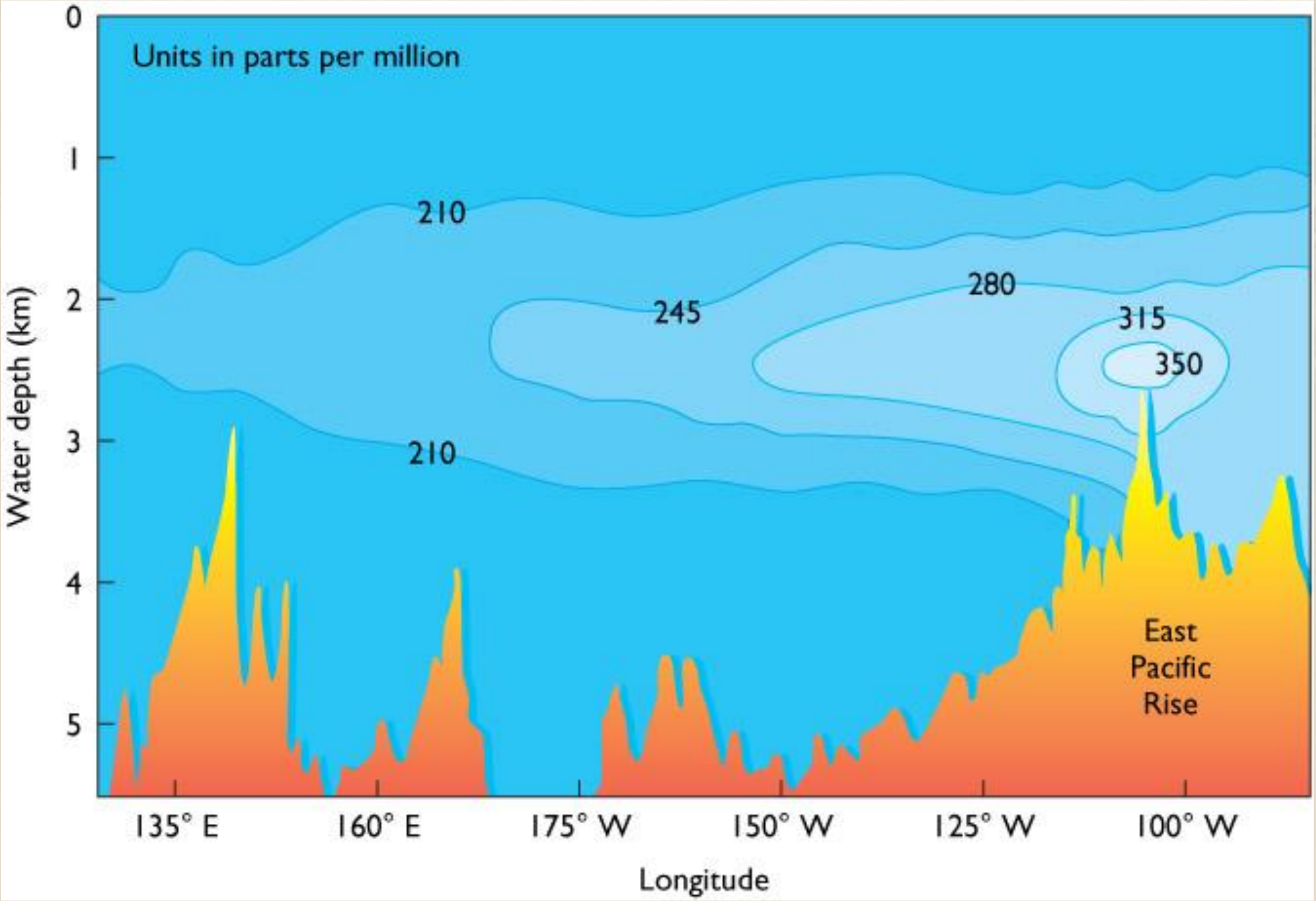


Figure 5-16 Helium-3

- Oxygen tends to be abundant in the water of the surface layer and deep layer, and lowest in the pycnocline.
- Surface layer is rich in oxygen because of photosynthesis and diffusion from the atmosphere layer.
- Oxygen minimum layer occurs at about 150 to 1500m below the surface and coincides with the pycnocline.

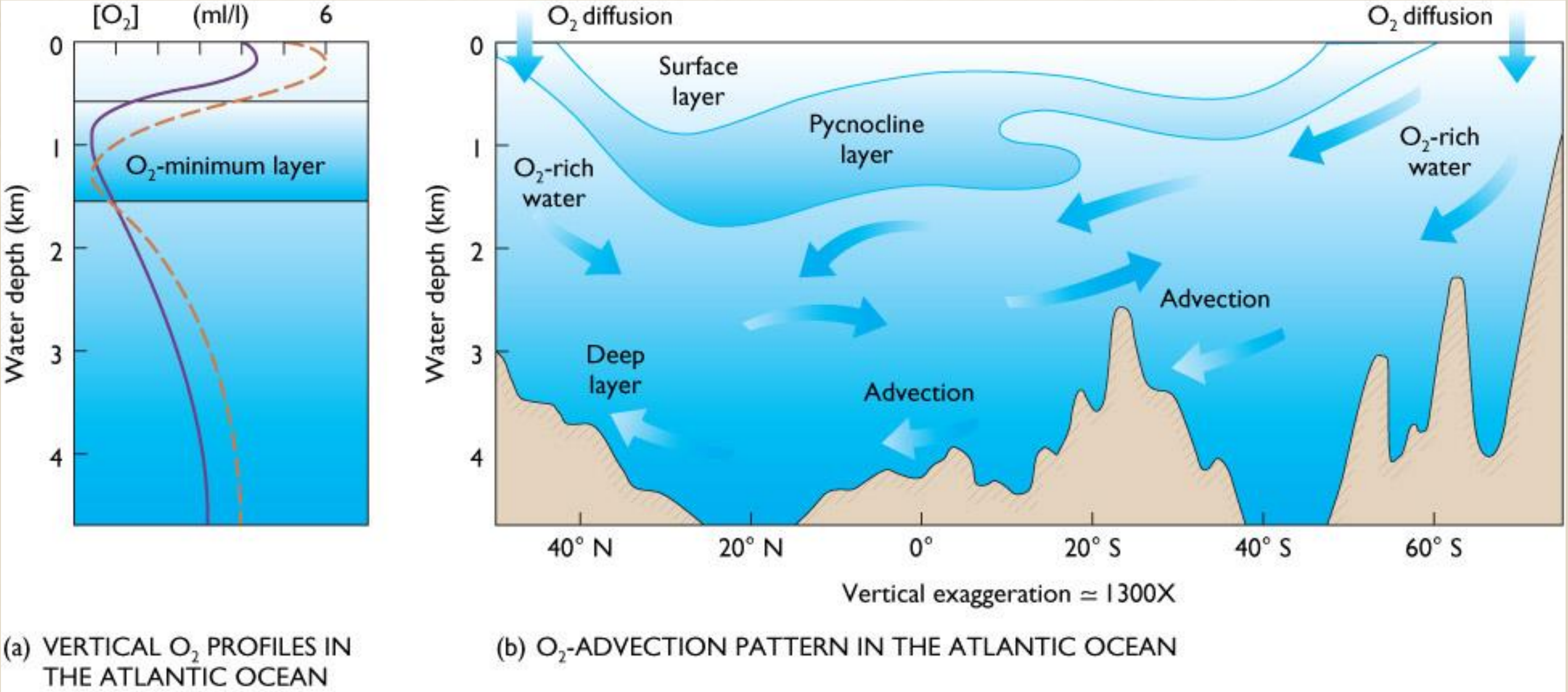


Figure 5-17 a Vertical O_2 Profiles in the Atlantic Ocean

5-6 Gases in Seawater

Distribution of Carbon Species in Water

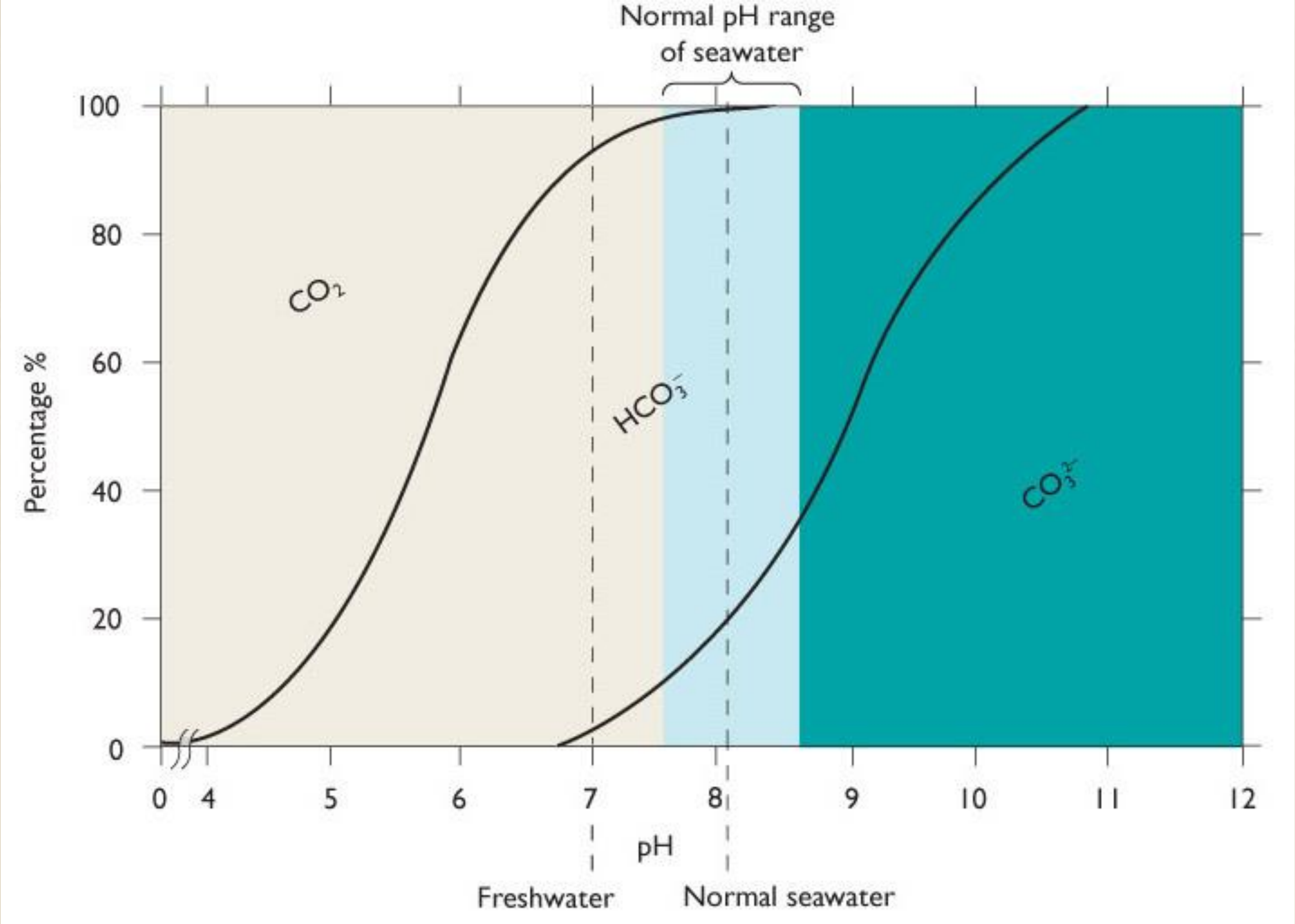


Figure 5-19a Distribution of Carbon Species in Water

5-6 Gases in Seawater

The CO_2 System

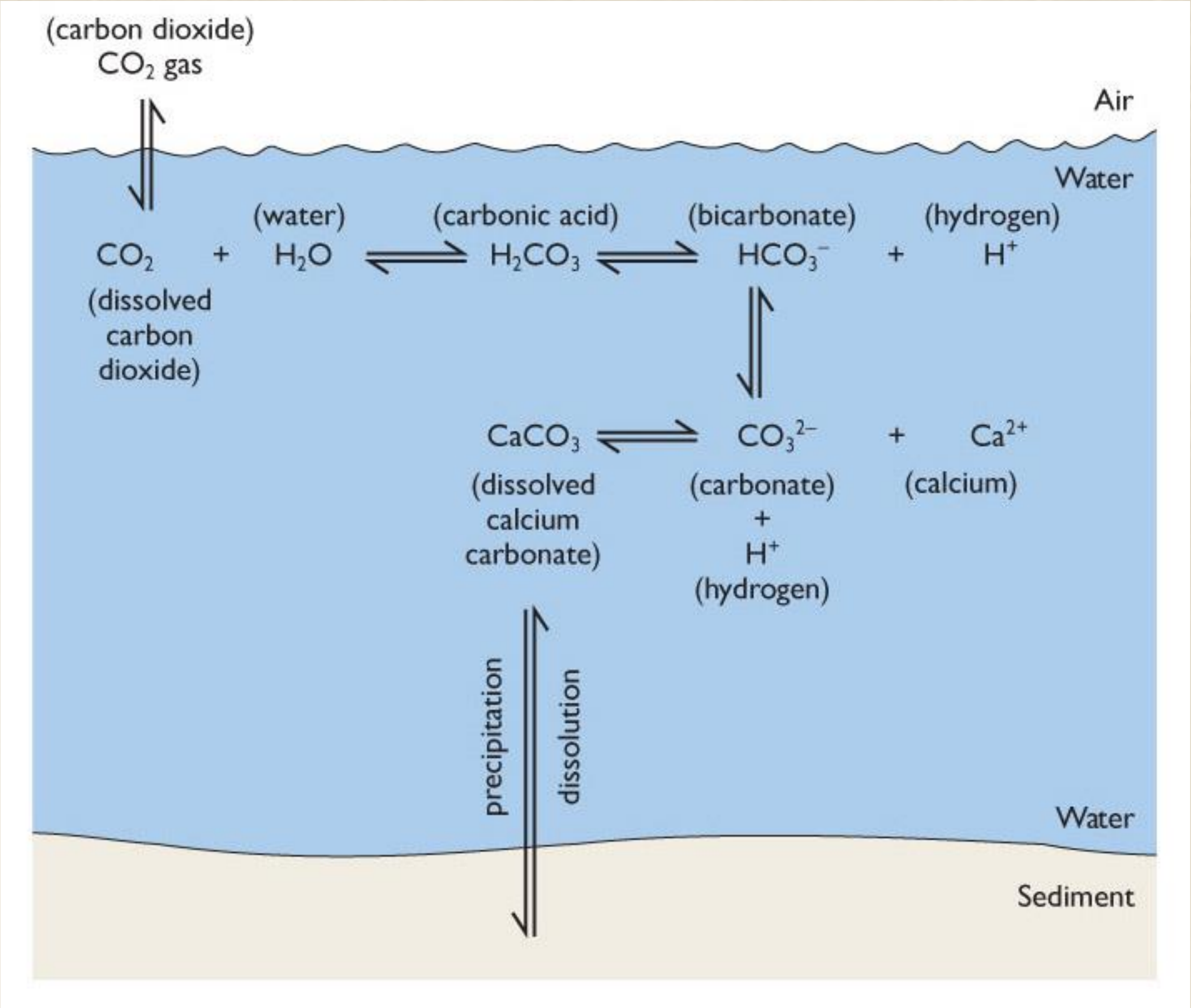


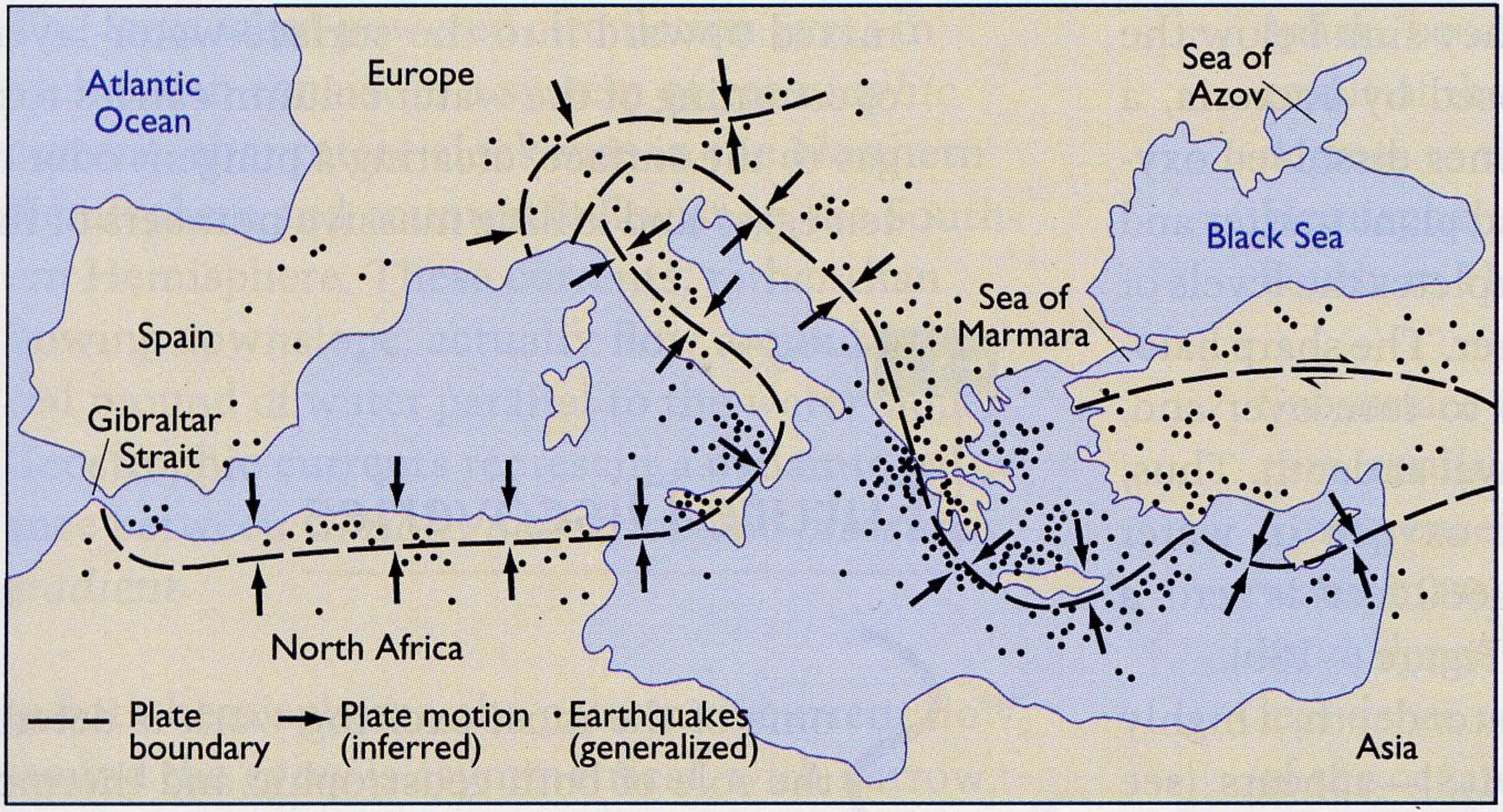
Figure 5-19c The CO_2 System

- Dissolved CO_2 in water acts as a **buffer**
  - A buffer is a substance that prevents large shifts in pH.

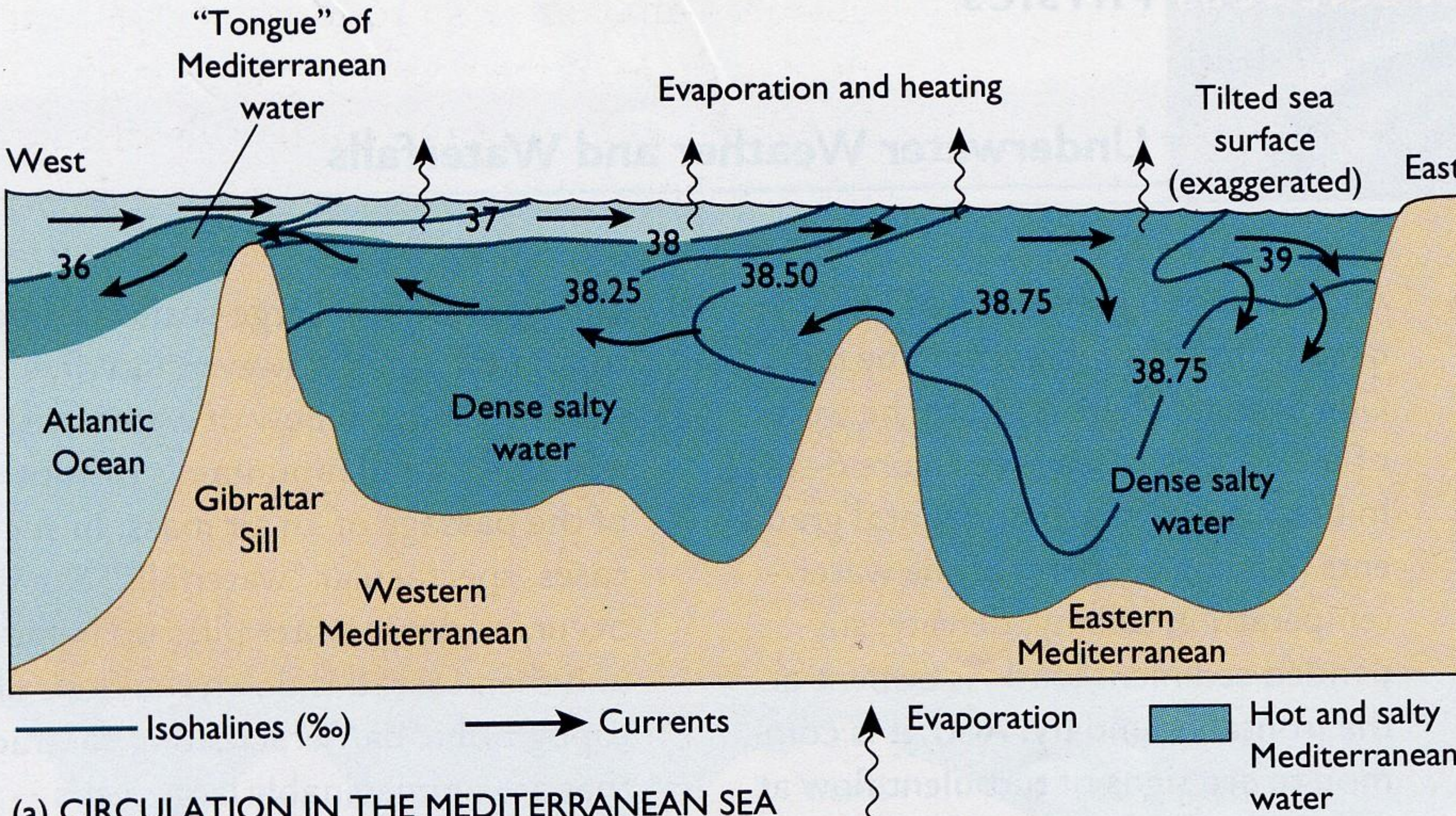
Seawater too basic: $H_2CO_3 \longrightarrow HCO_3^- + H^+$ pH drops

Seawater too acidic: $HCO_3^- + H^+ \longrightarrow H_2CO_3$ pH rises

Figure 5-19d Carbonate Buffer



(a) SUBDUCTION IN THE MEDITERRANEAN REGION



(a) CIRCULATION IN THE MEDITERRANEAN SEA

- **SOFAR Channel** is located where sound speed is at a minimum.
- Refraction of sound waves within the channel prevents dispersion of the sound energy.
- Sound waves travel for 1000s of kilometers within the channel.