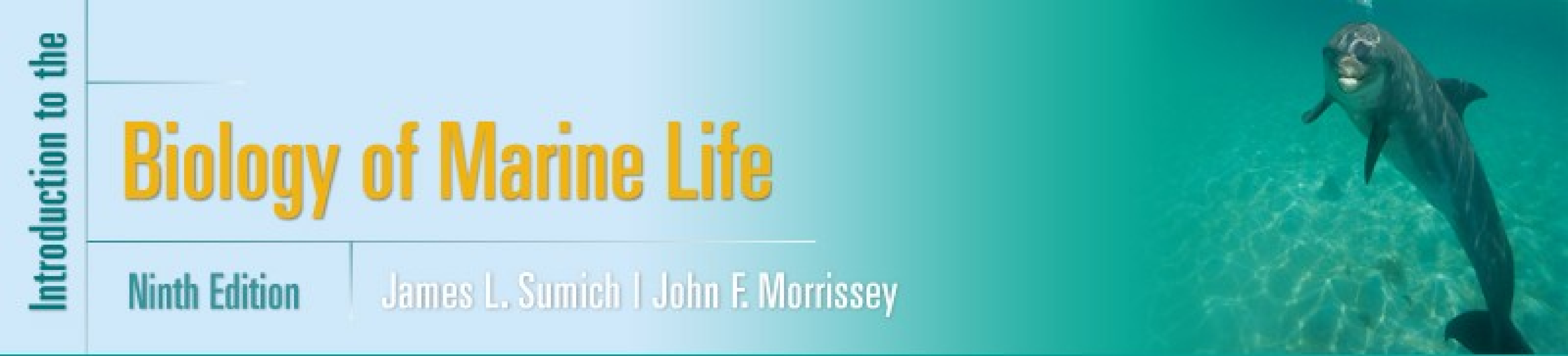


Chapter 1

The Ocean as a Habitat

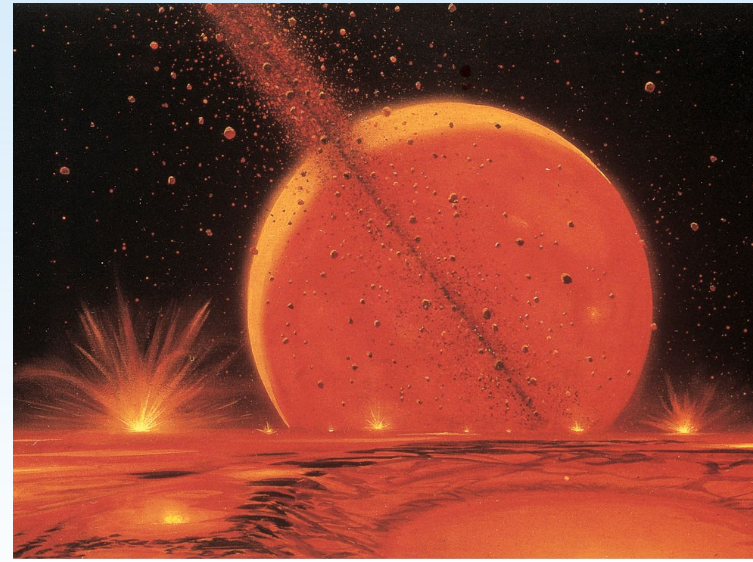
The Changing Marine Environment

Newsflash: Things have changed over the 5 billion year history of the Earth!!!

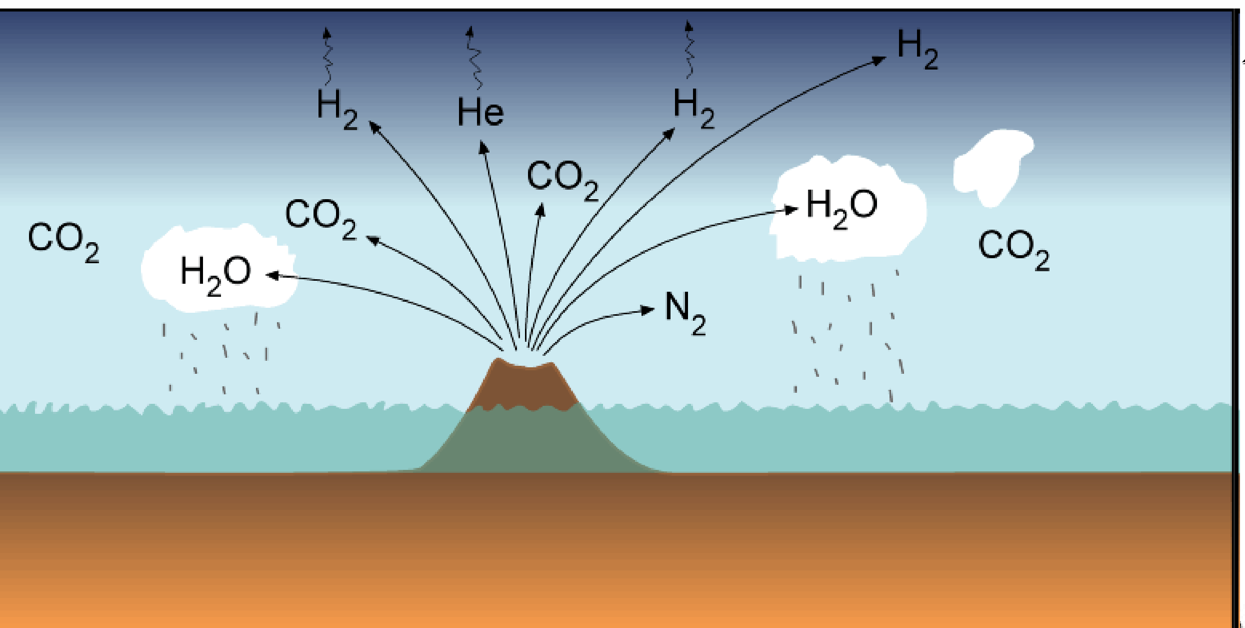
What changes???

Physically – How?

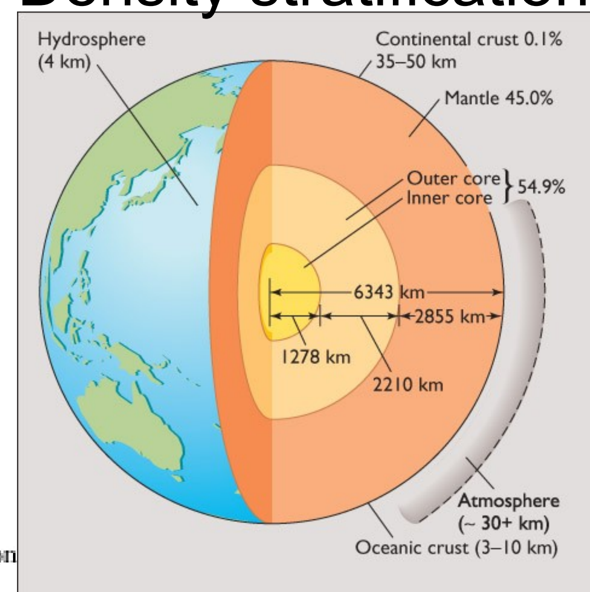
Chemically – How?



- Atmosphere w/ water vapor



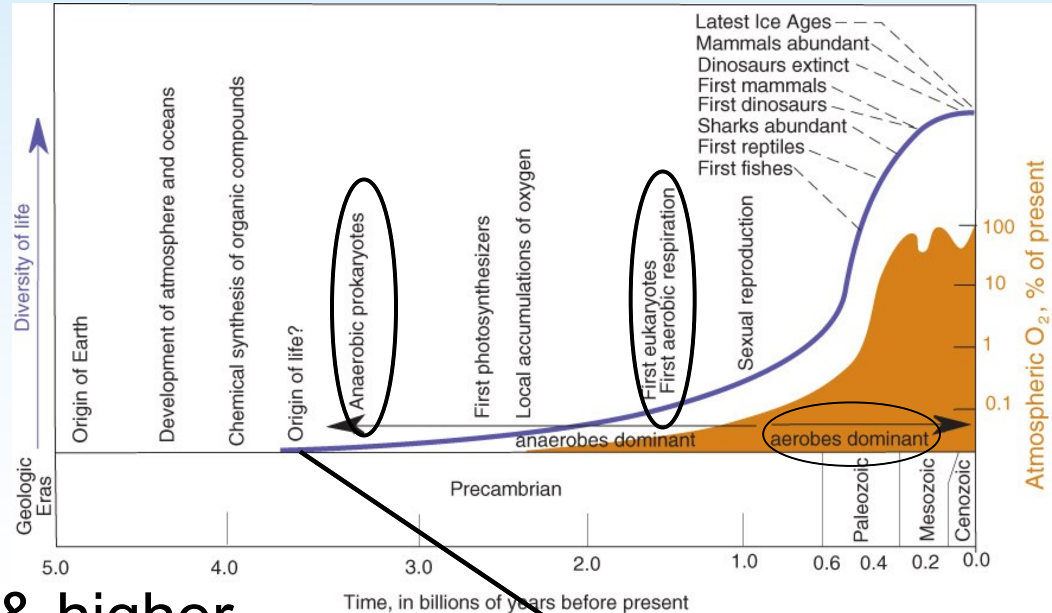
- Density stratification



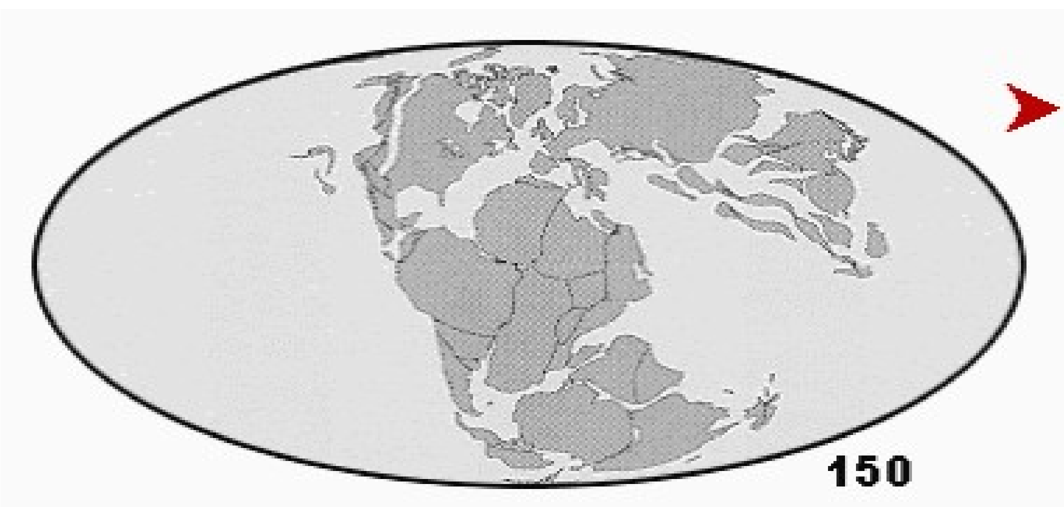
What changes???

Geologically – How?

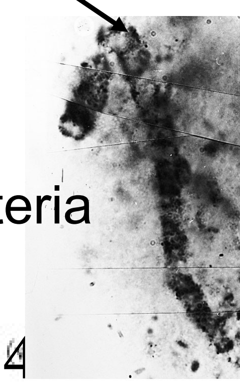
Biologically – How?



- Oceans getting deeper
- Continents getting larger & higher



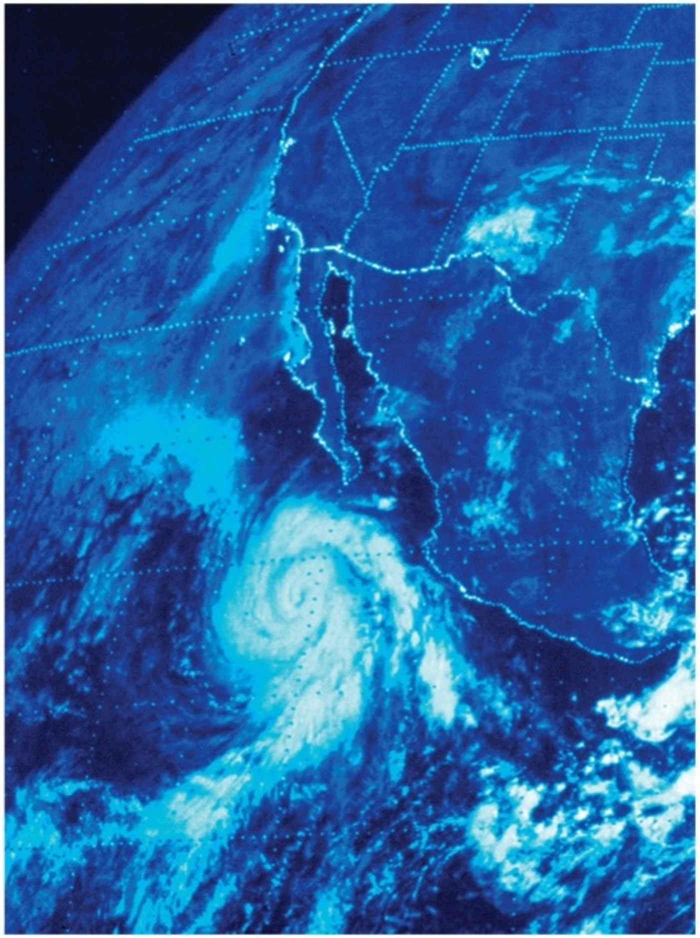
- Oxygen revolution
  - Ozone layer
- Marine bacteria



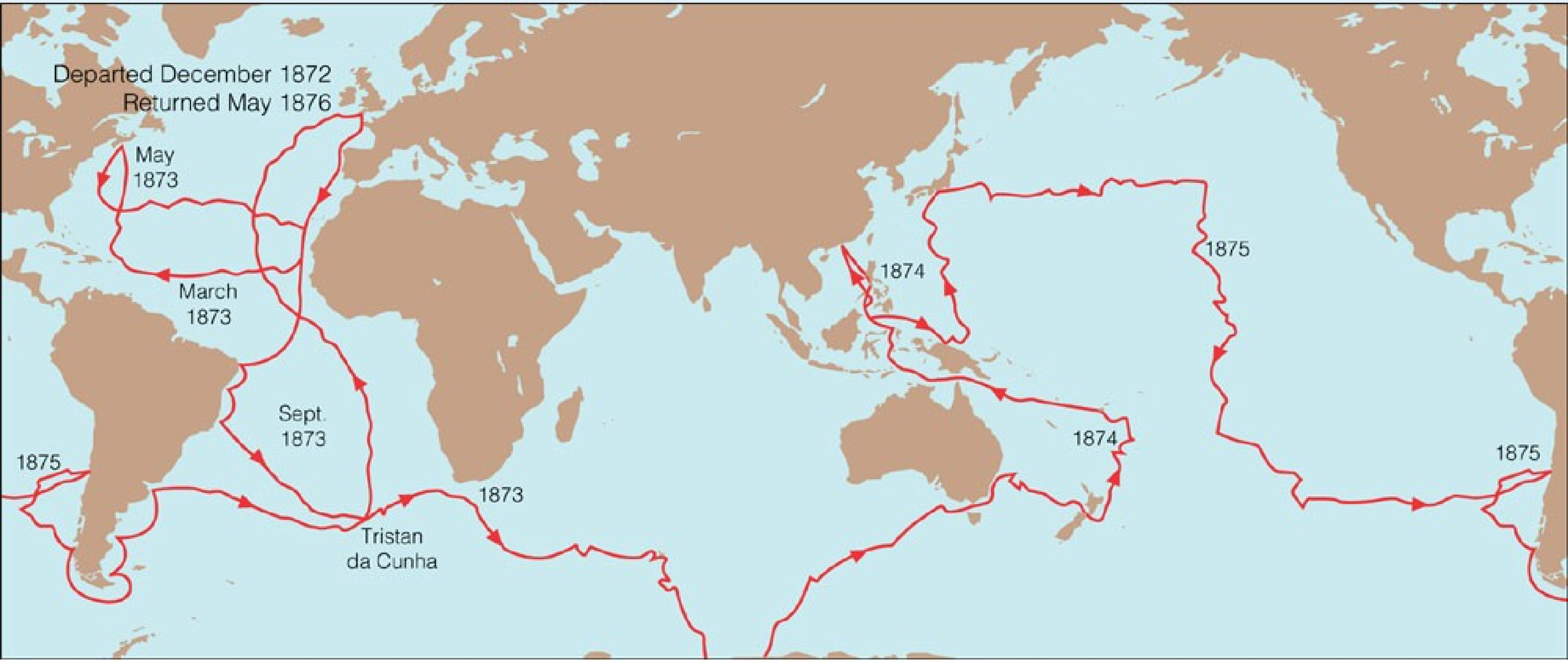
World ocean covers nearly 71% of earth's surface

Average depth??? Guesses???

- 3800 meters!!!



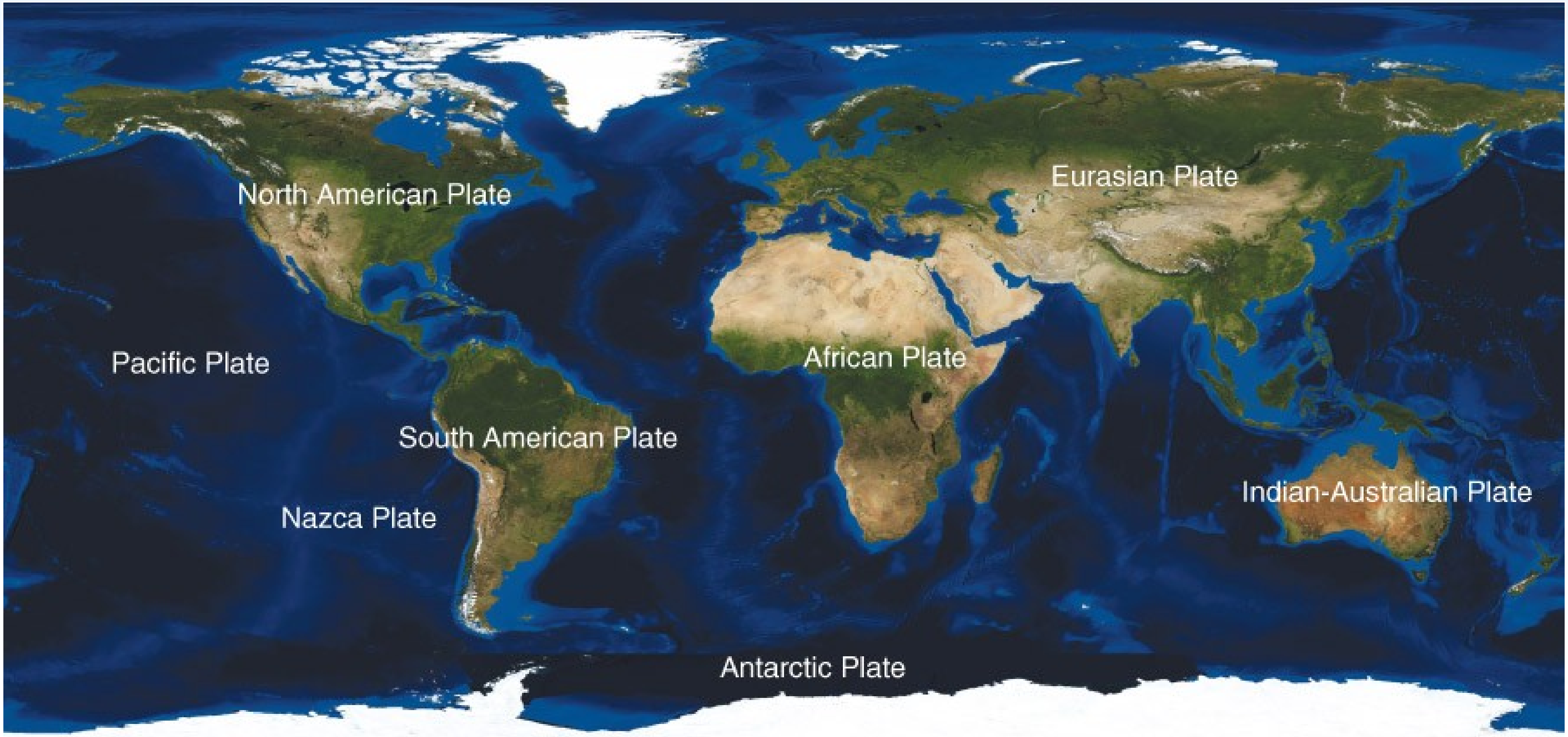
Charting the Deep



The Challenger's Voyage
69,000 nautical miles!!!

Charting the Deep

- The interrelated concepts of continental drift and plate tectonics have radically changed our view of the ocean’s structure.



Layers of the earth

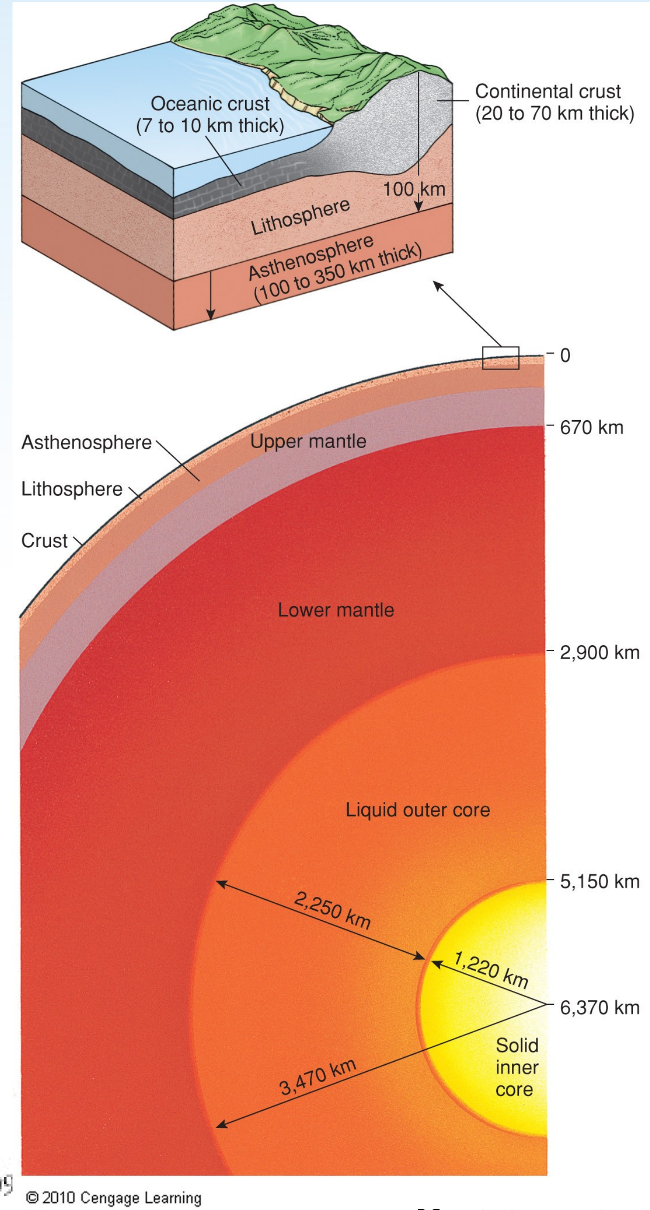
Inner core

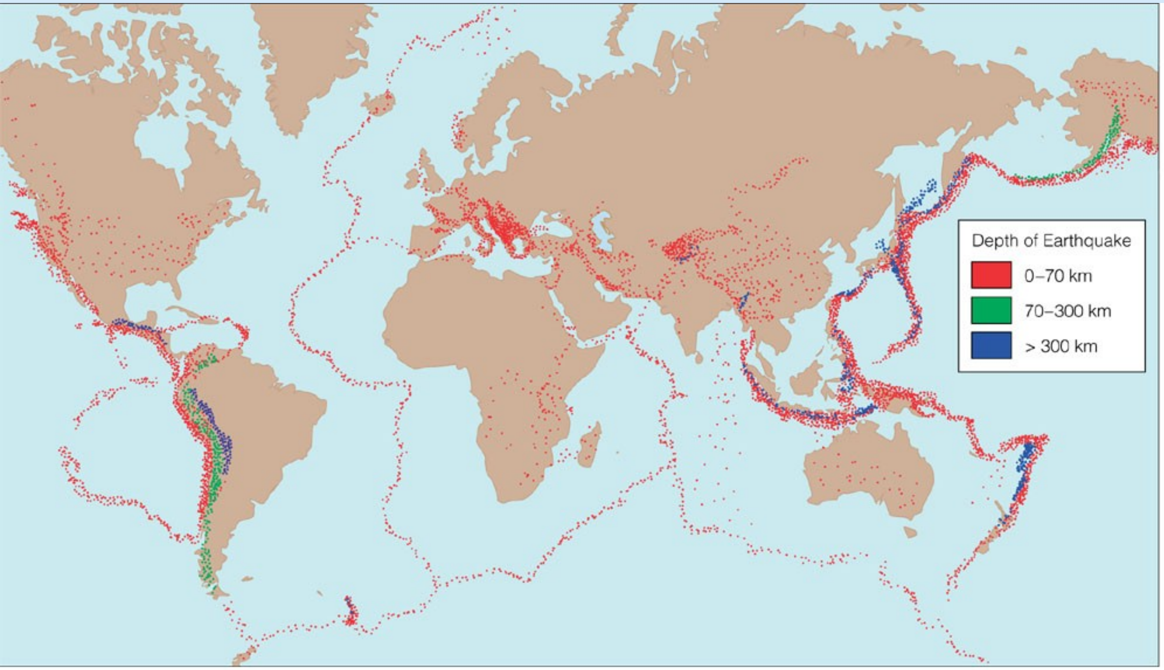
Outer core

Mantle

Crust

- Lithosphere: crust and upper mantle
- Athenosphere: below lithosphere (liquid)

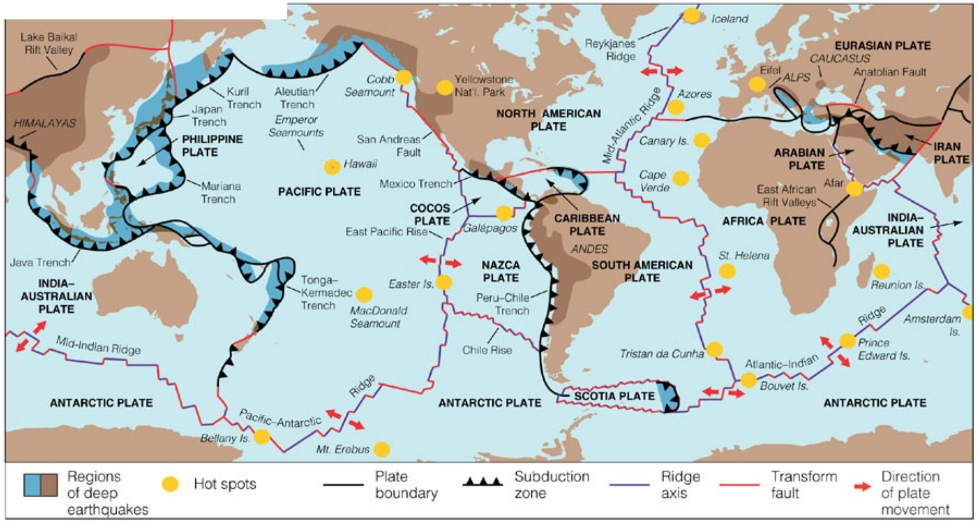




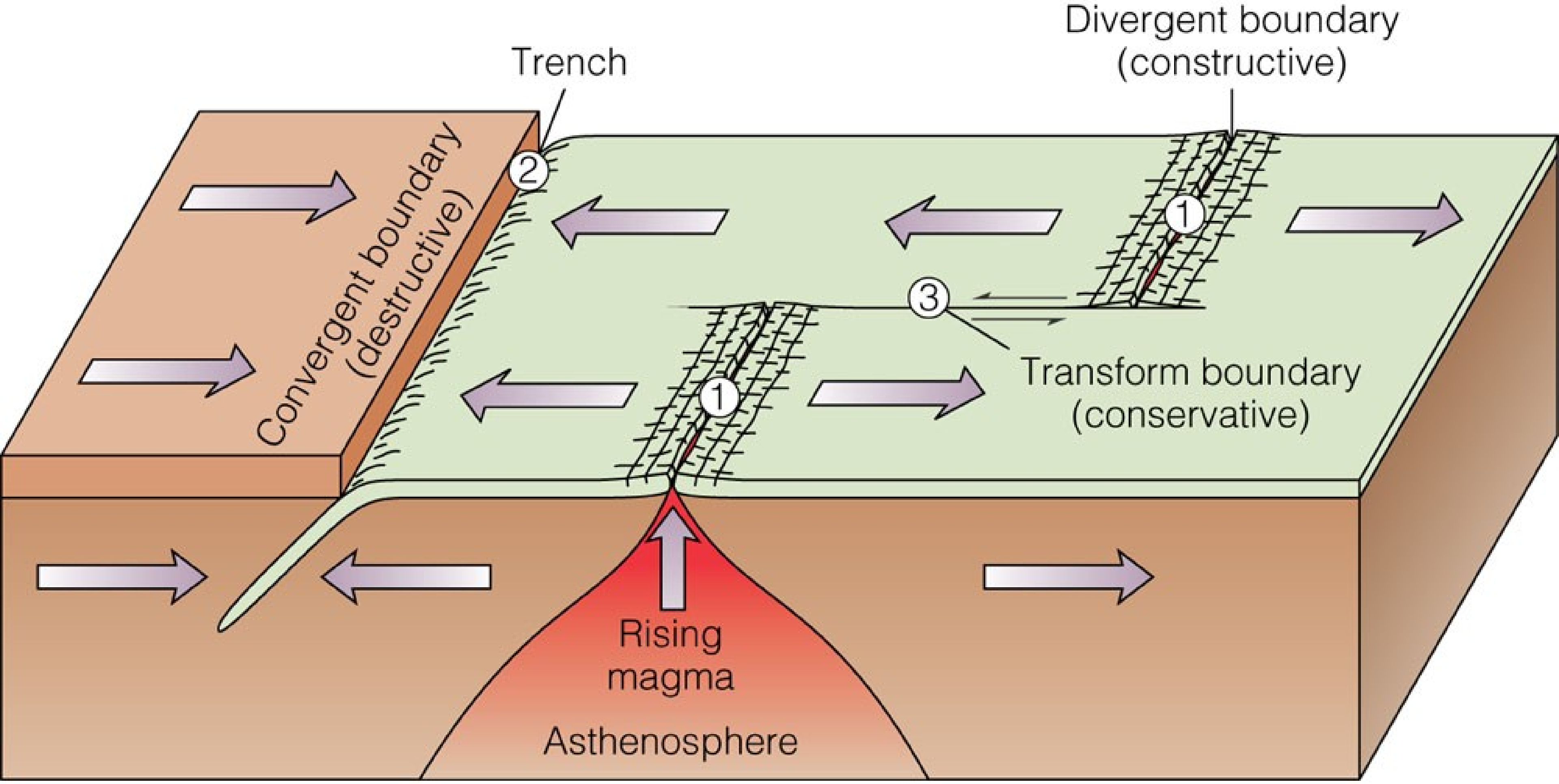
- Earthquakes rock!

Plate tectonics –

The lithosphere is broken up into tectonic plates



Plates can come together and move apart



A Different View of the Ocean Floor

Crust destroyed Crust created

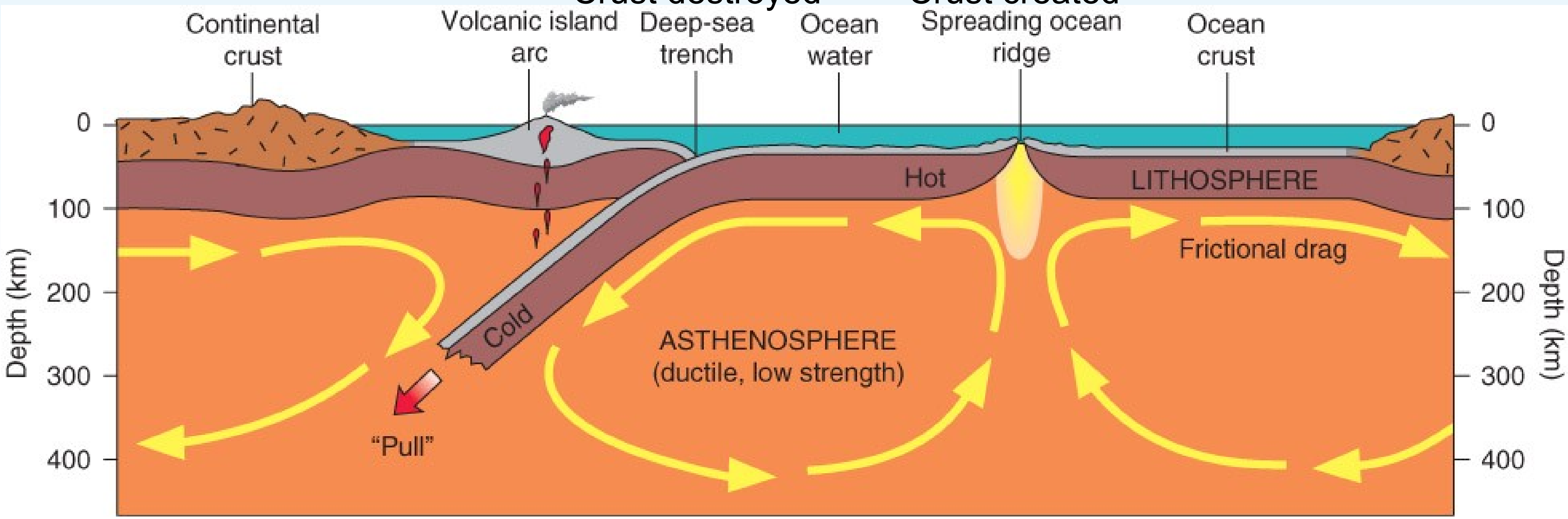
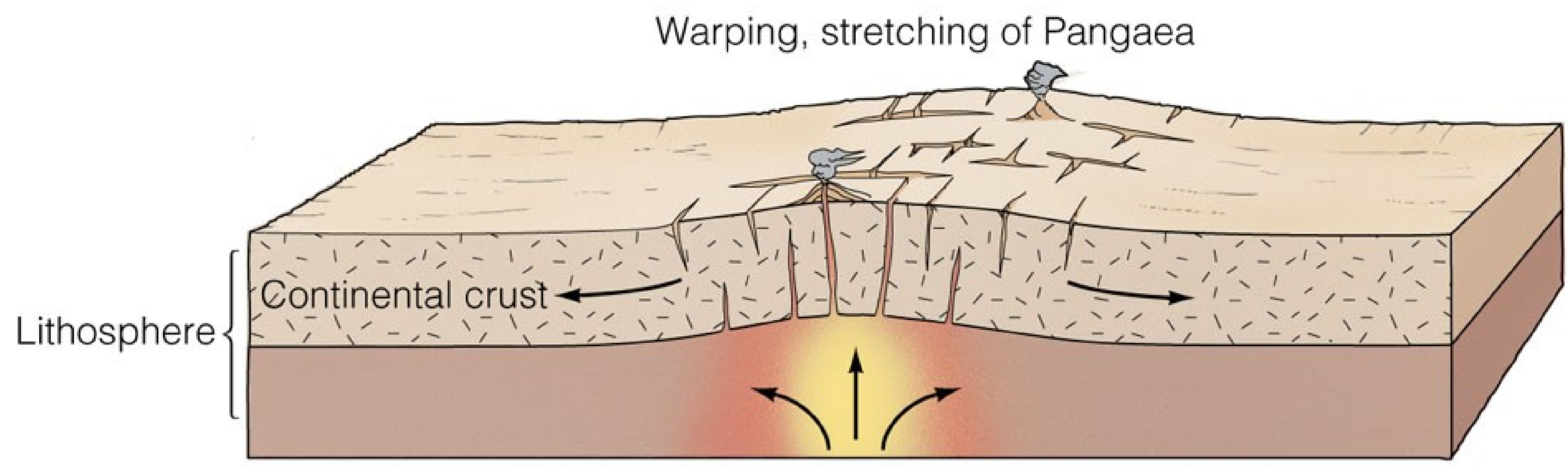
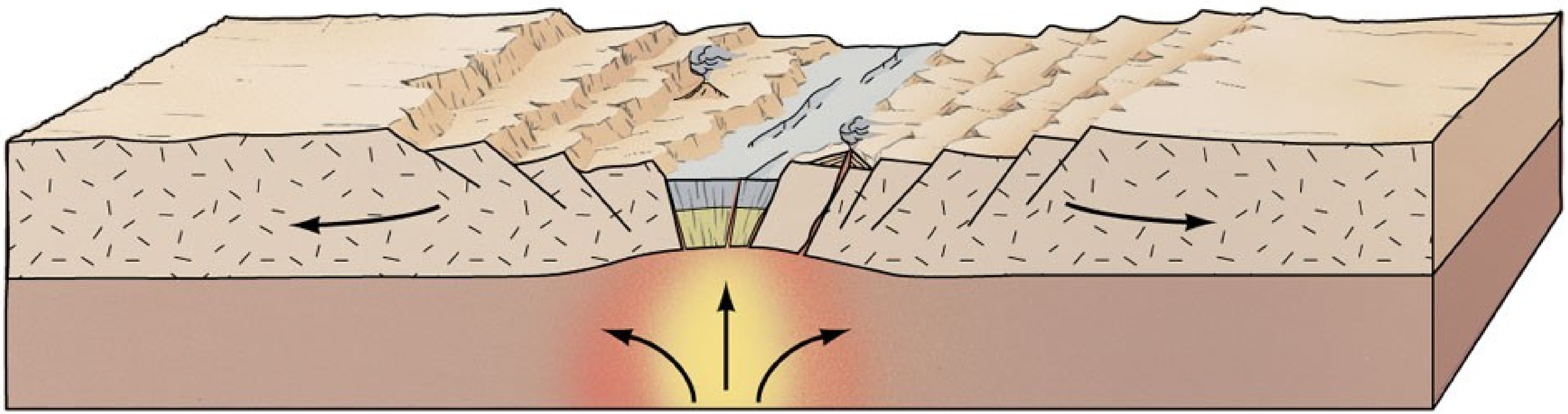
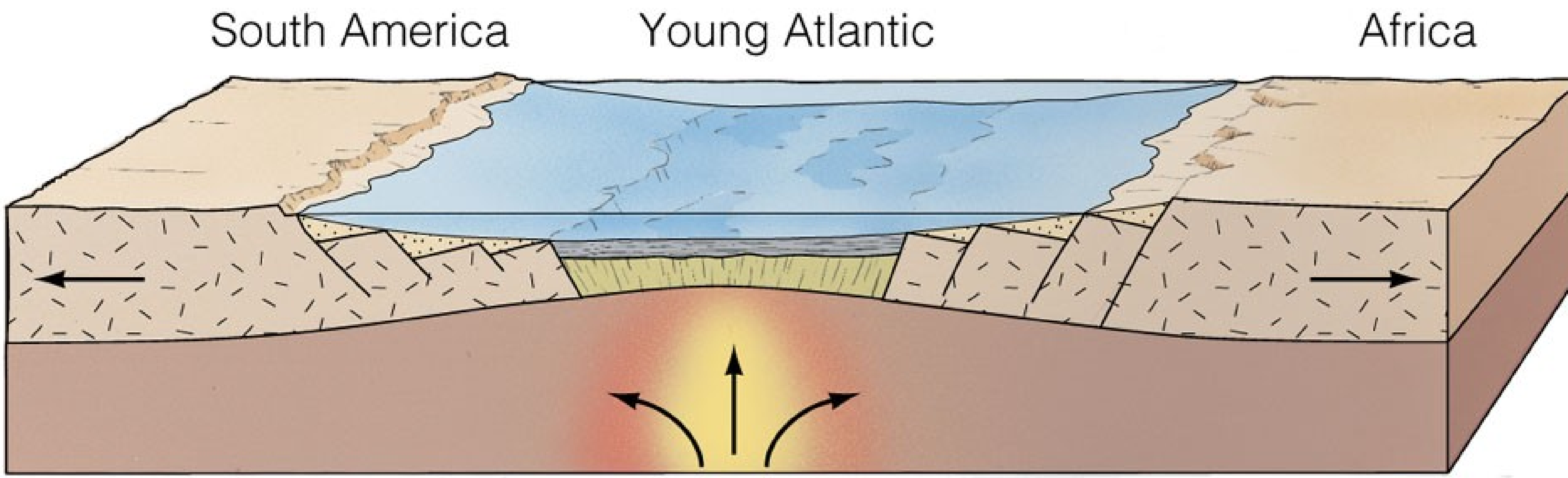


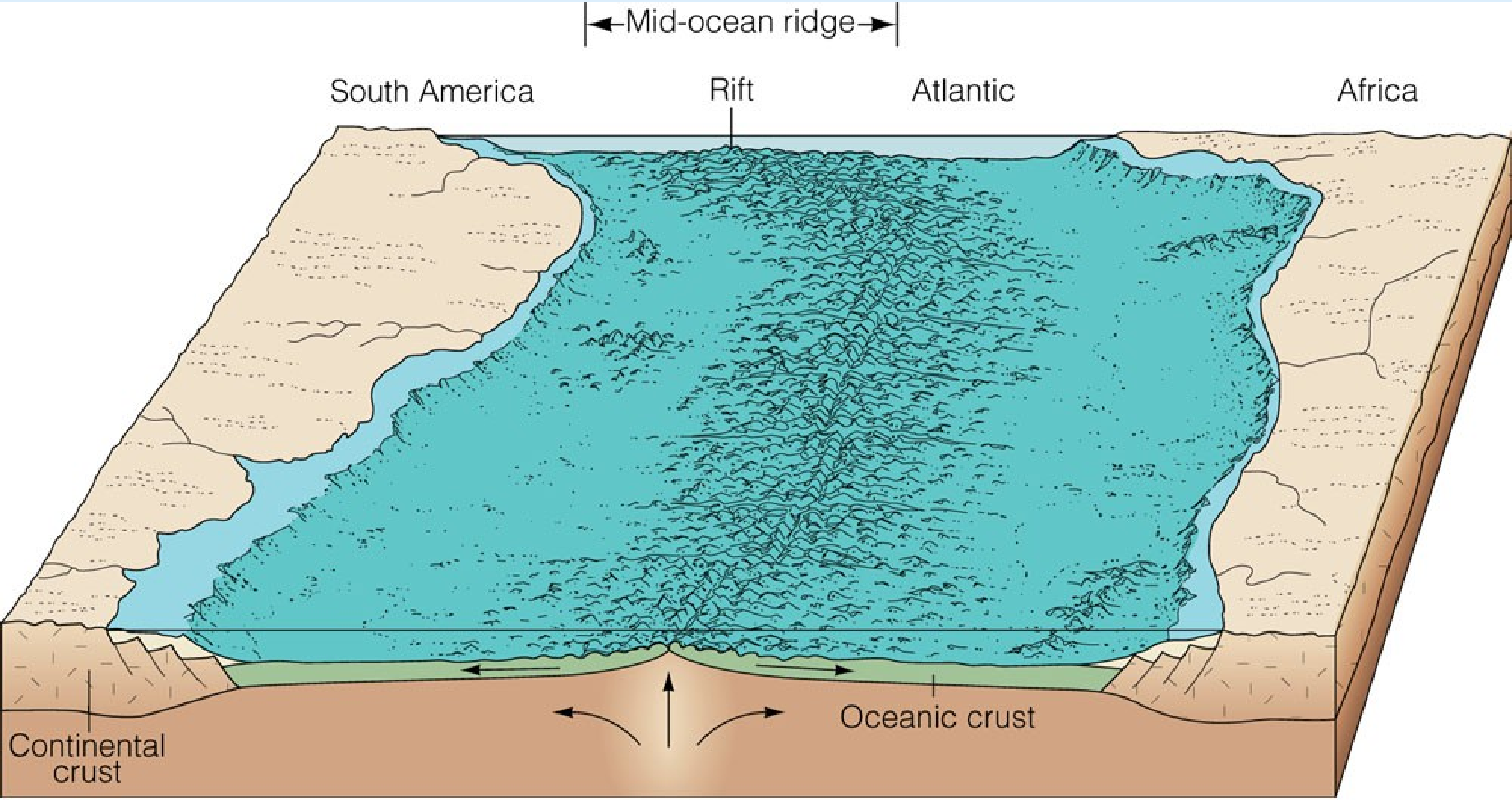
Fig. 1.6 Cross-section of a spreading ocean floor, illustrating the relative motions of oceanic and continental crusts. New crust is created at the ridge axis, and old crust is lost in trenches.

- Seafloor spreading – the mechanism of continental drift: occurs at ridges

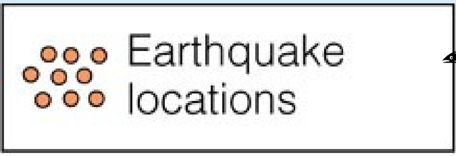


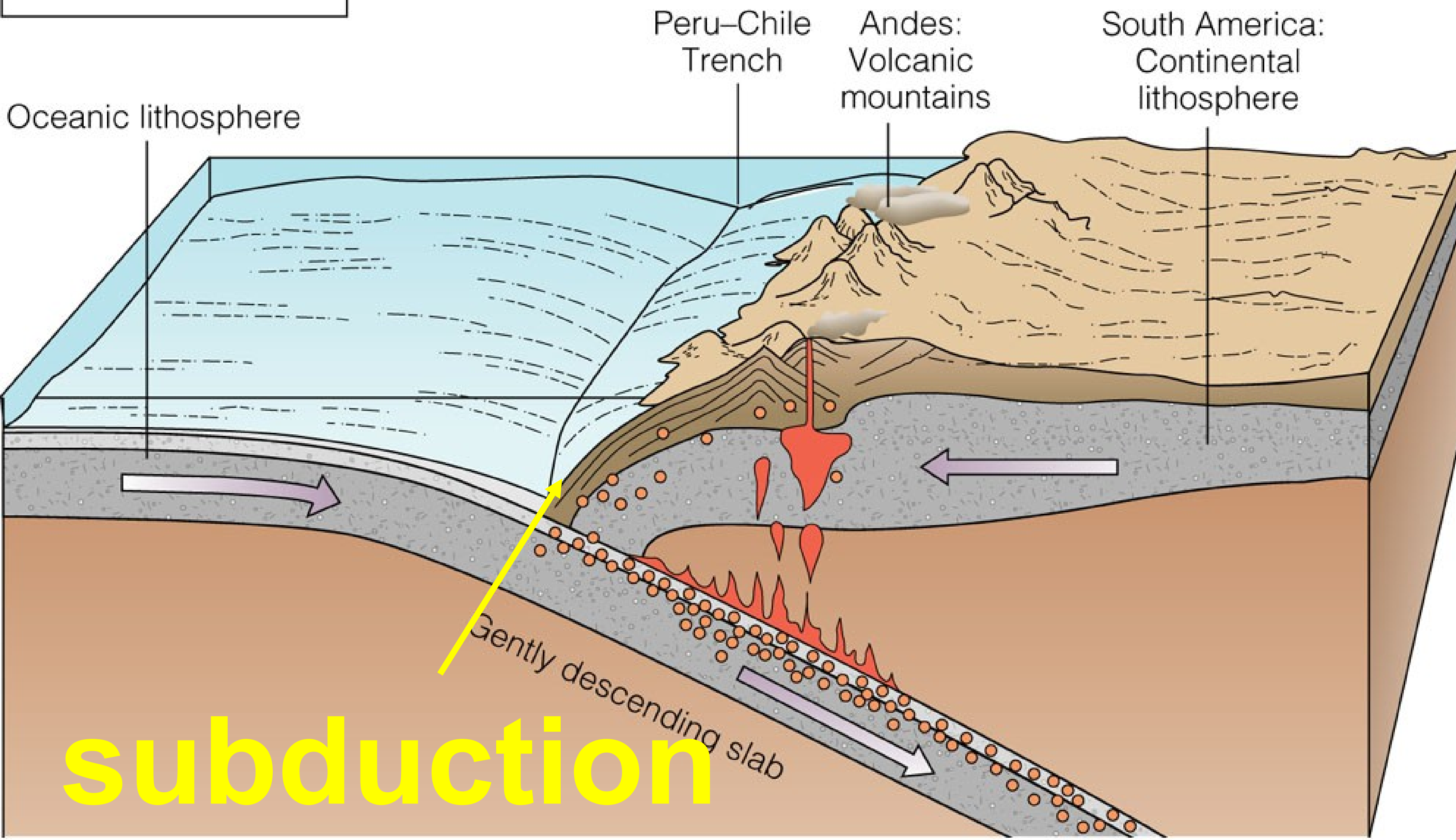

Formation of rift valley


South America
Young Atlantic
Africa


Mid-ocean ridge
South America
Rift
Atlantic
Africa
Oceanic crust
Continental crust

Subduction zones occur at trenches



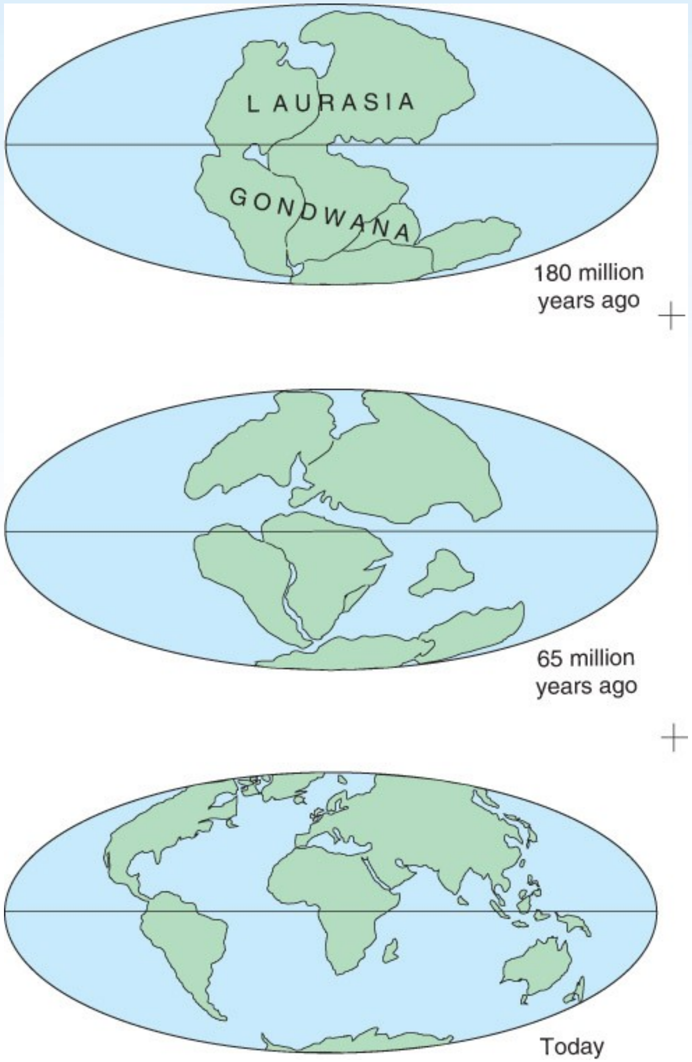


Continental Drift

- All continents were once part of a supercontinent – **Pangaea** – that split and drifted apart

The distribution of glacial features can be best explained if the continents were part of Pangaea.

A Different View of the Ocean Floor



- About 200 million years ago, Pangaea, separated into Laurasia and Gondwana.

The World Ocean

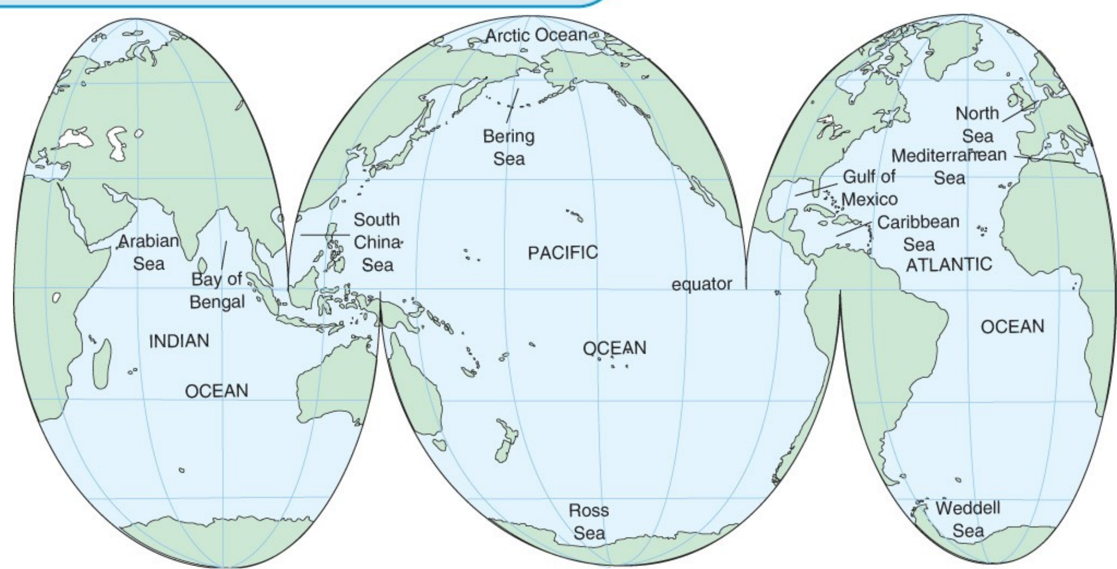
Visualizing the World Ocean

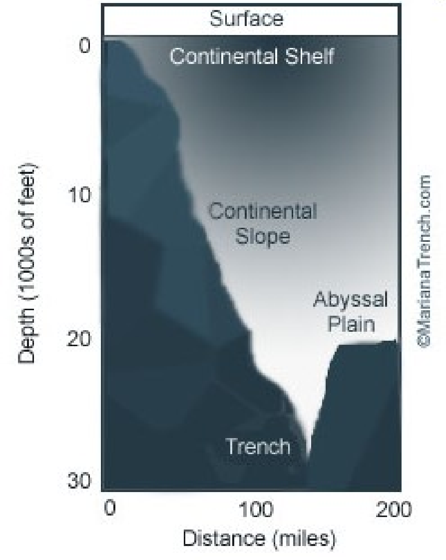
- Earth's oceans exist as a large inter-connected system of mixing seawater.

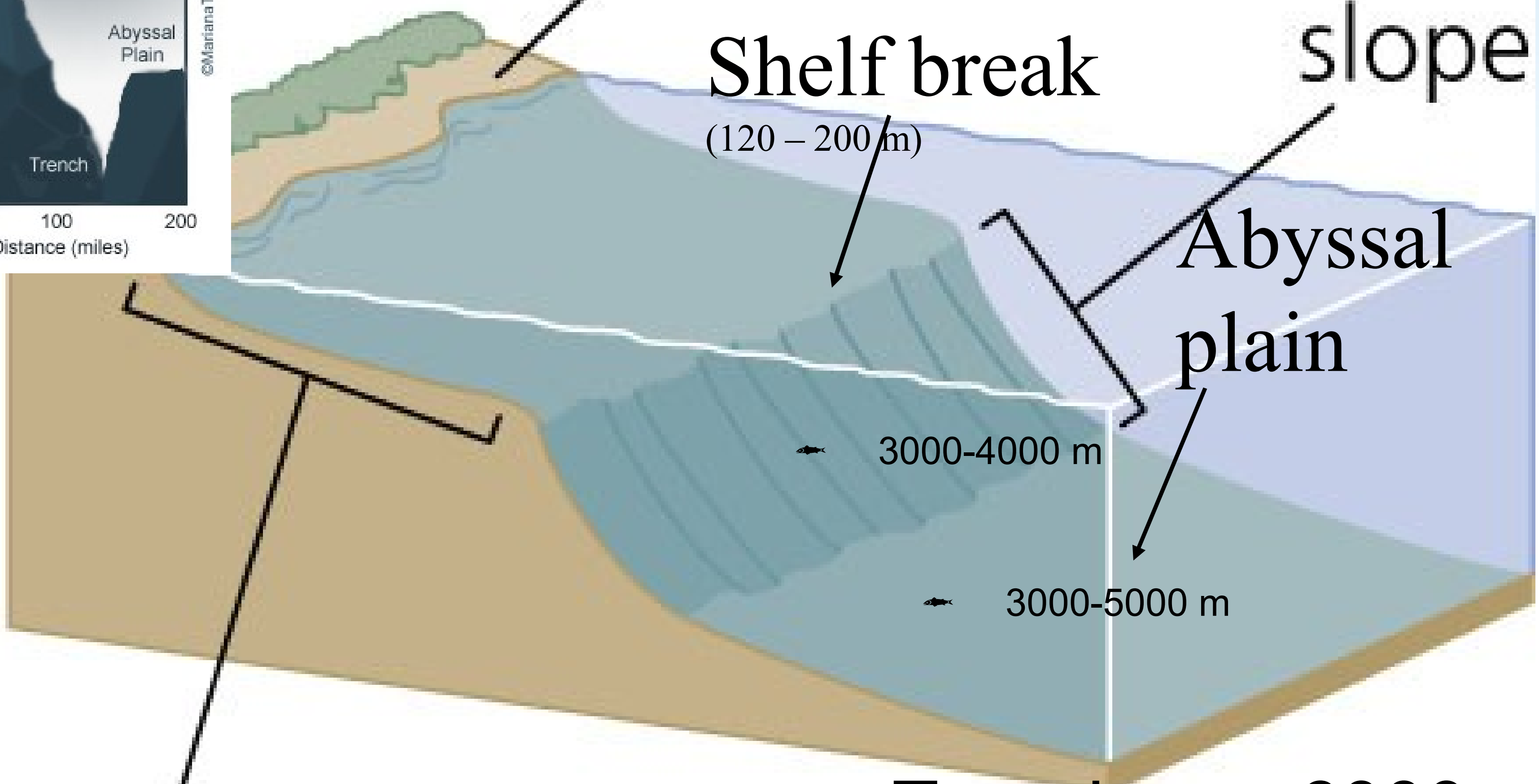
Table 1.1

Some Comparative Features of the Major Ocean Basins

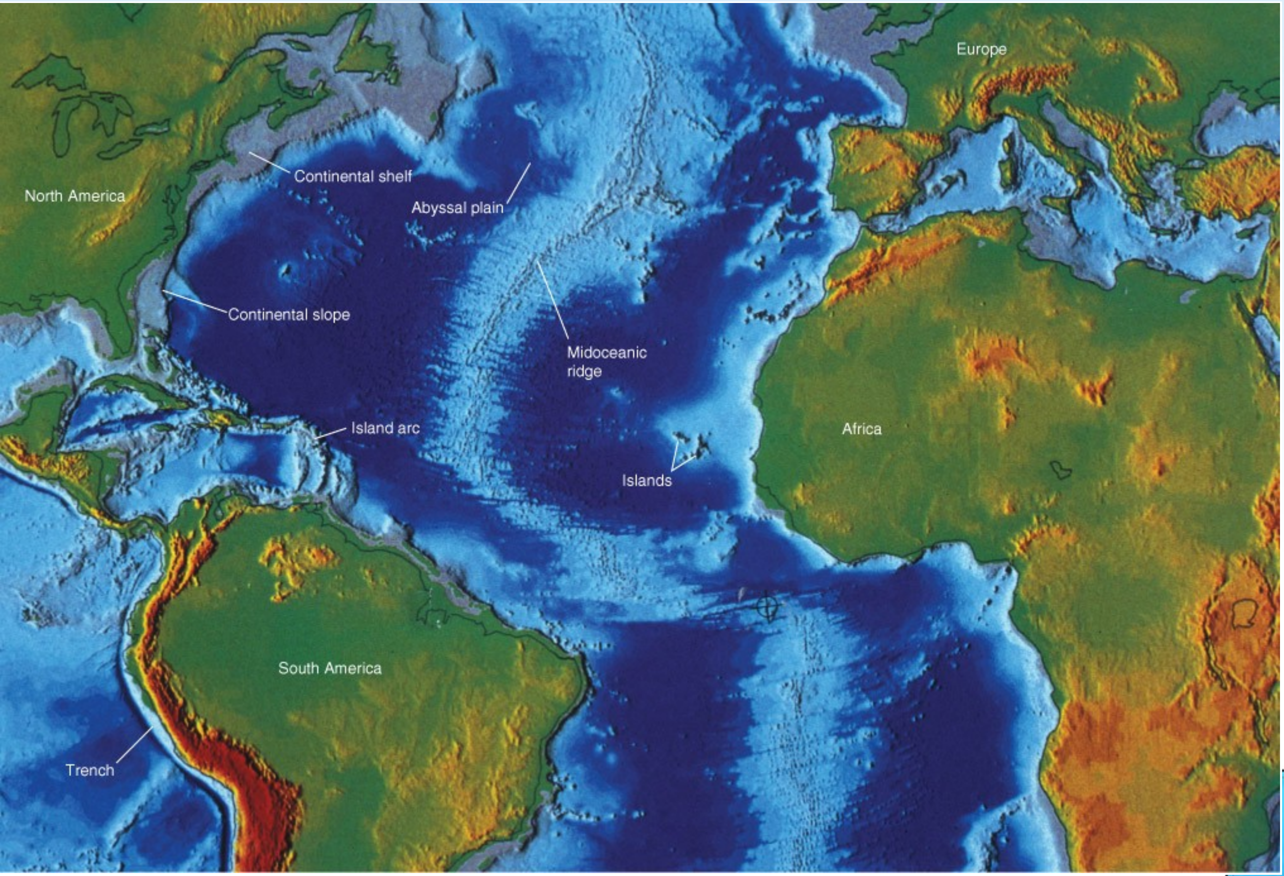
Ocean or Sea	Area 3 10^6 km^2	Volume 3 10^6 km^3	Average depth (m)	Maximum depth (m)
Pacific	165.2	707.6	4282	11,033
Atlantic	82.4	323.6	3926	9200
Indian	73.4	291.0	3963	7460
Arctic	14.1	17.0	1205	4300
Caribbean	4.3	9.6	2216	7200
Mediterranean	3.0	4.2	1429	4600
Other	18.7	17.3		
Totals (average)	361.1	1370.3	(3795)	

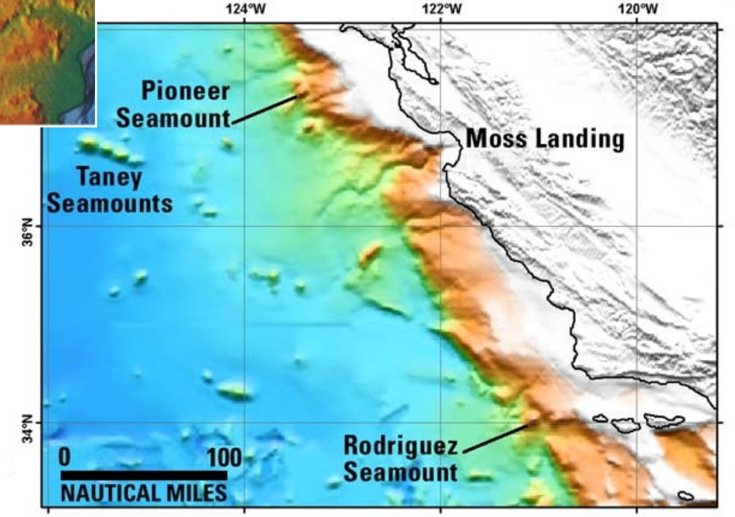



Surface
Continental Shelf
Continental Slope
Abyssal Plain
Trench
Depth (1000s of feet)
0
10
20
30
Distance (miles)
0
100
200
©MarianaTrench.com


coastline
continental slope
Shelf break
(120 – 200 m)
Abyssal plain
3000-4000 m
3000-5000 m
Trenches > 6000m
continental shelf

The World Ocean



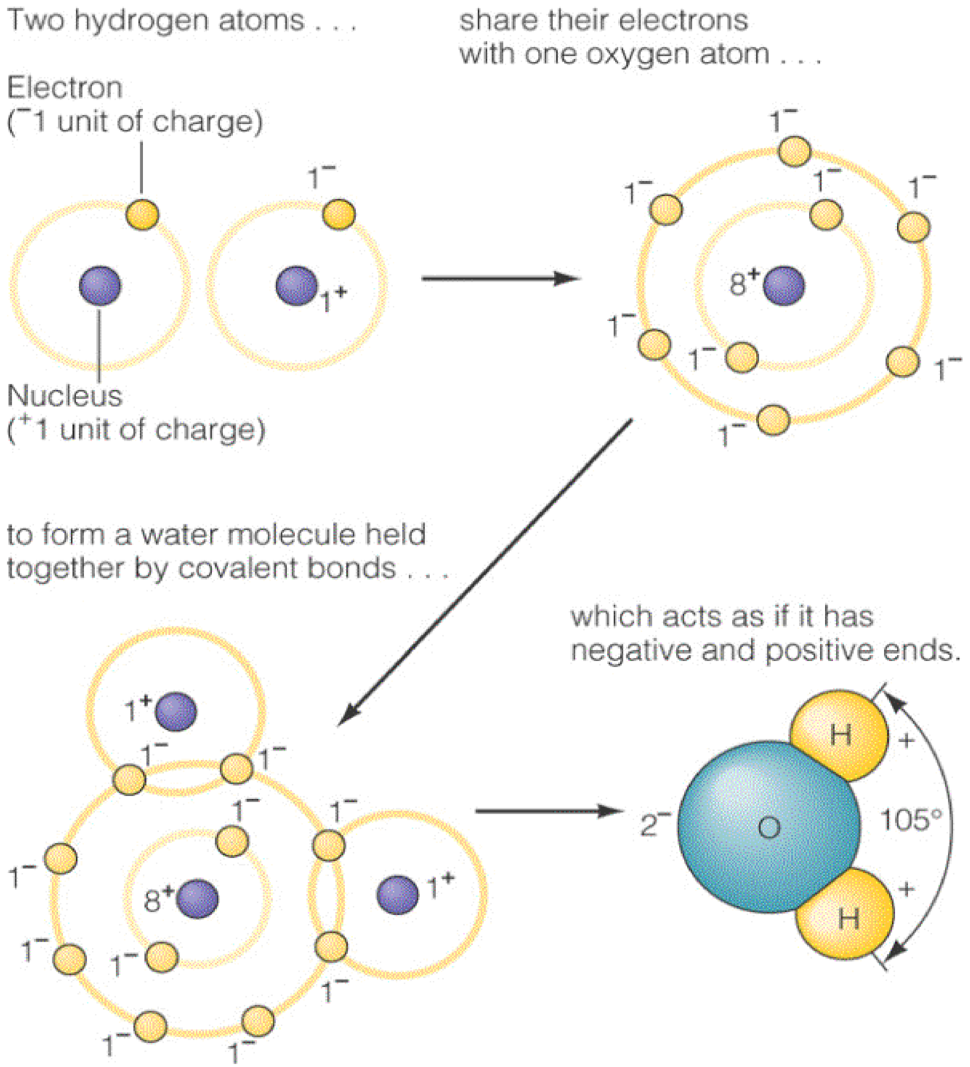


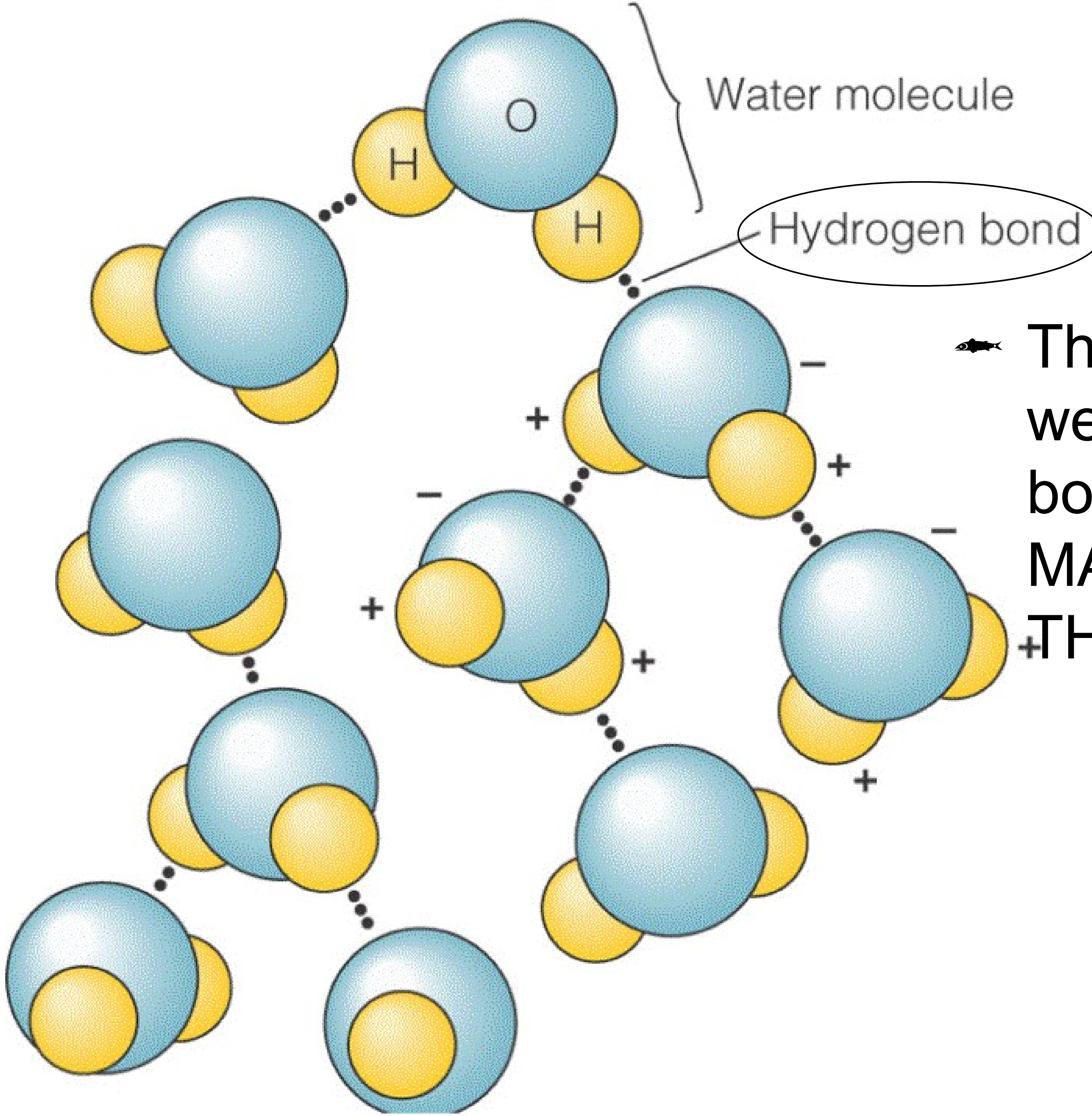
- Seamounts, islands, abyssal hills

Courtesy National Geophysical Data Center/NOAA


Properties of Seawater

- Polar molecule
- Covalent bond – the strongest bond





- The weakest bond, but MANY OF THEM!!!

Properties of Seawater

Pure Water

Table 1.2

Some Biologically Important Physical Properties of Water

Property	Comparison with other substances	Importance in biological processes
Boiling point	High (100°C) for molecular size	Causes most water to exist as a liquid at Earth surface temperatures
Freezing point	High (0°C) for molecular size	Causes most water to exist as a liquid at Earth surface temperatures
Surface tension	Highest of all liquids	Crucial to position maintenance of sea-surface organisms
Density of solid	Unique among common natural substances	Causes ice to float and inhibits complete freezing of large bodies of water
Latent heat of vaporization	Highest of all common natural substances (540 cal/g)	Moderates sea-surface temperatures by transferring large quantities of heat to the atmosphere through evaporation Inhibits large-scale freezing of the oceans
Latent heat of fusion	Highest of all common natural substances (80 cal/g)	Moderates daily and seasonal temperature changes
Solvent power	Dissolves more substances in greater amounts than any other liquid	Maintains a large variety of substances in solution, enhancing a variety of chemical reactions
Heat capacity	High (1 cal/g/°C) for molecular size	Stabilizes body temperatures of organisms

Properties of Seawater

1. Highest Viscosity and Surface Tension of all liquids!

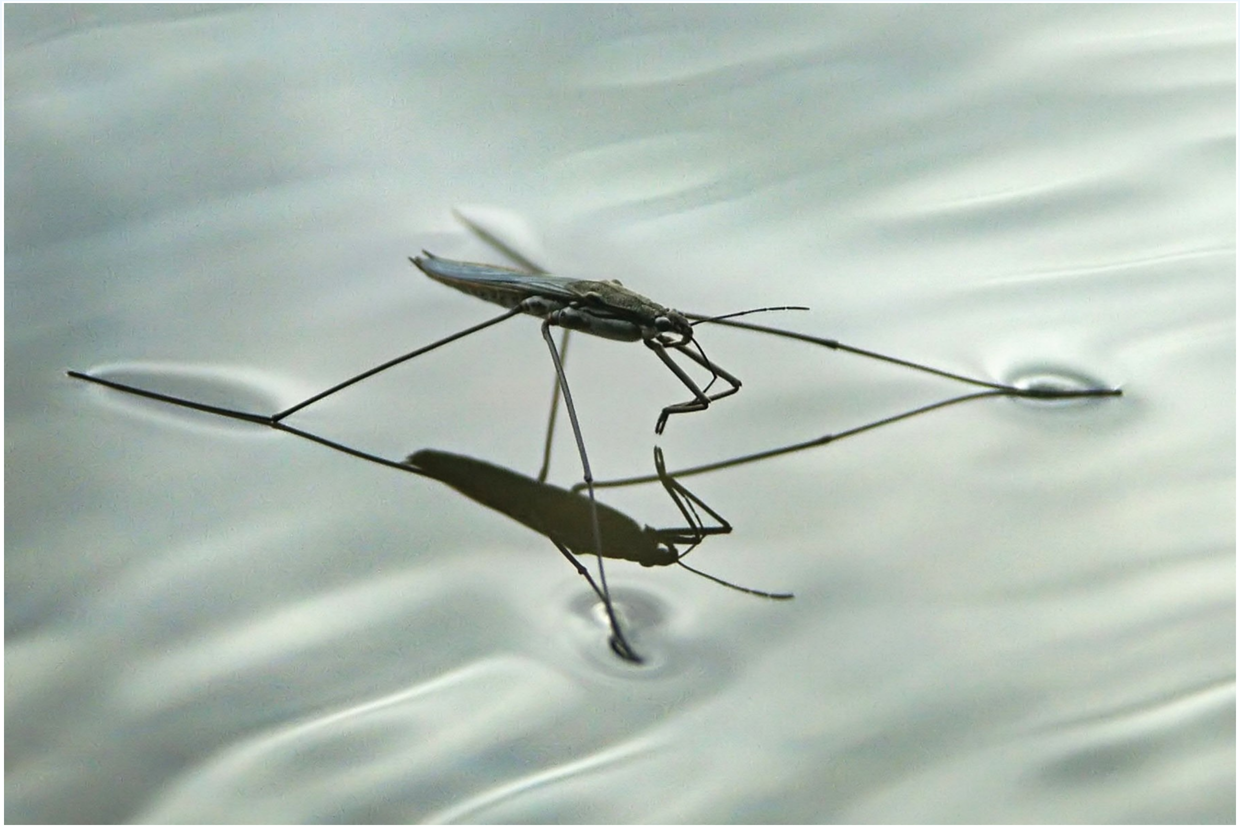
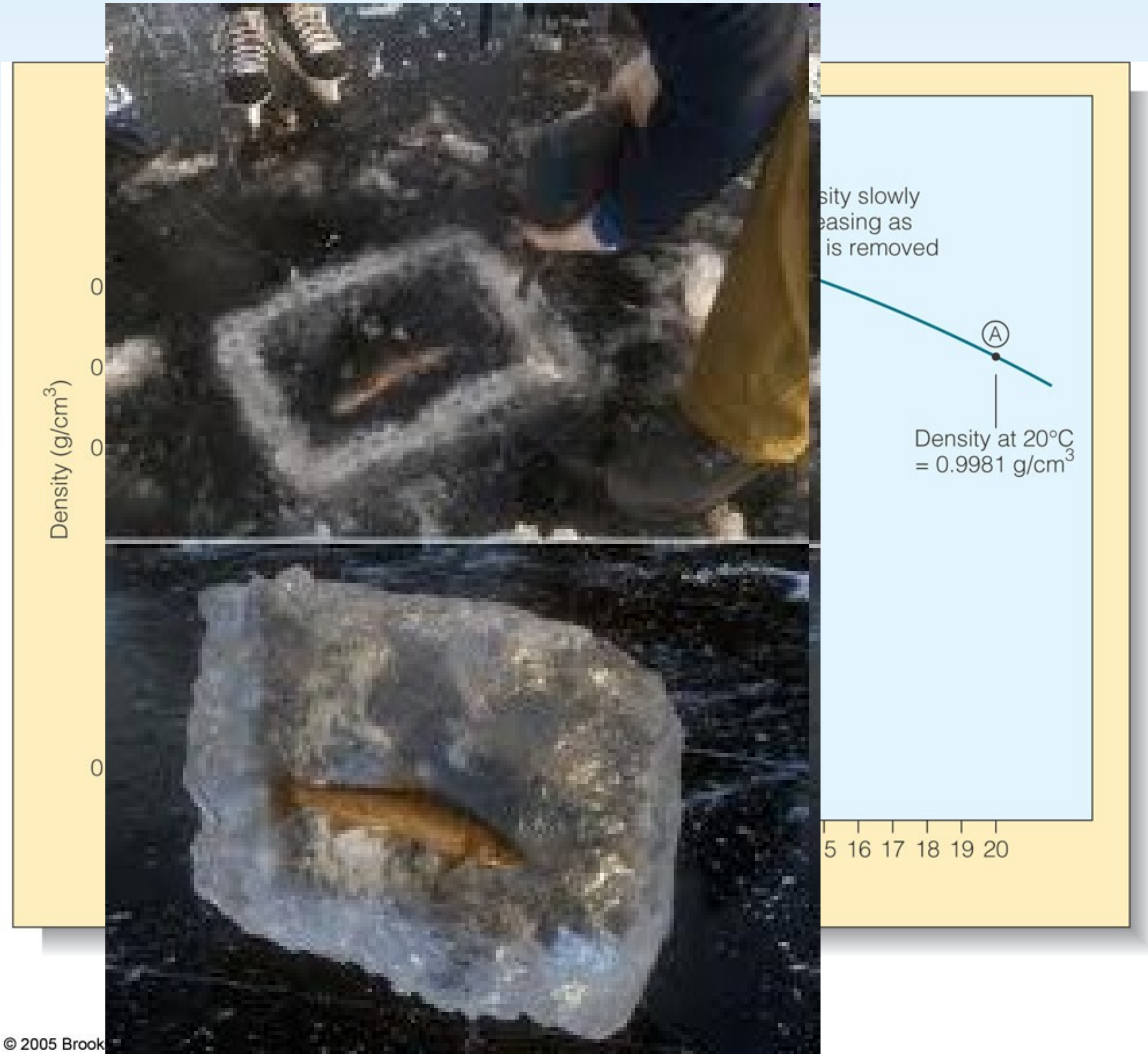


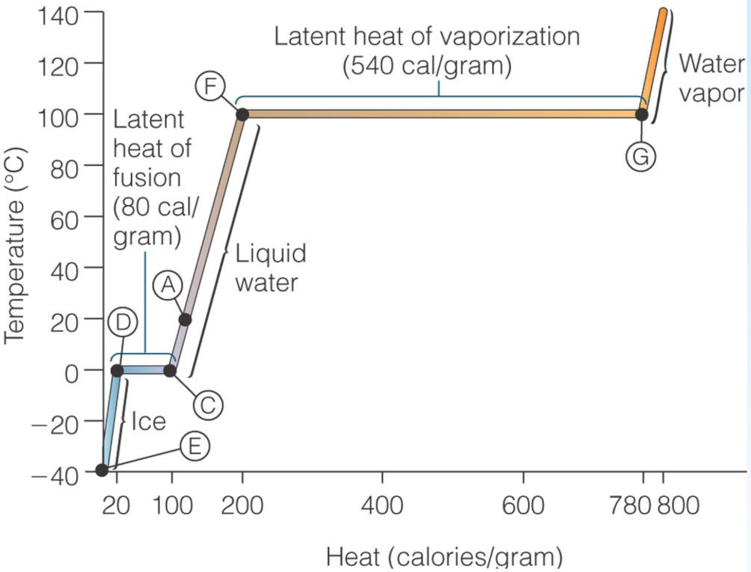
Fig. 1.15 A water strider (*Halobates*), one of the few completely marine insects, is supported by the surface tension of seawater.

Water Temperature and Density

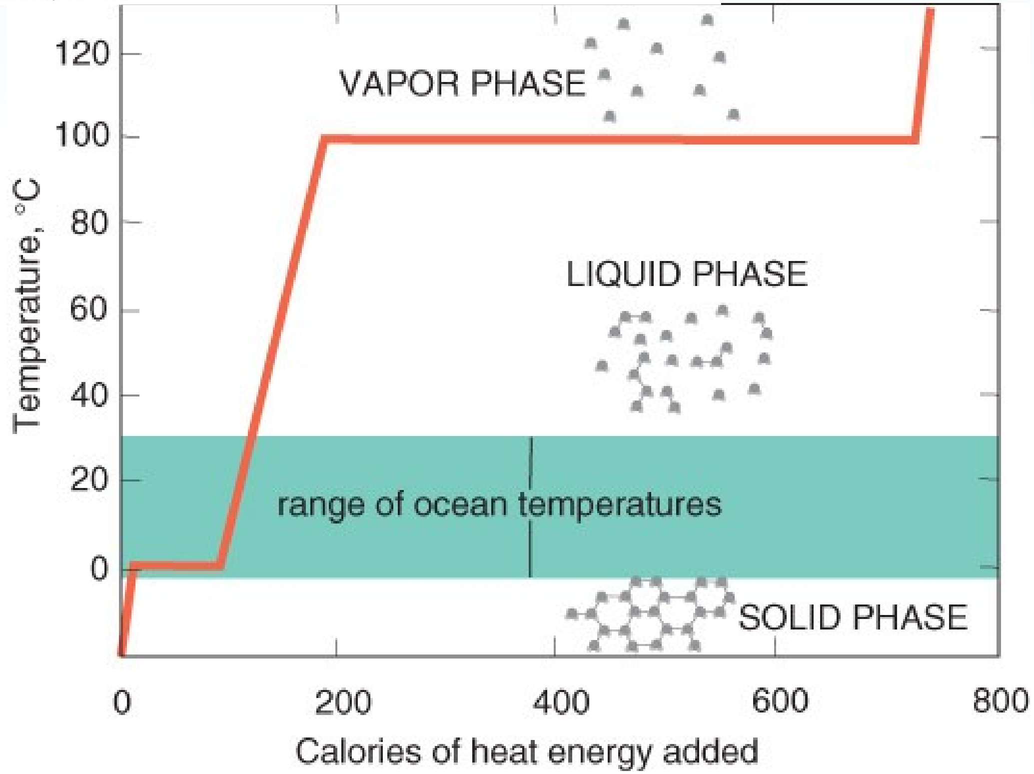
- 2. Solid form is less dense than liquid form
- Ice floats
- No large-scale freezing!



Properties of Seawater



© 2005 Brooks/Cole - Thomson

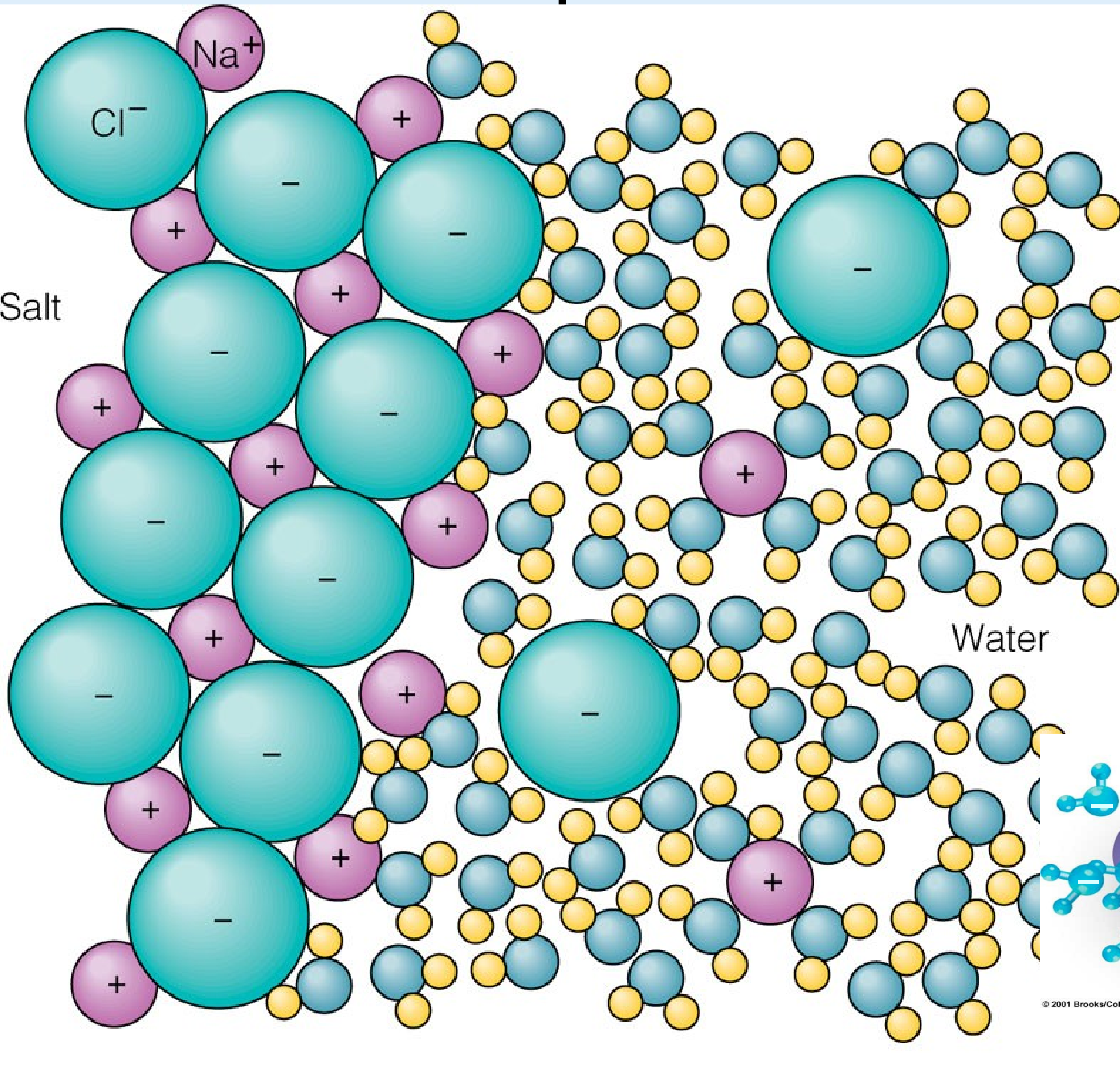


3. High Heat Capacity

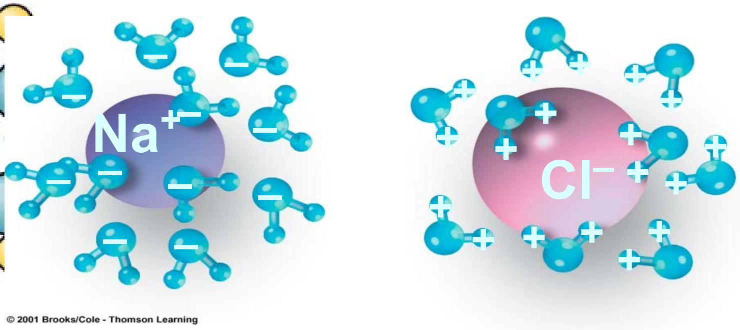
- A. High latent heat of fusion
- B. High latent heat of vaporization
- C. High boiling point
- D. High freezing point

- What does this mean for water and the “global” ocean?

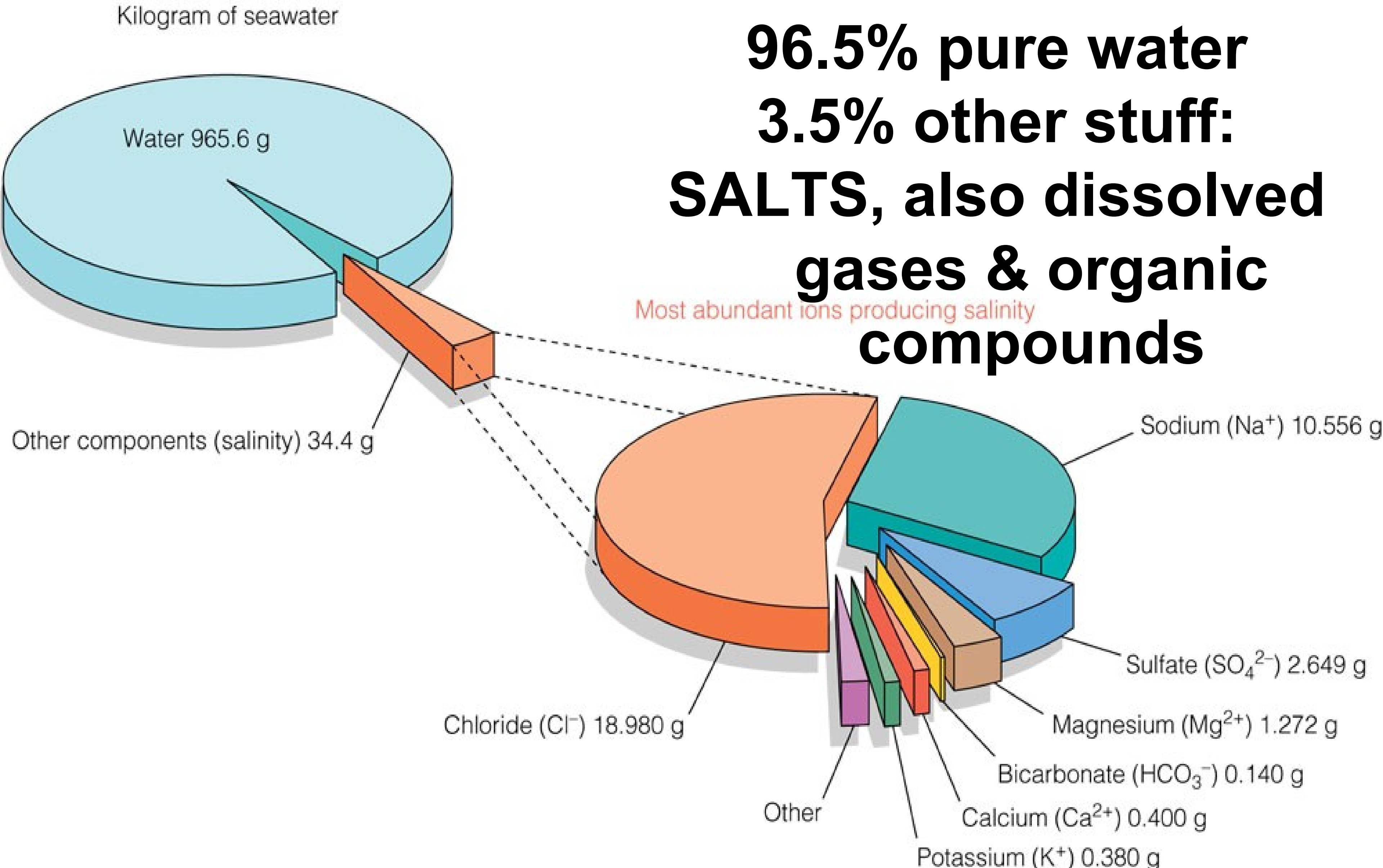
Properties of Seawater



- 4. Water's a good solvent!



96.5% pure water
3.5% other stuff: SALTS, also dissolved gases & organic compounds



- Amount of salts = salinity!!!

Properties of Seawater

Ocean Salinity

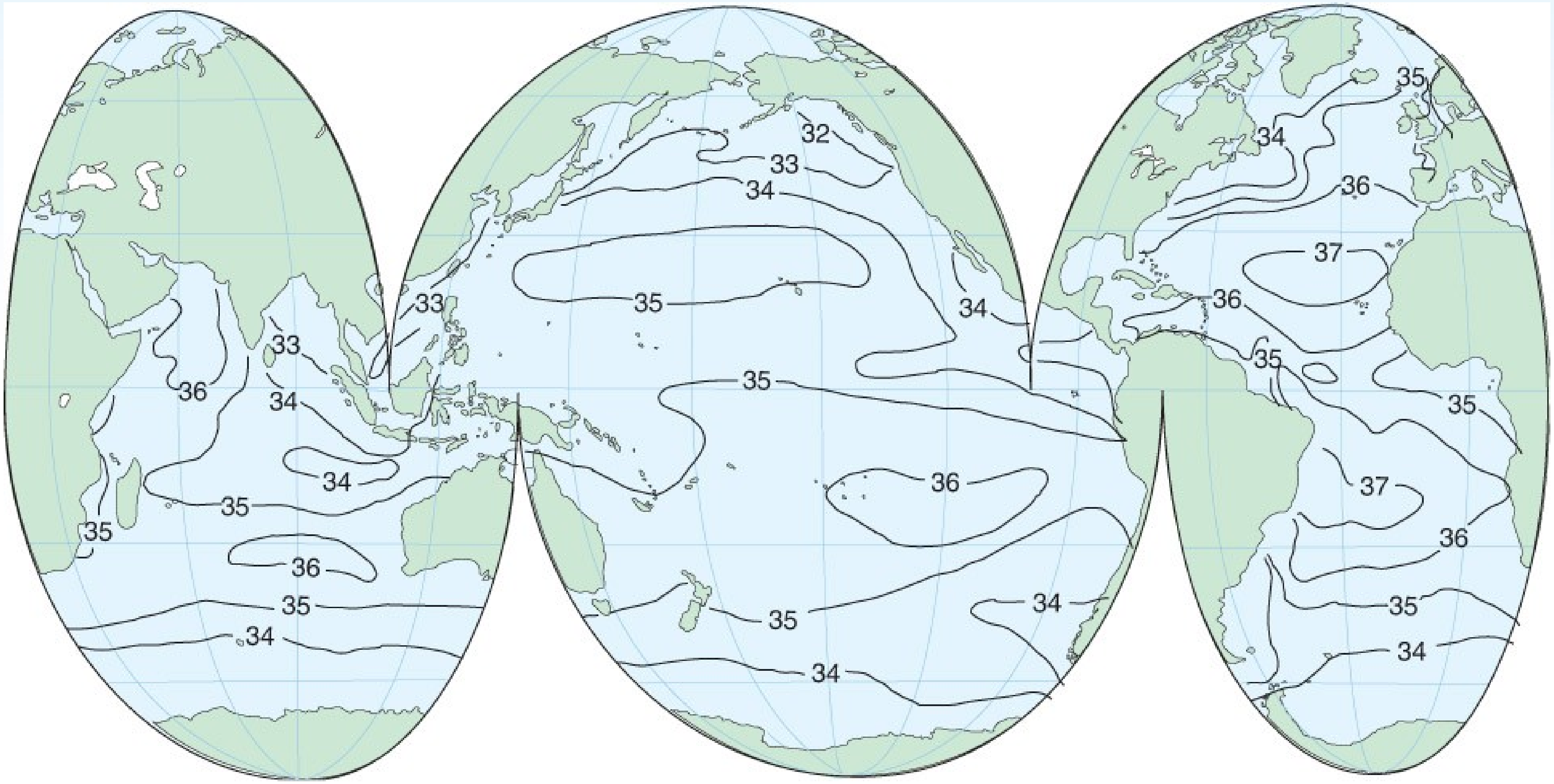
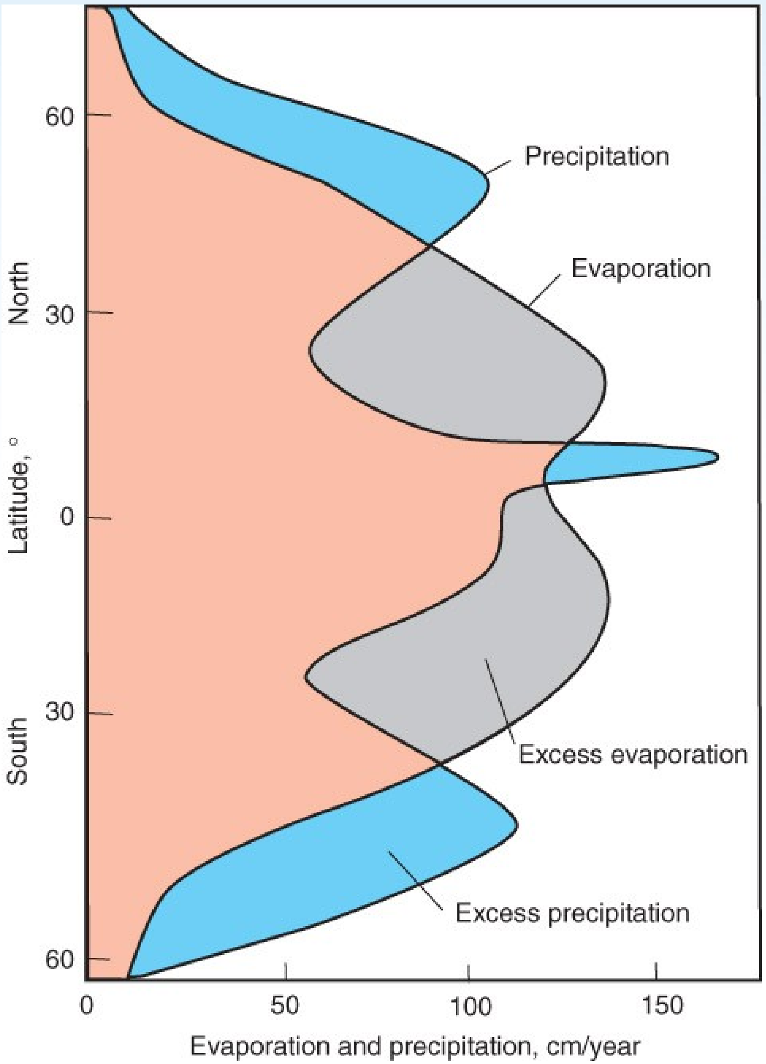


Fig. 1.18 Geographic variations of surface ocean salinities, expressed in parts per thousand (‰).

Properties of Seawater



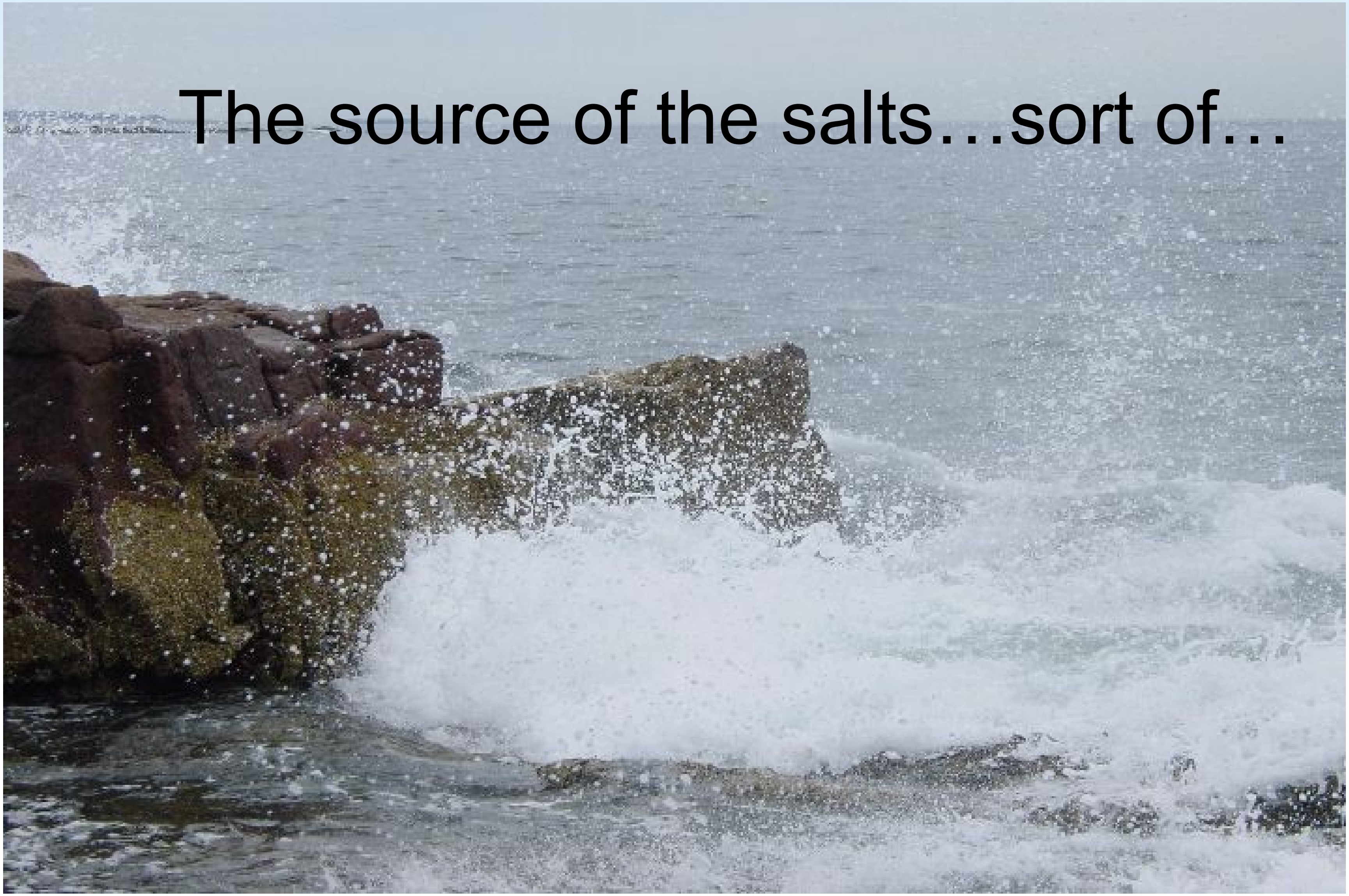
Adapted from G. Dietrich. General Oceanography, 1963.

Causes of Variation in Ocean Salinity

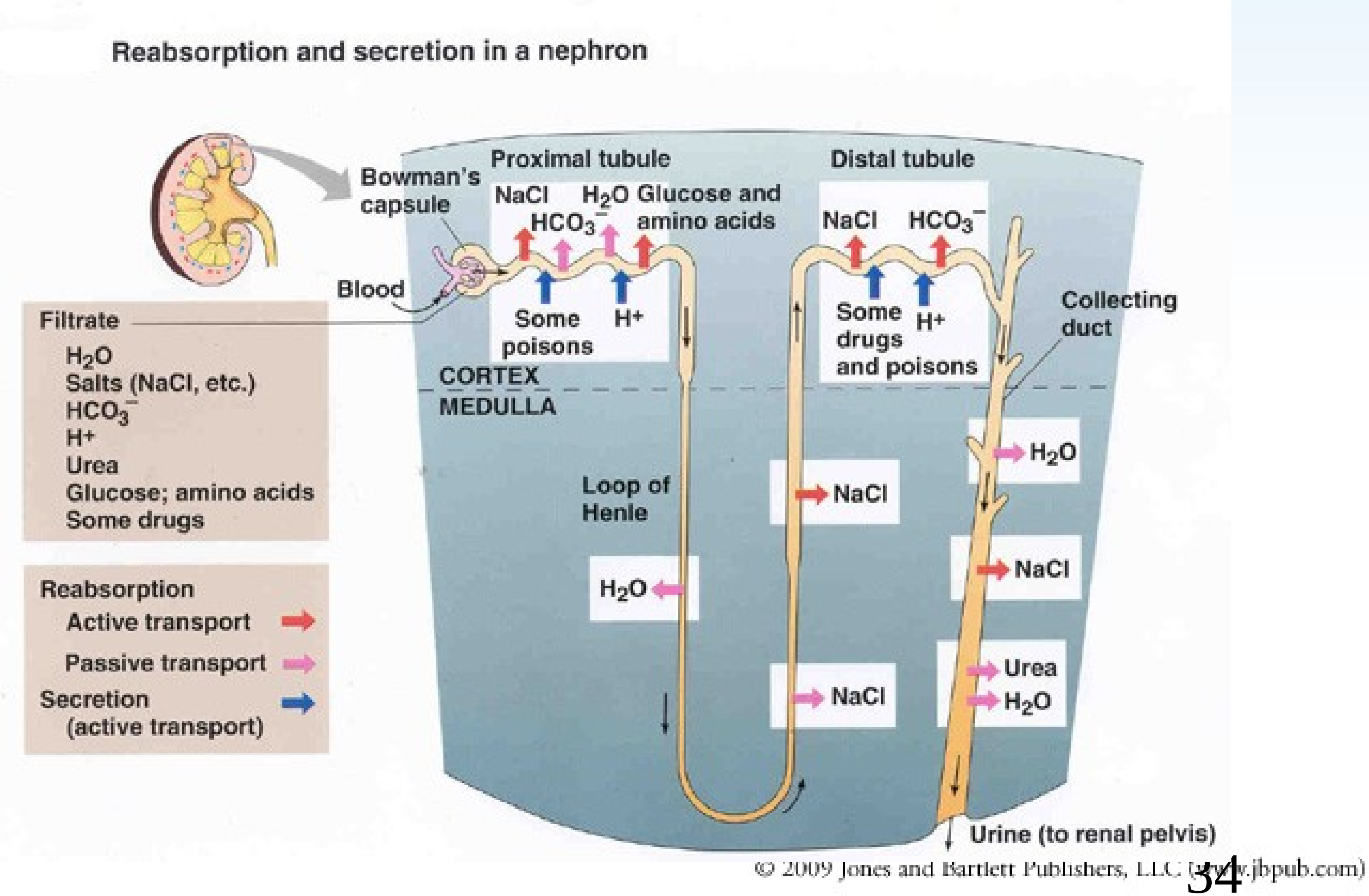
Fig. 1.19 Average north-south variation of sea surface evaporation and precipitation.

- Where is the ocean more saline? The tropics or the poles? Why?

The source of the salts…sort of…



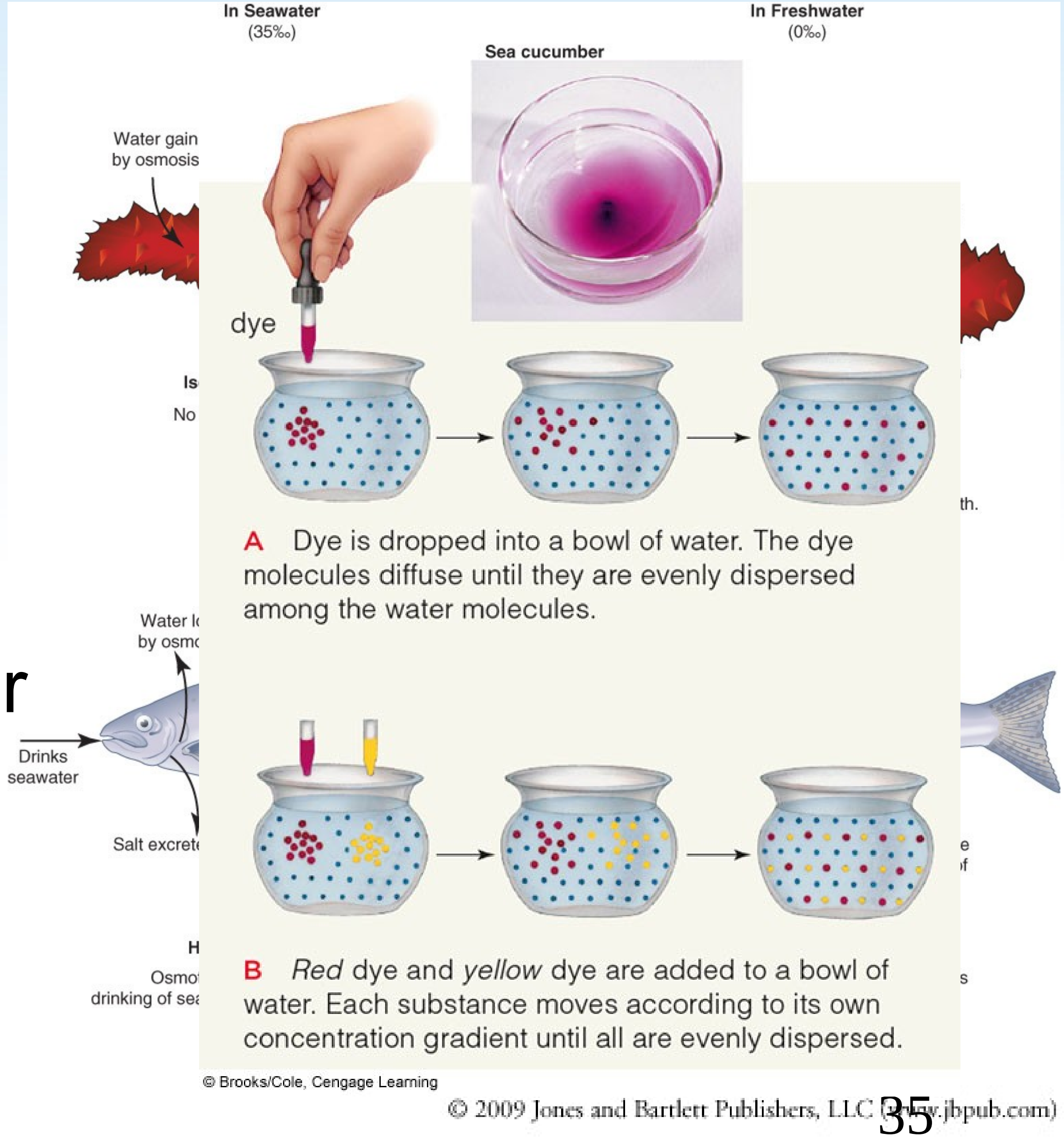
Salt and Water Balance in Organisms (Homeostasis)



- Which organism can maintain homeostasis better???

Properties of Seawater

Fig. 1.20 A comparison of the osmotic conditions of a sea cucumber and a salmon in seawater and fresh water.



- How does water move???

There are rules!!!

Diffusion!!!

Properties of Seawater

Light and Temperature in the Sea

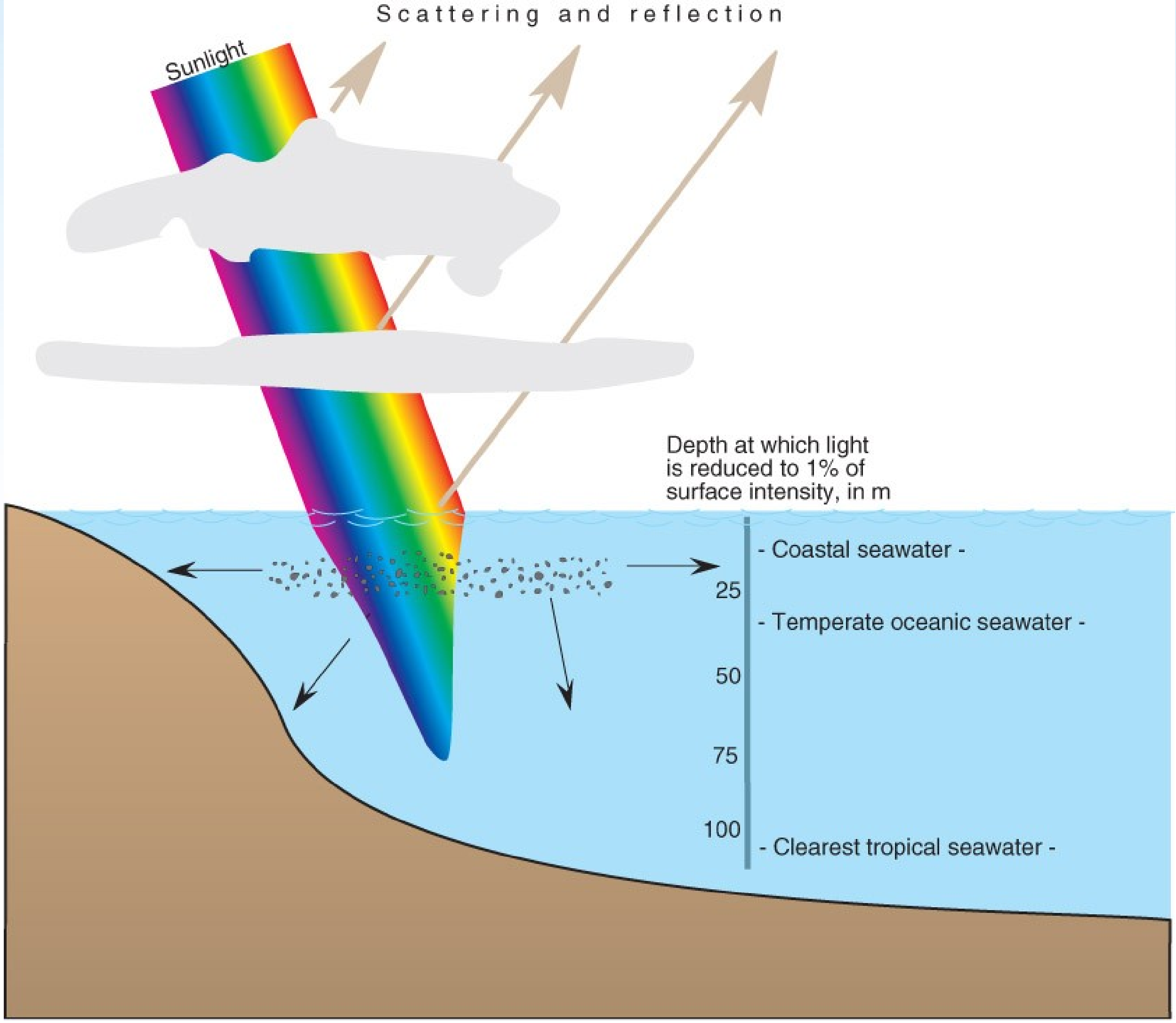


Fig. 1.21 Fate of sunlight as it enters seawater. The violet and red ends of the visible spectrum are absorbed first.

Properties of Seawater

Light and Temperature in the Sea

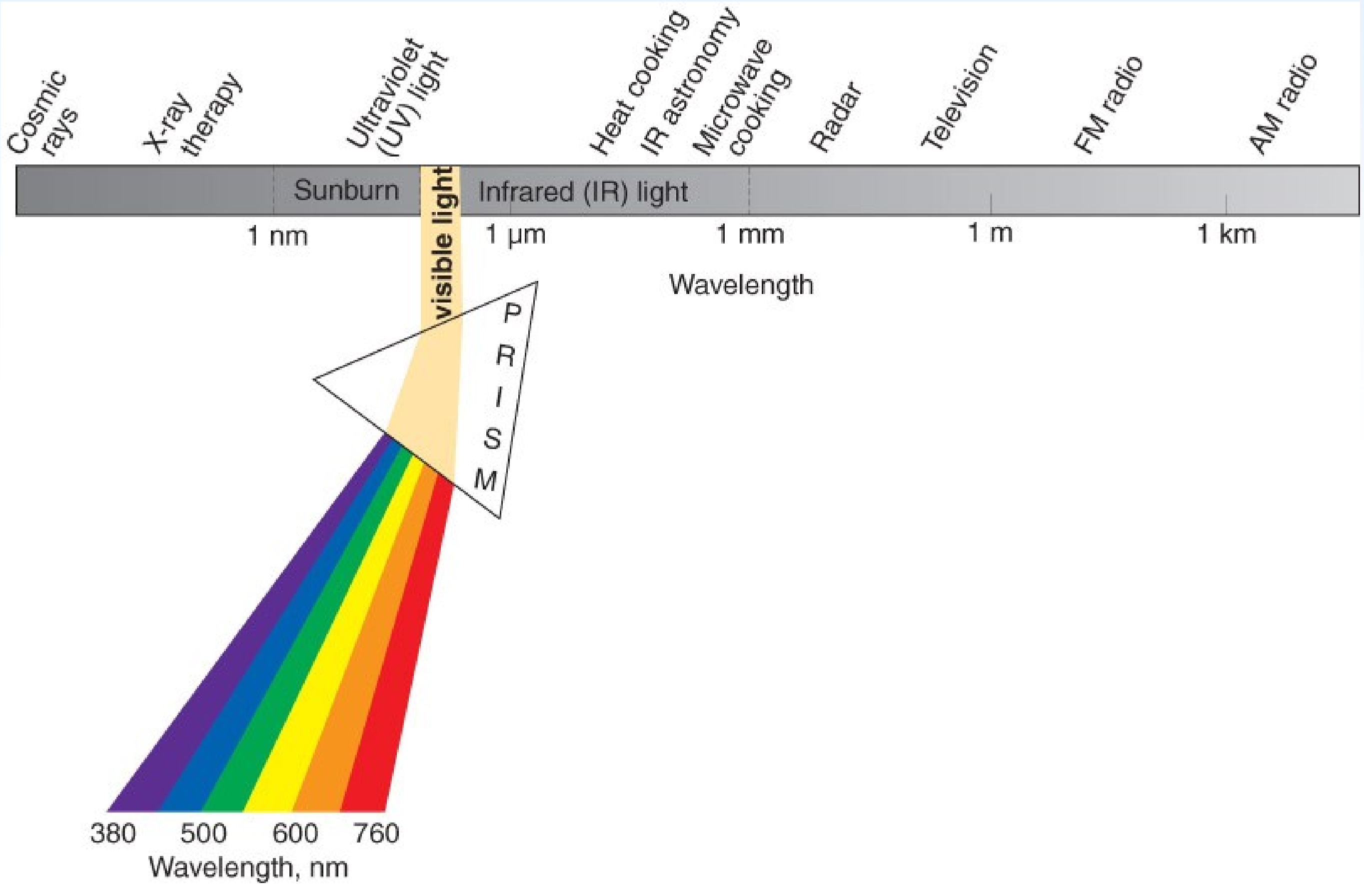


Fig. 1.22 The electromagnetic radiation spectrum. The small portion known as visible light is passed through a prism to separate the light into its component colors.

Properties of Seawater

Light and Temperature in the Sea

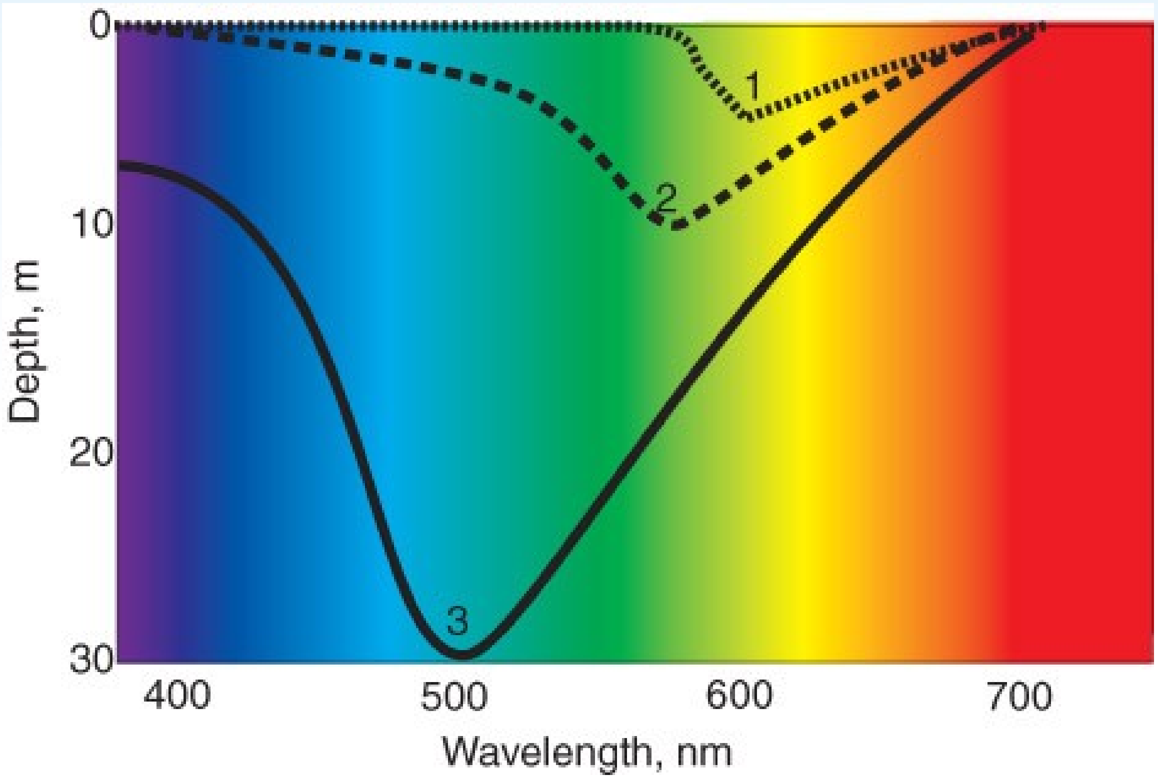
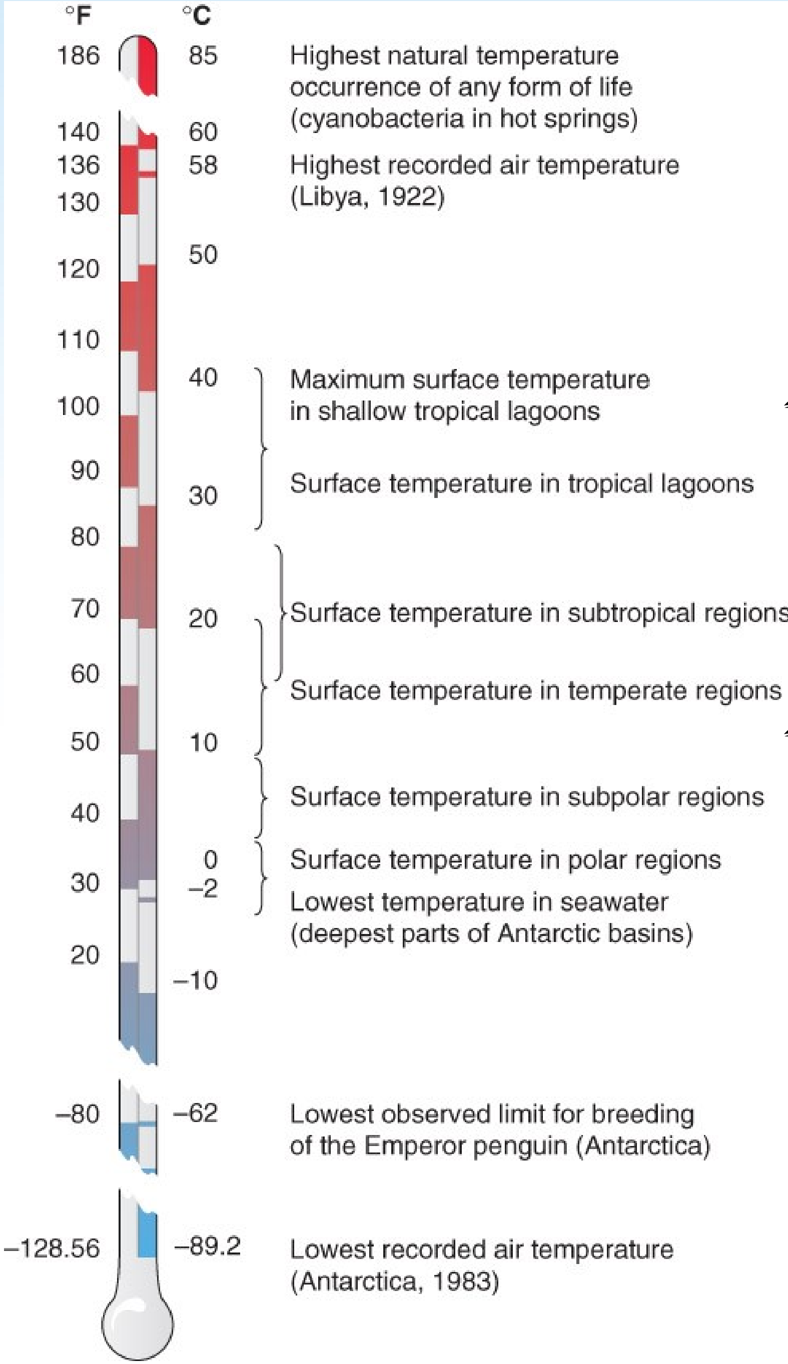


Fig. 1.23 Penetration of various wavelengths of light in three different water types: (1) very turbid coastal waters, (2) moderately turbid coastal water, and (3) clear tropical water. Note the shift to shorter wavelengths (bluer light) in clearer water.



Properties of Seawater

Light and Temperature in the Sea

- How do land and ocean temperatures vary in their ranges?
- How do organisms deal with these temperature fluctuations?
  - Poikilotherms
  - Ectotherms
  - Endotherms

Properties of Seawater

Light and Temperature in the Sea

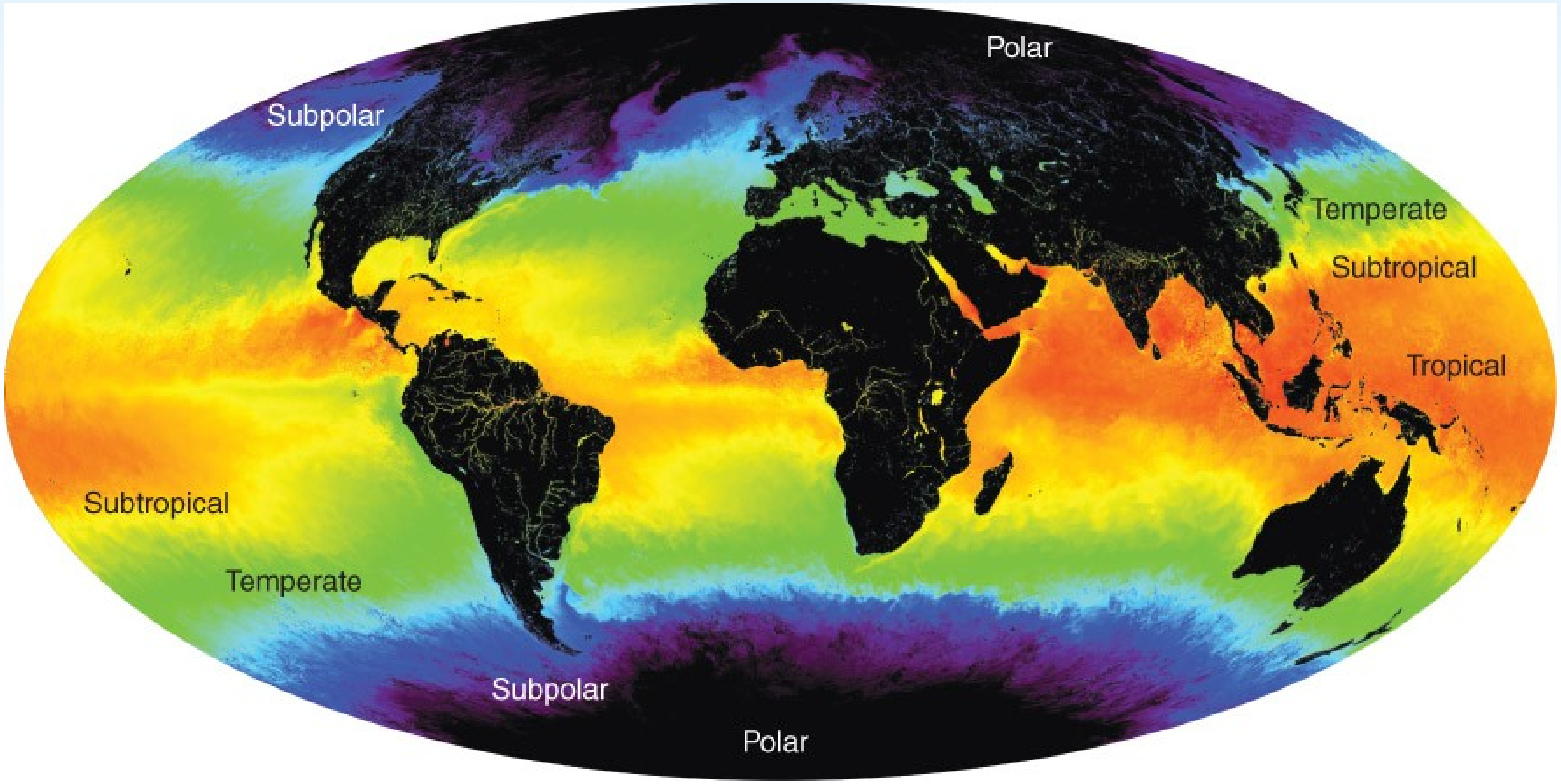


Fig. 1.27 Earth's sea surface temperatures obtained from two weeks of satellite infrared observations July 1984. Temperatures are color coded, with red being warmest and decreasing through oranges, yellows, greens, blues, and black. The temperature ranges of the labeled marine climatic zones are listed in Figure 1.24 and are shifted slightly northward during the Northern Hemisphere summer.

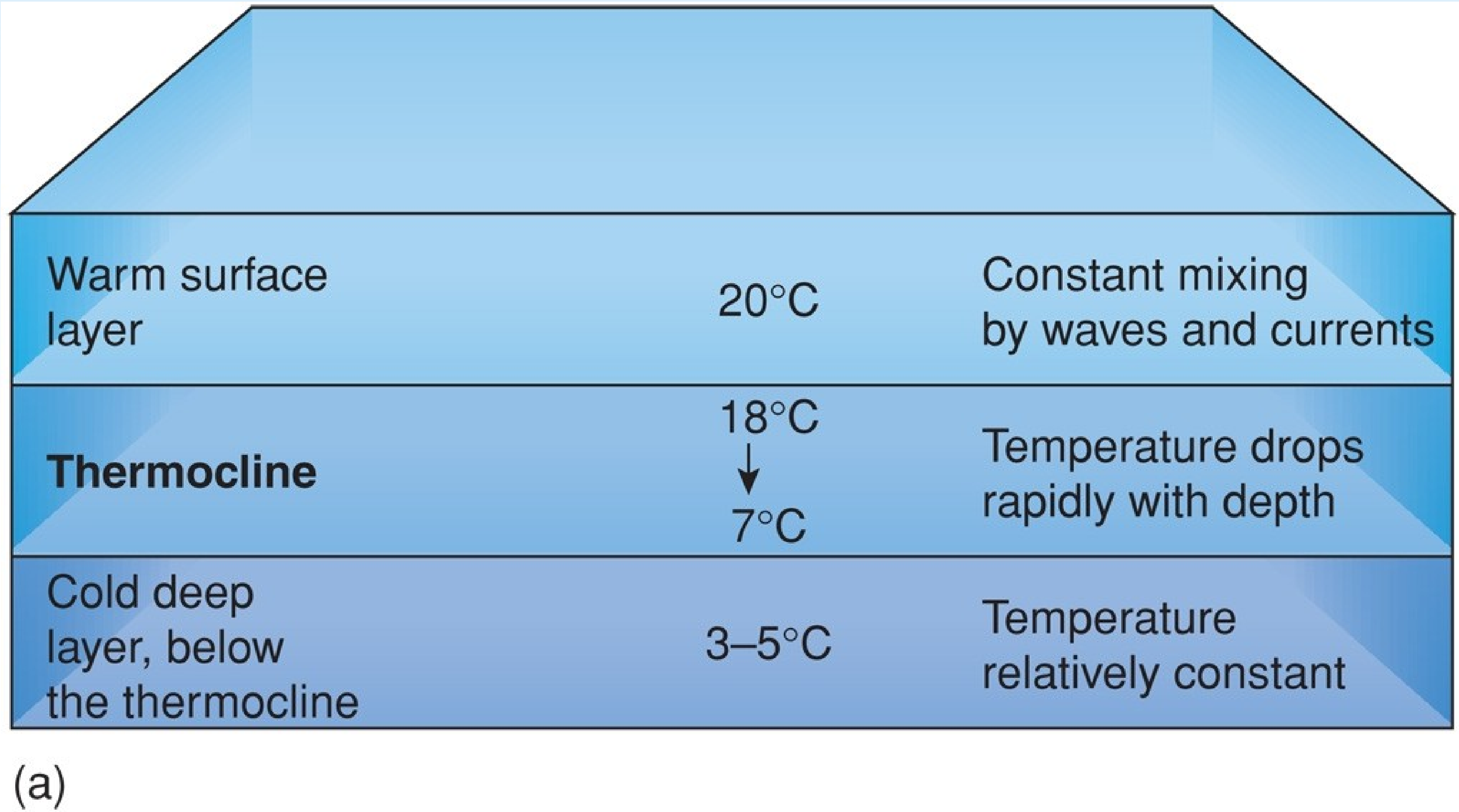
Image courtesy MODIS Ocean Group, NASA GSFC, and the University of Miami

Properties of Seawater
Ocean Layers

The ocean is layered!!!

How is it layered???

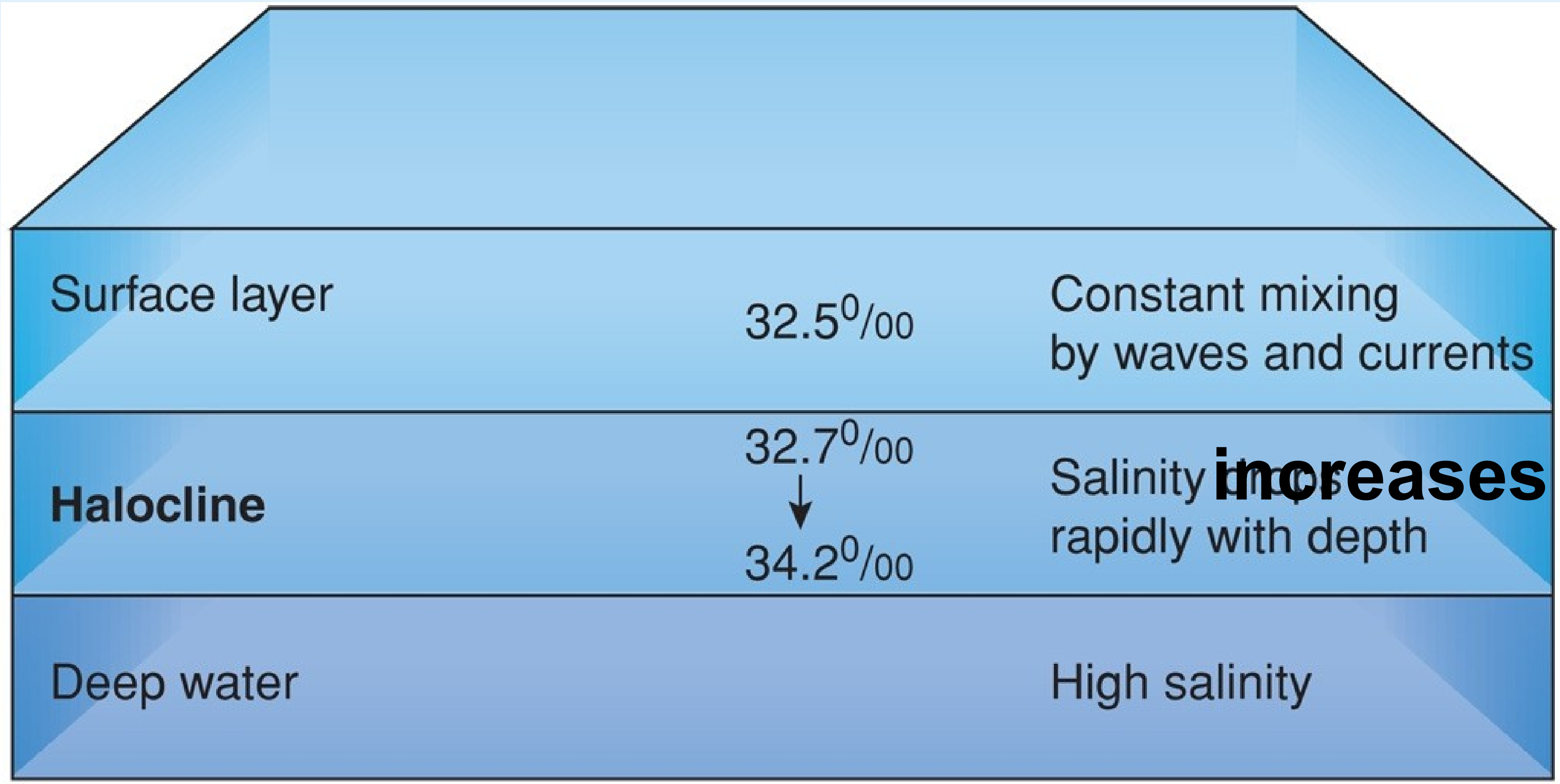
By temperature!



Thermocline – zone of rapid temperature change

Fig. 4-18, p. 85

By salinity!



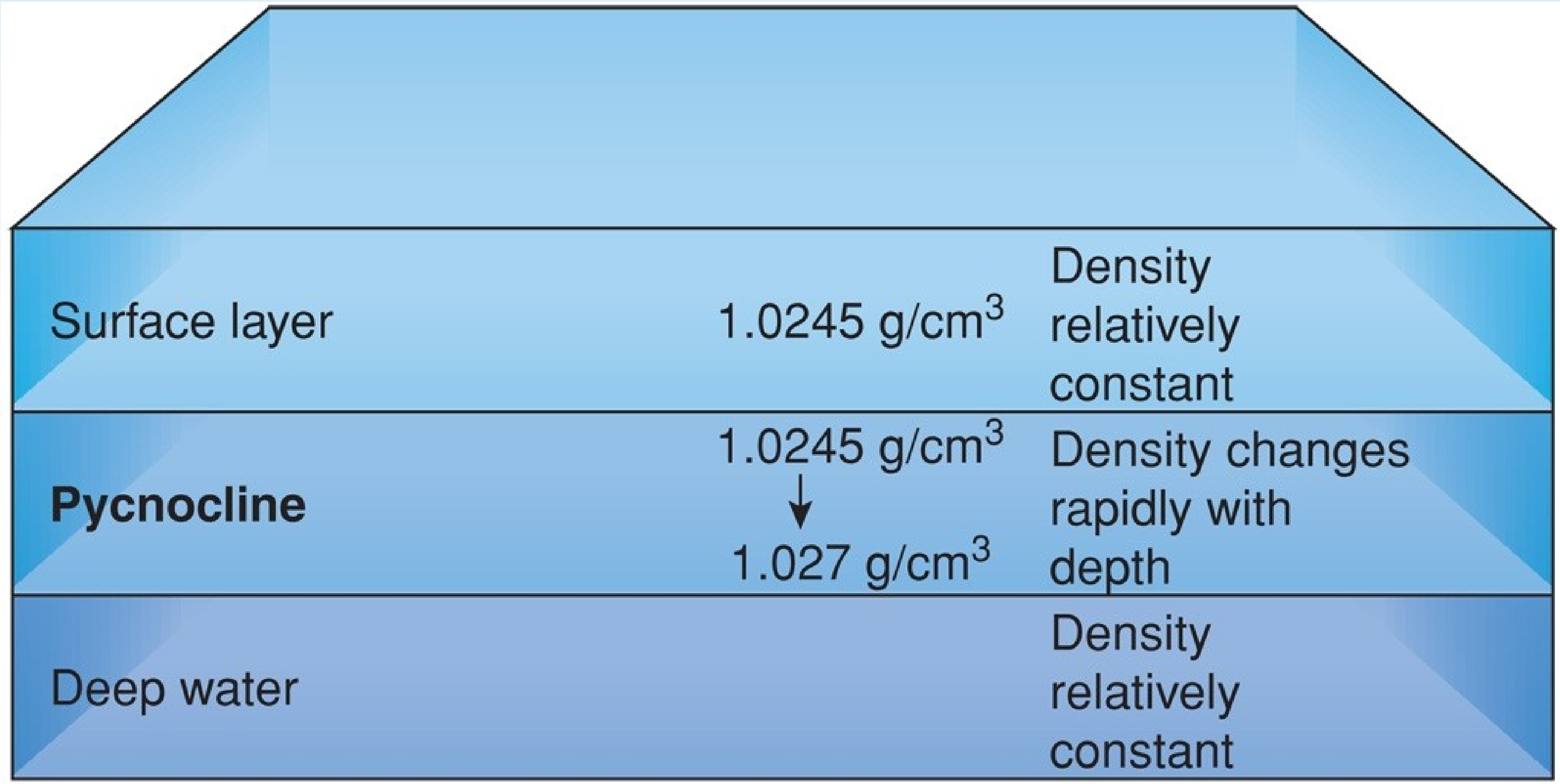
increases

(b)

Halocline – zone of rapid change in salinity

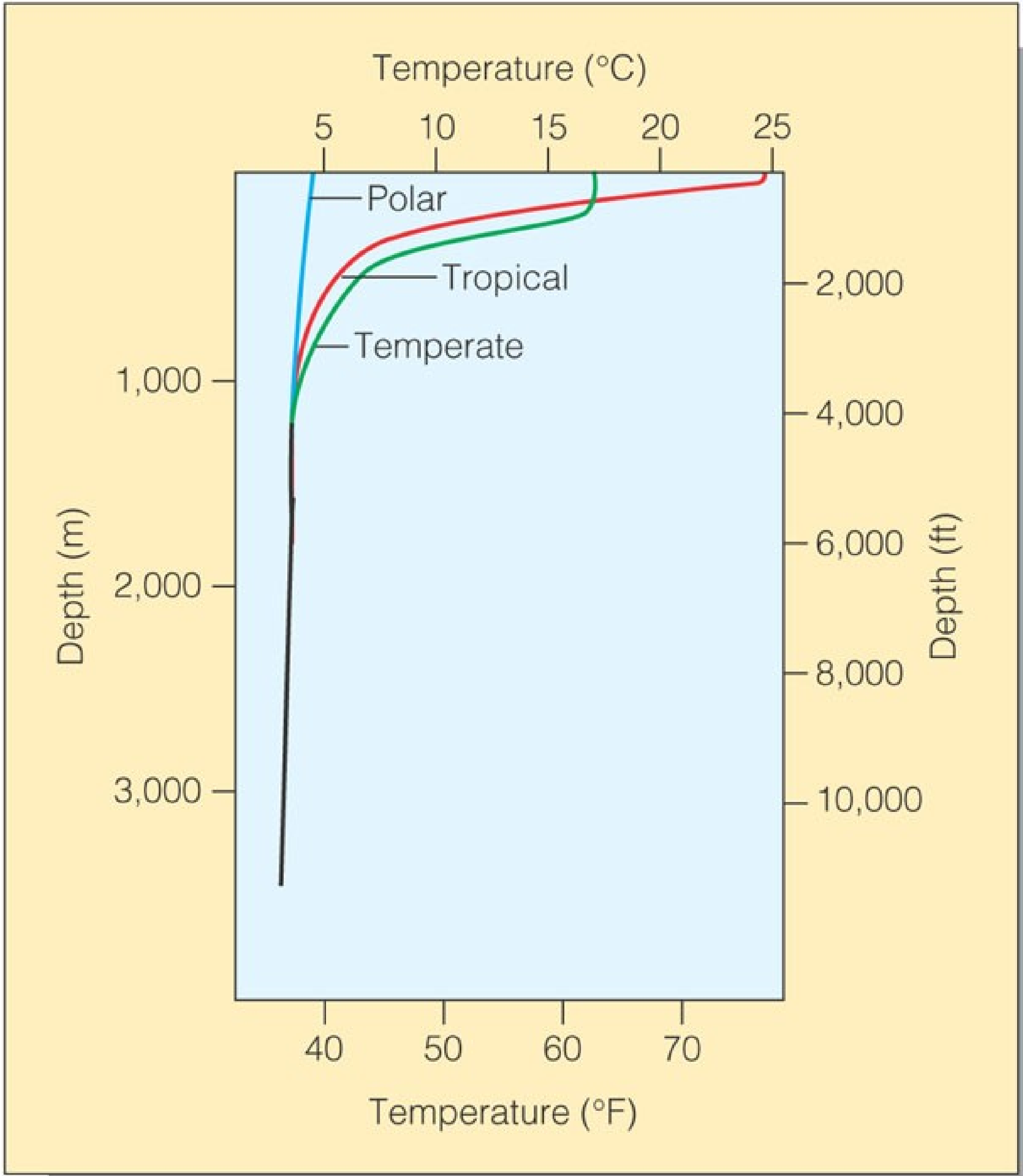
Fig. 4-18, p. 85

So, the density increases rapidly with depth!



(c)

Pycnocline – zone of rapid change in density; caused by temp. & salinity changes



Thermoclines can vary with season, local conditions, currents, and many other factors

Properties of Seawater

Salinity-Temperature-Density Relationships

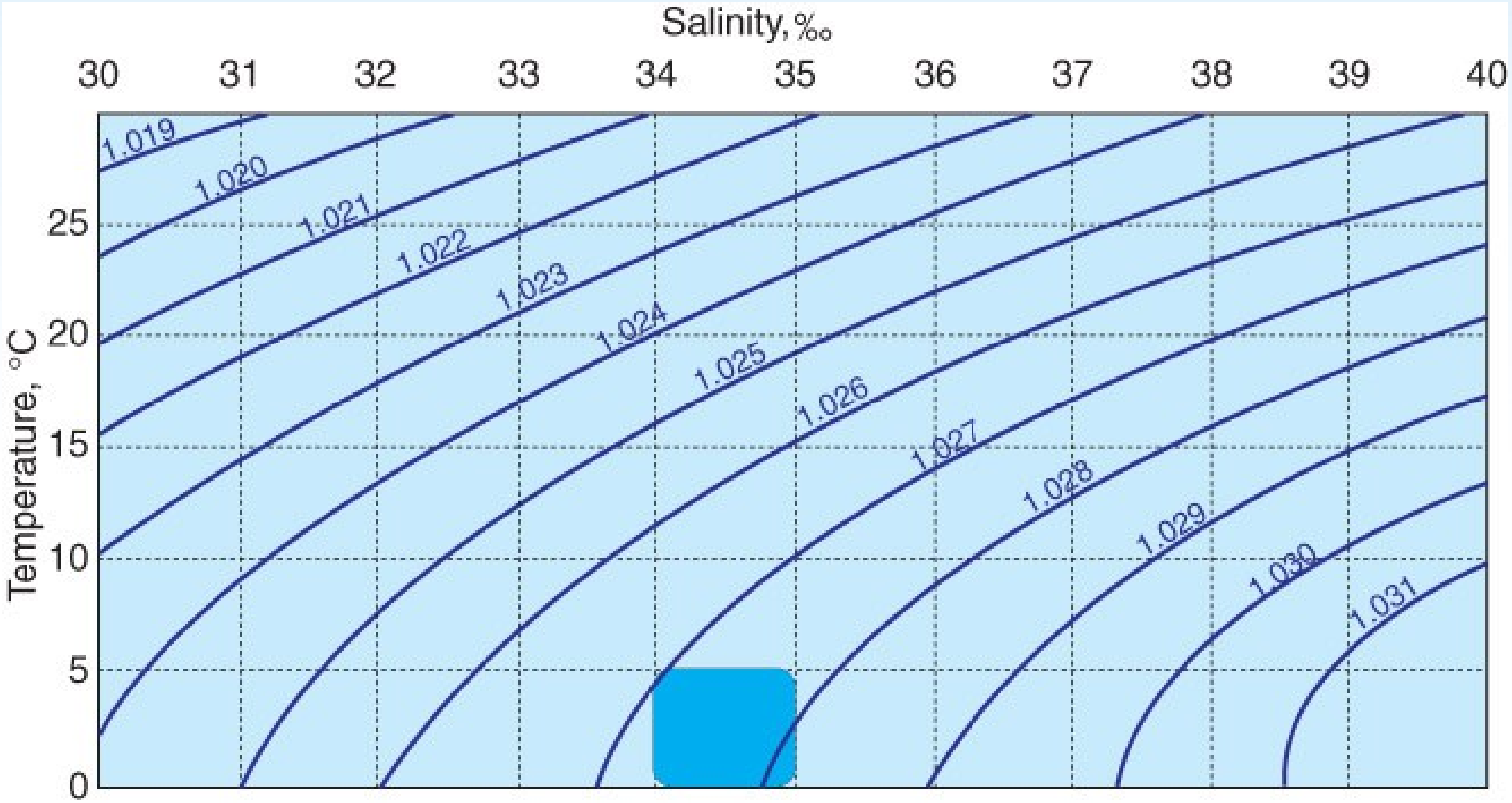


Fig. 1.29 Temperature-salinity-density diagram for seawater. Purple curved lines represent density values (in g/cm^3) resulting from the combined effects of temperature and salinity. Three fourths of the volume of the ocean is remarkably uniform, with salinity, temperature, and density characteristics defined by the dark blue area.

Properties of Seawater

Salinity-Temperature-Density Relationships

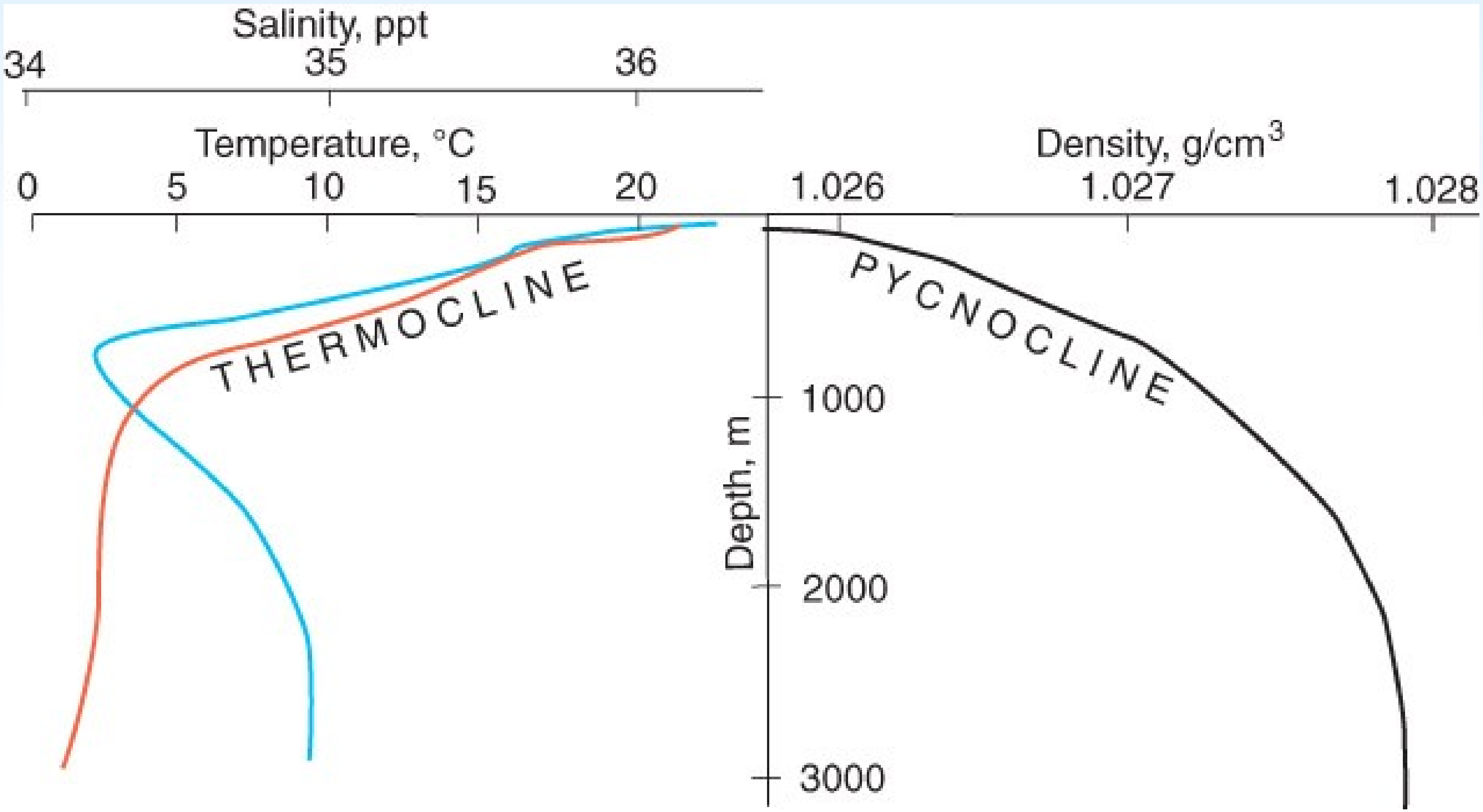
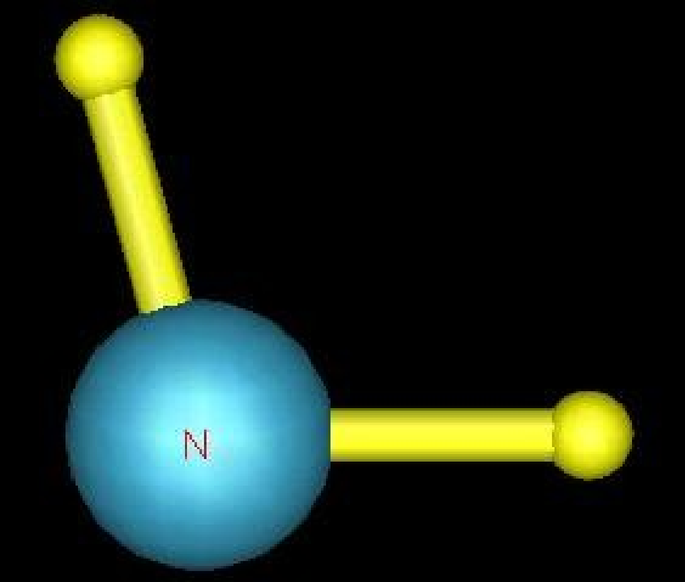


Fig. 1.30 Variations in water temperature (orange curve) and salinity (blue curve) at a GEOSECS station in the western South Atlantic Ocean. The resulting density profile is shown at the right (black curve).


I’ve got gas!!!

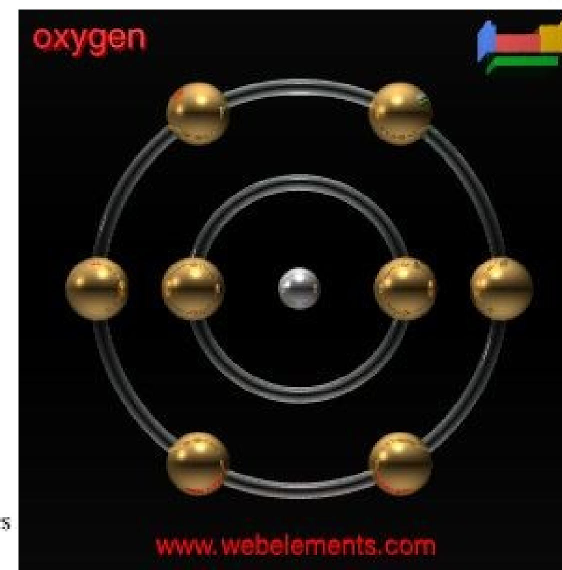


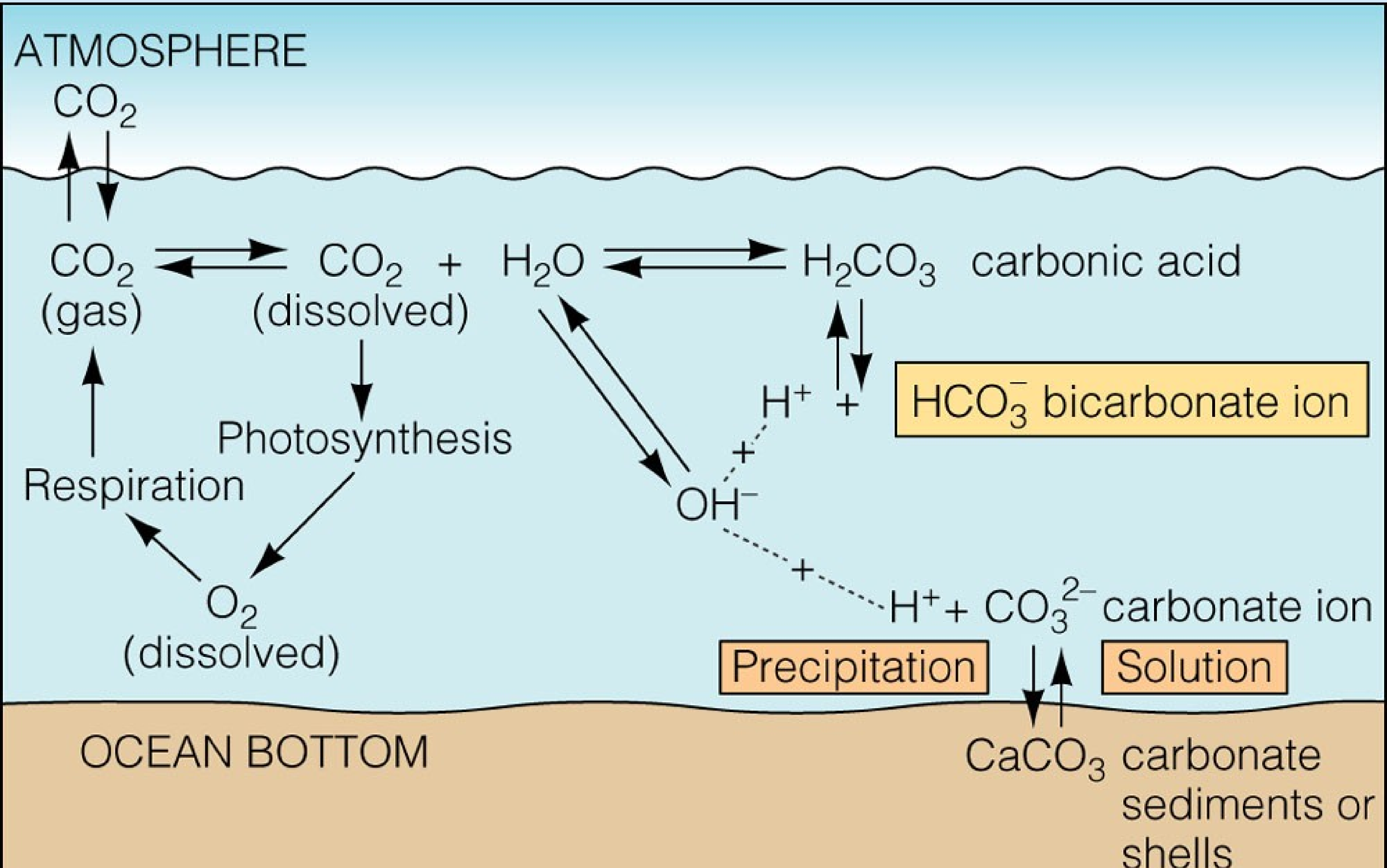
d Ocean

Gas	Percent of Gas in Atmosphere, by Volume	Percent of Dissolved Gas in Seawater, by Volume	Concentration in Seawater in Parts per Million, by Mass
Nitrogen (N_2)	78.08%	48%	10–18 ppm
Oxygen (O_2)	20.95%	36%	0–13 ppm
Carbon dioxide (CO_2)[a]	0.035%	15%	64–107 ppm

Sources: Data from Weihaupt, 1979; Hill, 1963.
[a] Also present in seawater as carbonic acid, carbonate ions, and bicarbonate ions.

- Nitrogen – not exciting
- CO_2 & Oxygen – photosynthesis & respiration & CO_2 as buffer





- A buffer is a substance that can maintain the pH of a solution at a relatively constant point.

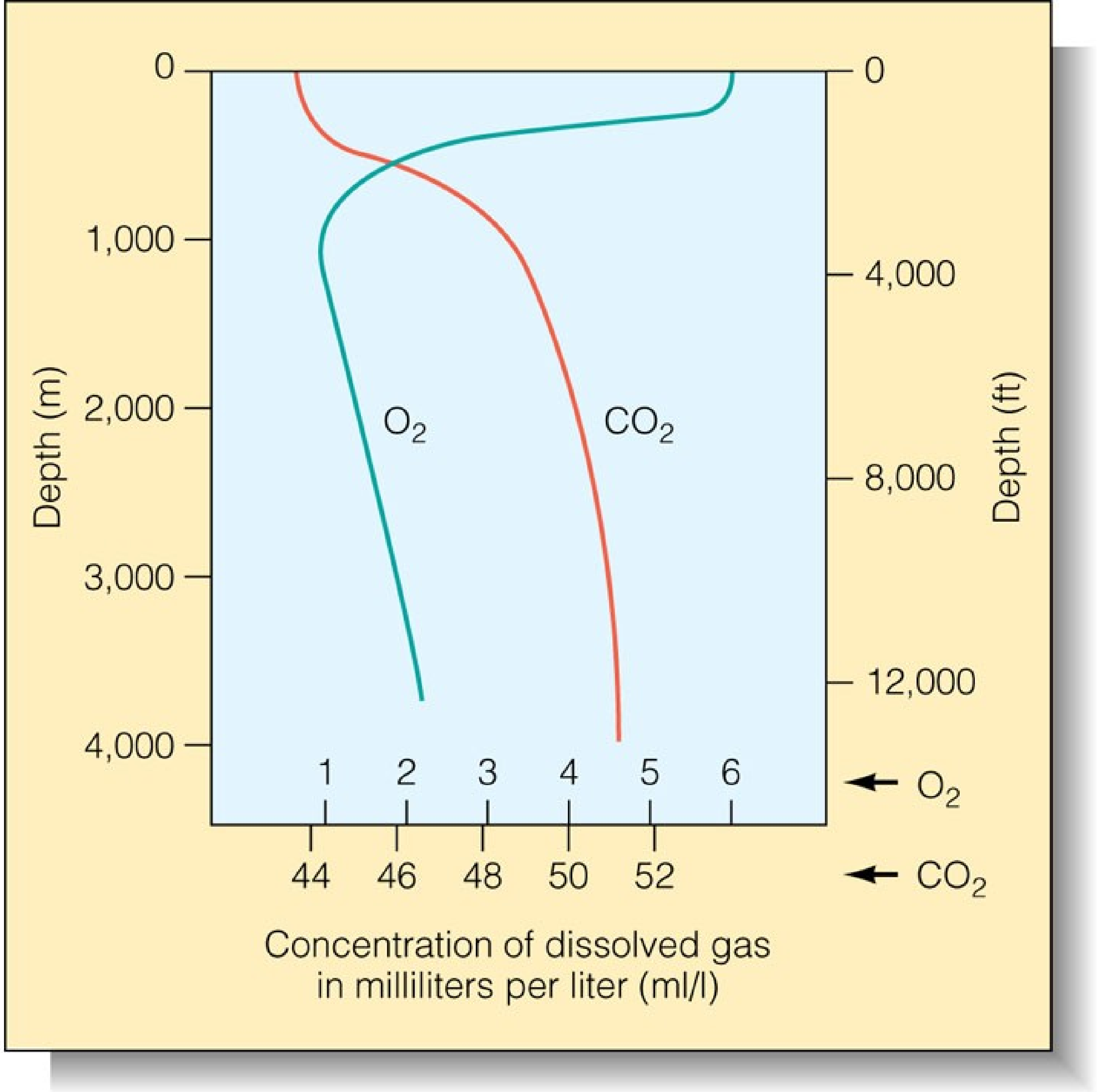
	pH	$[H^+]$	$[OH^-]$	Example
Acidic Solutions	1	10^{-1}	10^{-13}	Hydrochloric acid
	2	10^{-2}	10^{-12}	Lime juice
	3	10^{-3}	10^{-11}	Acetic acid
	4	10^{-4}	10^{-10}	Tomato juice
	5	10^{-5}	10^{-9}	Black coffee
	6	10^{-6}	10^{-8}	Milk
Neutral	7	10^{-7}	10^{-7}	Pure water
Basic Solutions	8	10^{-8}	10^{-6}	Seawater
	9	10^{-9}	10^{-5}	Borax solution
	10	10^{-10}	10^{-4}	
	11	10^{-11}	10^{-3}	Milk of magnesia
	12	10^{-12}	10^{-2}	Household ammonia
	13	10^{-13}	10^{-1}	Lye
	14	10^{-14}	10^{-0}	Sodium hydroxide

Properties of Seawater

Dissolved Gases and Acid-Base Buffering

The ocean is slightly basic

- Oxygen Minimum Zone



Properties of Seawater

Dissolved Nutrients and the Influence of the Pycnocline

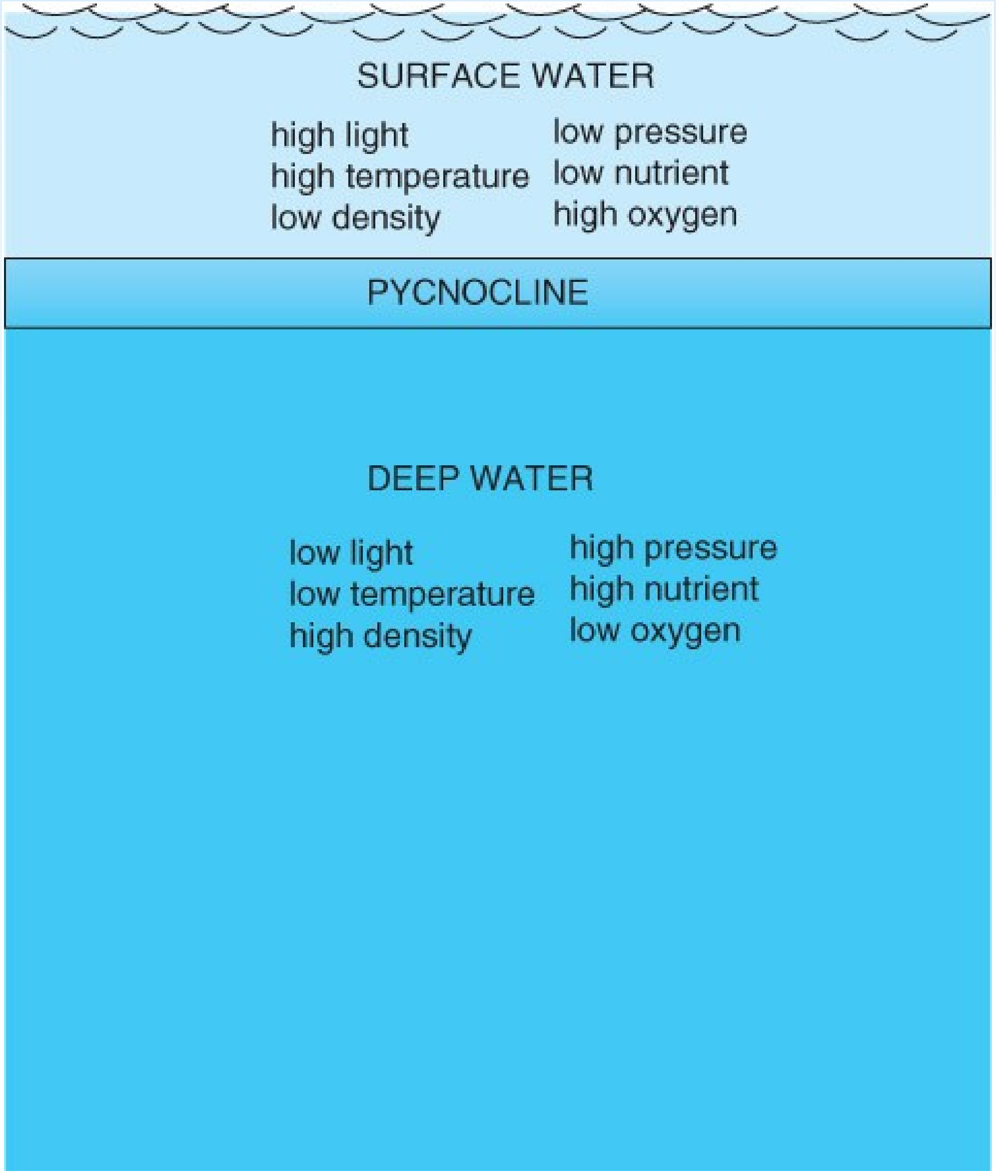


Fig. 1.33 Contrasting features of shallow and deep ocean water resulting in a two-layer system separated by a pycnocline.

The Ocean in Motion

The sea is constantly moving, both horizontally and vertically.

Winds, waves, tides, currents, sinking water masses, and upwelling all contribute to the remarkable homogeneity of the world ocean.

The Ocean in Motion

Wind Waves

- The character of wind-driven ocean waves depends on the wind's speed, duration, and fetch.

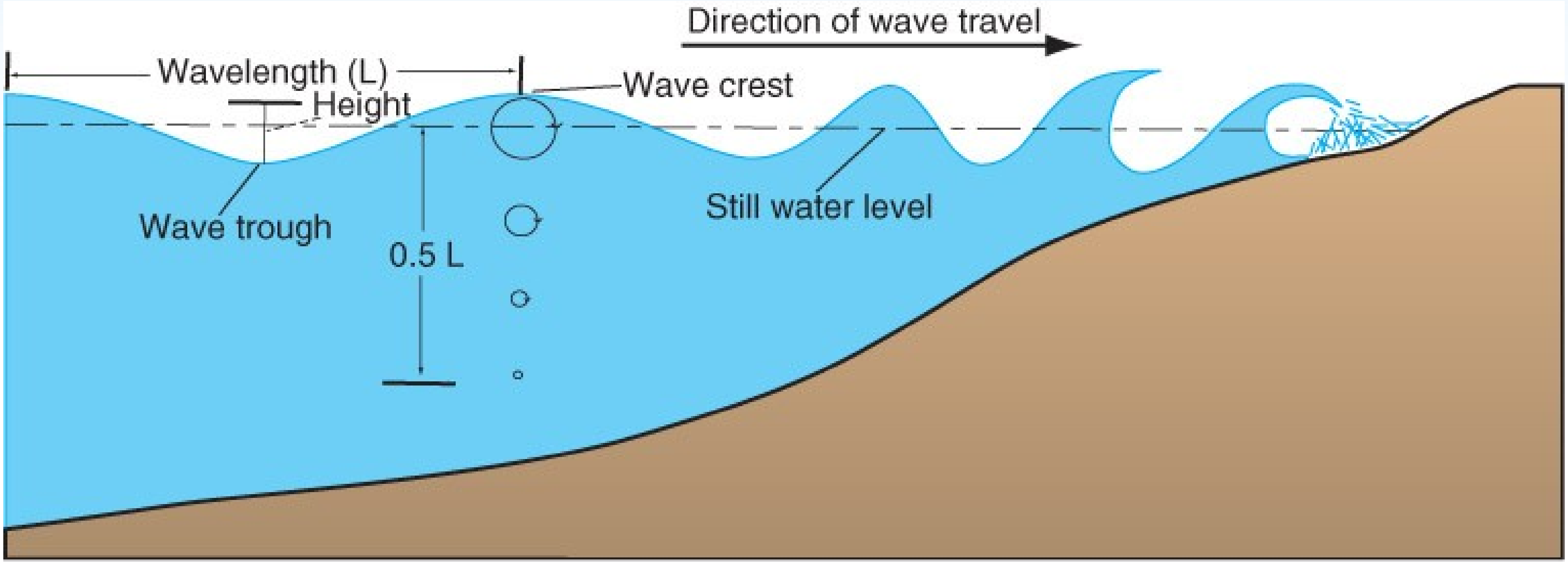
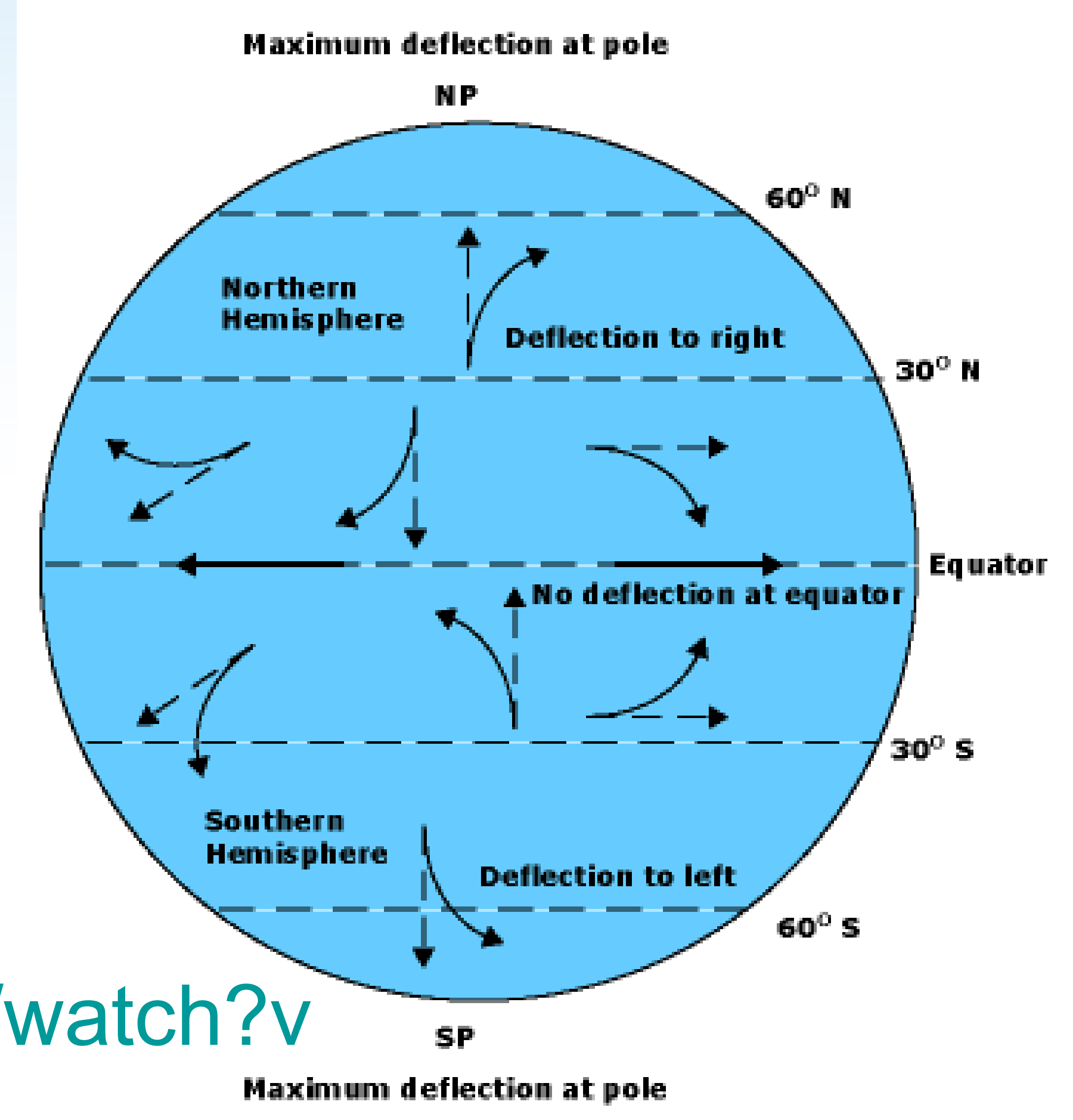


Fig. 1.35 Wave form and pattern of water motion in a deep-water wave as it moves to the right toward a shoreline. Circles indicate orbits of water particles diminishing with depth. There is little water motion below a depth equal to one half of the wavelength.

The Ocean in Motion

Surface Currents

- Ocean surface currents are driven by stable patterns of surface winds.
- Affected by Coriolis Effect – deflection due to Earth's rotation



- http://www.youtube.com/watch?v=_36MiCUS1ro

The Ocean in Motion

Coriolis Effect causes the Ekman Spiral

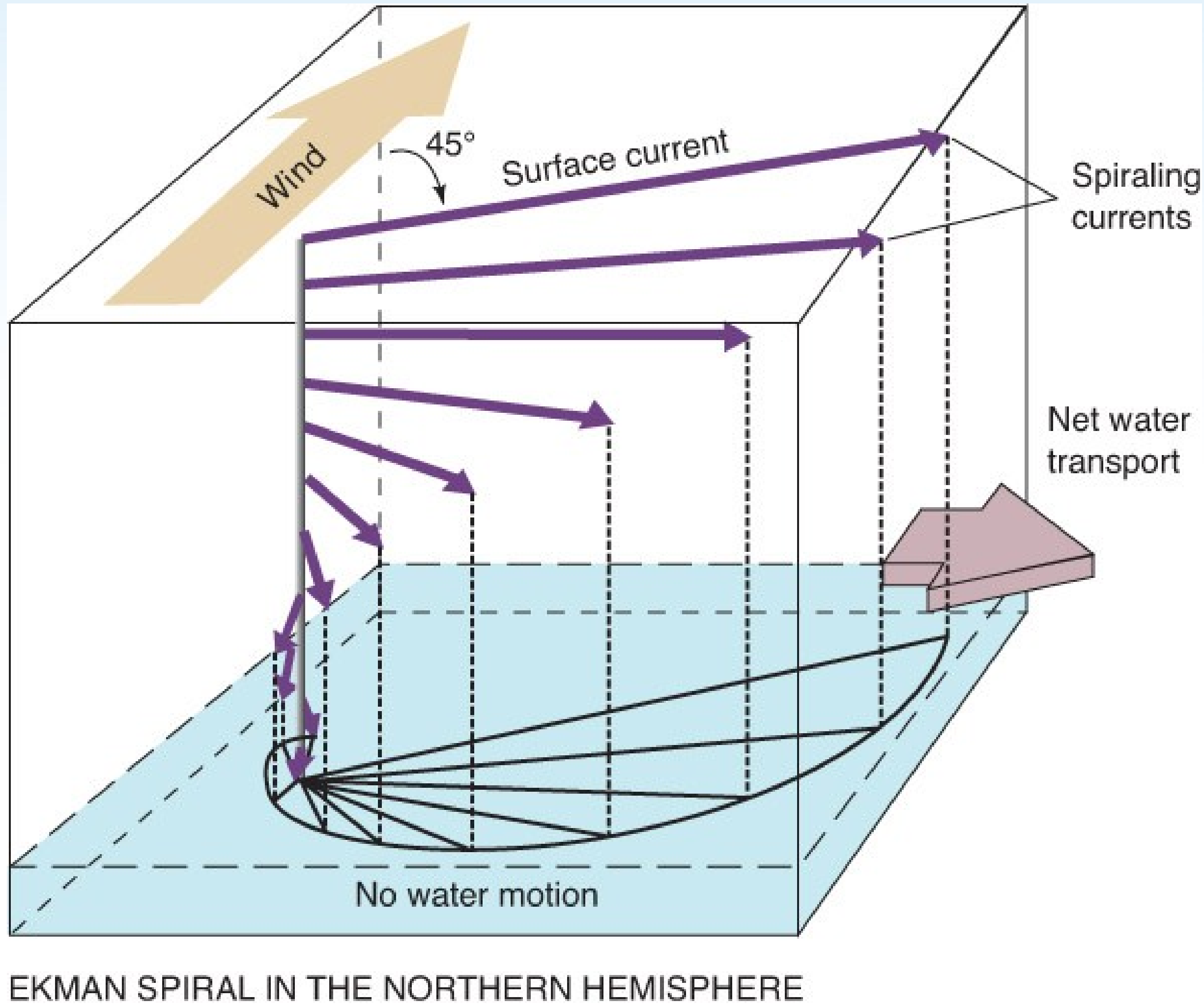
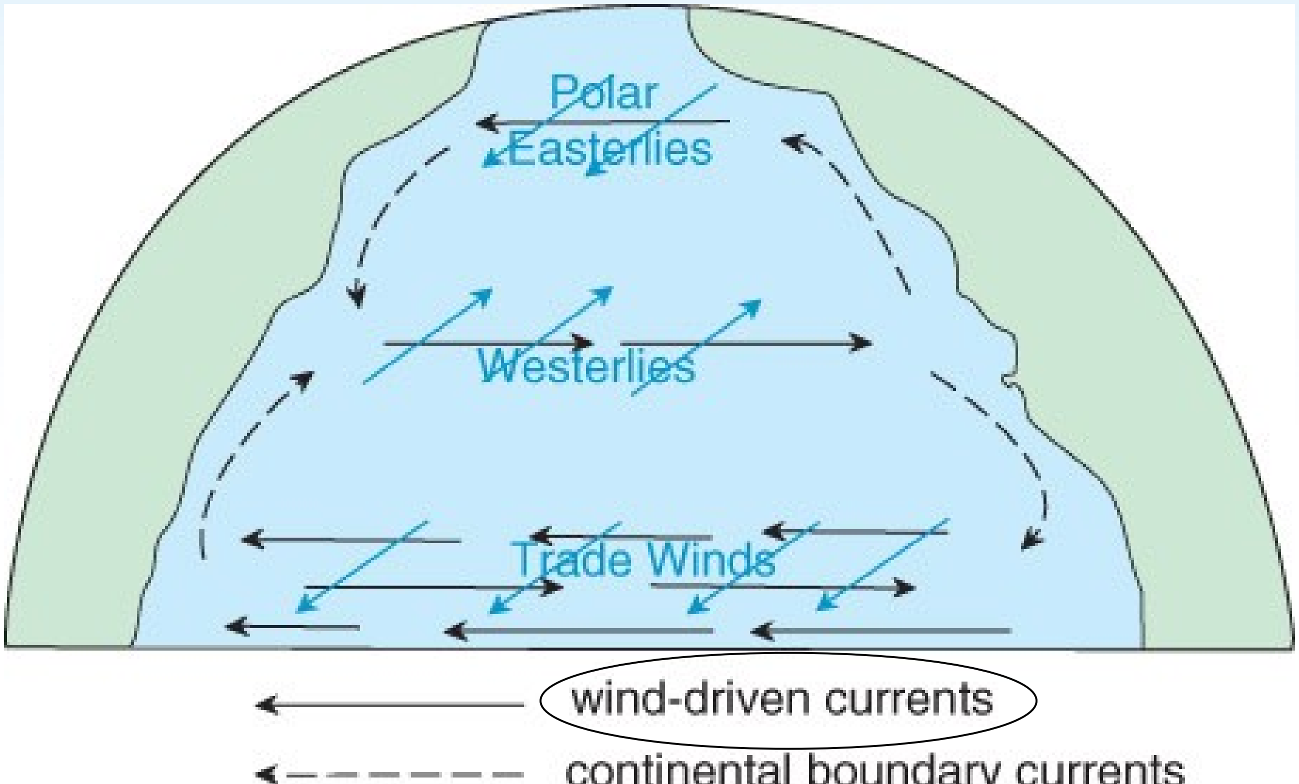


Fig. 1.36 A spiral of current directions, indicating greater deflection to the right (in the Northern Hemisphere), which increases with depth due to the Coriolis effect. The arrow length indicates relative current speed.

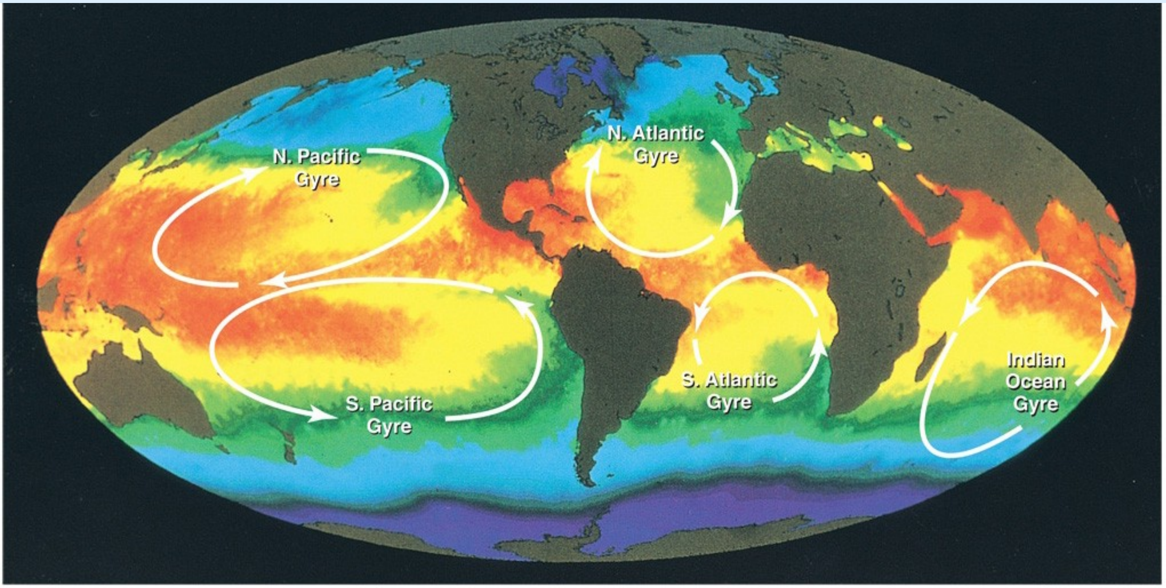
The Ocean in Motion



The North Pacific Gyre

The largest surface currents are organized into huge circuits known as gyres

The Ocean in Motion - gyres



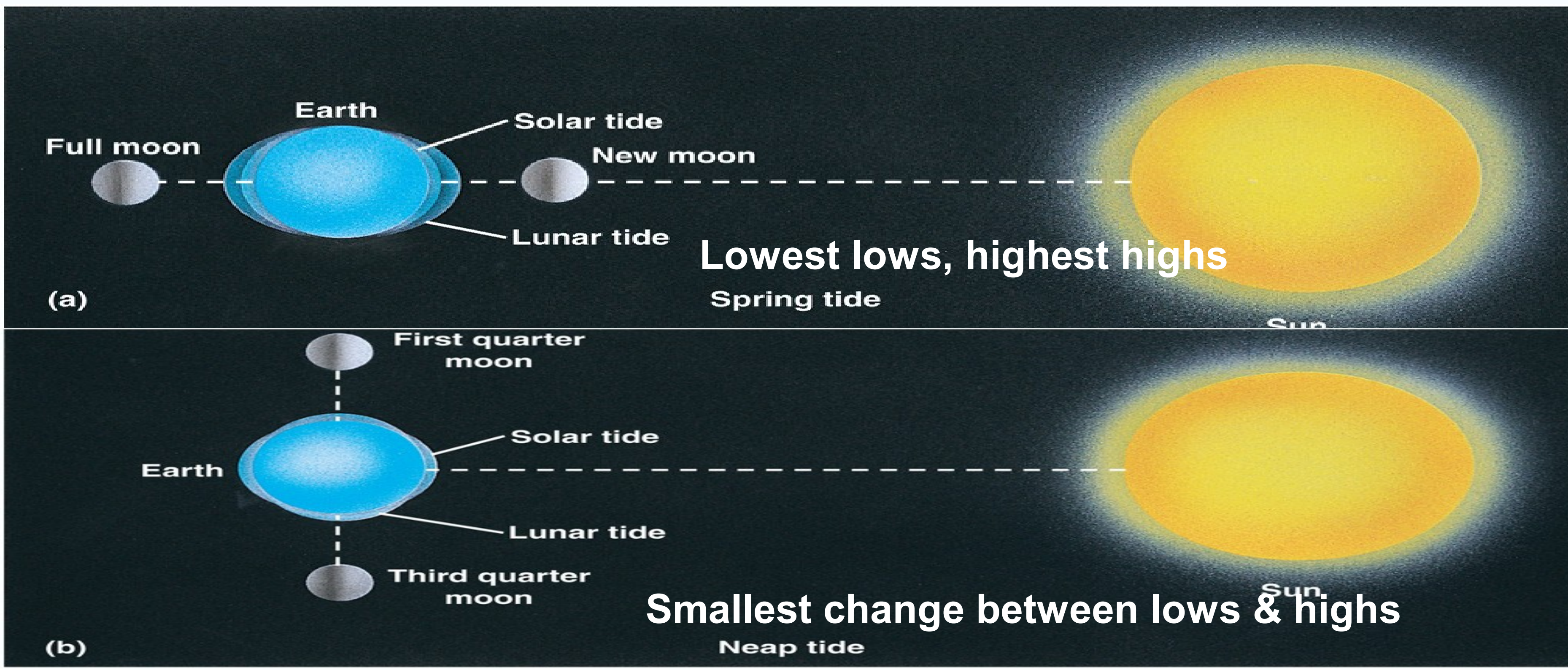
(b)

Adapted from Pickard, G. L. and W. J. Emory, eds. Descriptive Physical Oceanography. Pergamon Press, 1982.

The Ocean in Motion - Tides

Tides are the periodic changes in water level that occur along coastlines.

They are a result of the gravitational pull of the moon and the sun on the water of the oceans.



The Ocean in Motion
Ocean Tides

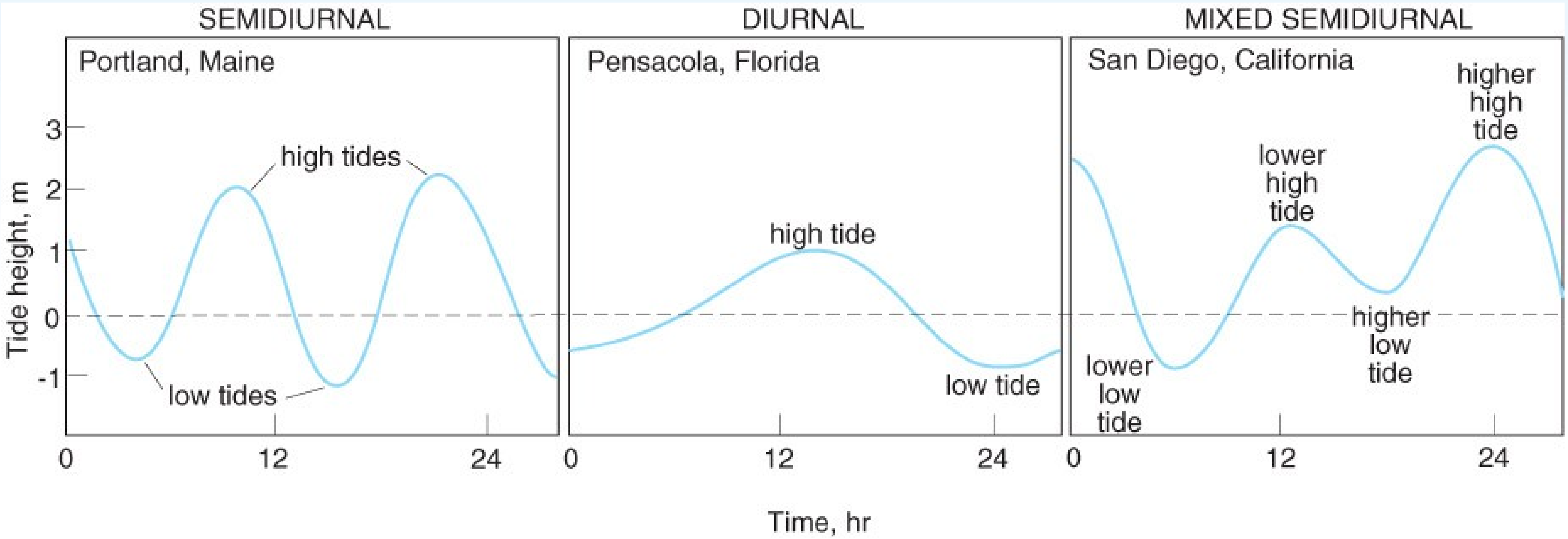


Fig. 1.42 Three common types of tides.

The Ocean in Motion

Ocean Tides

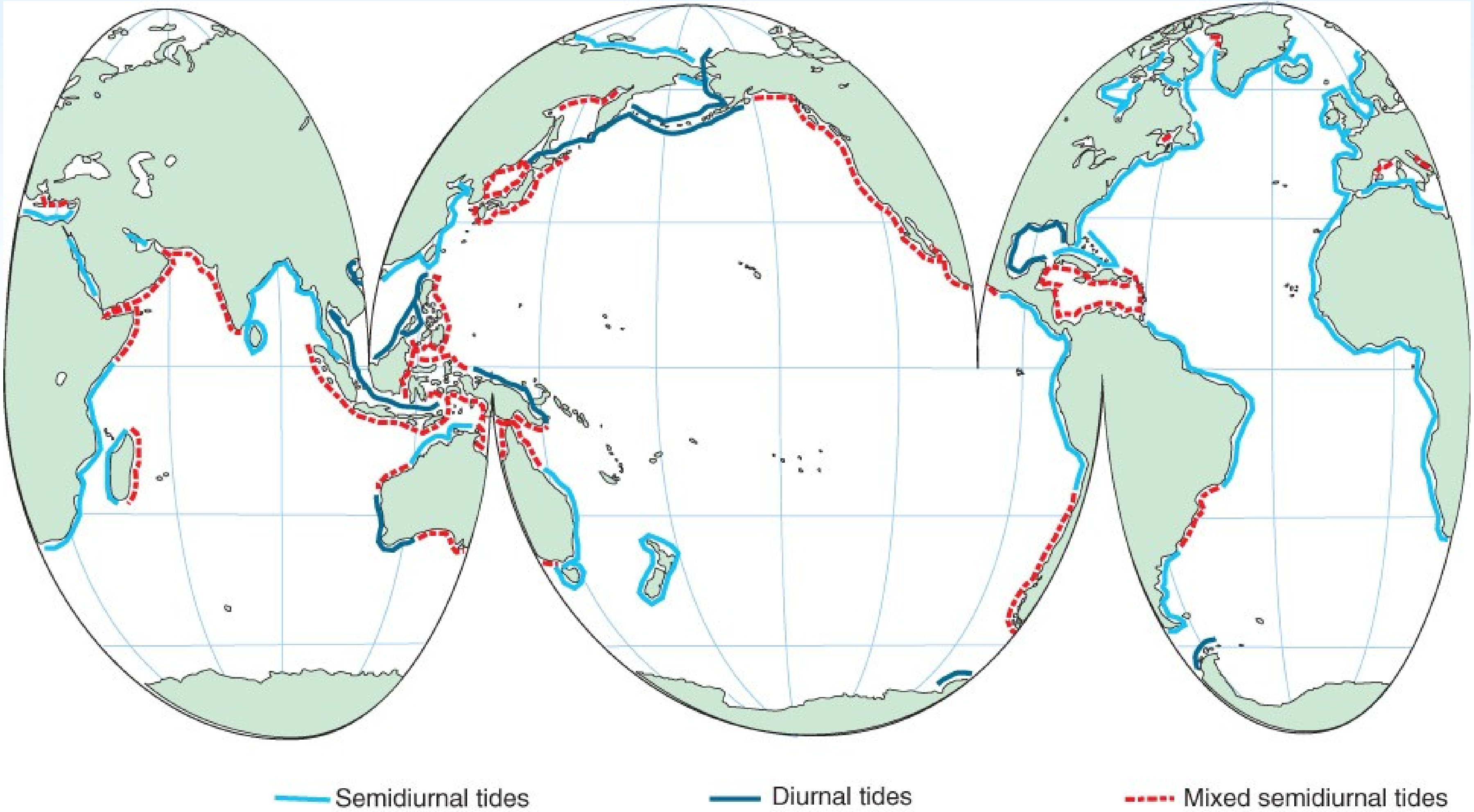


Fig. 1.43 The geographic occurrence of the three types of tides described in Figure 1.42.

The Ocean in Motion

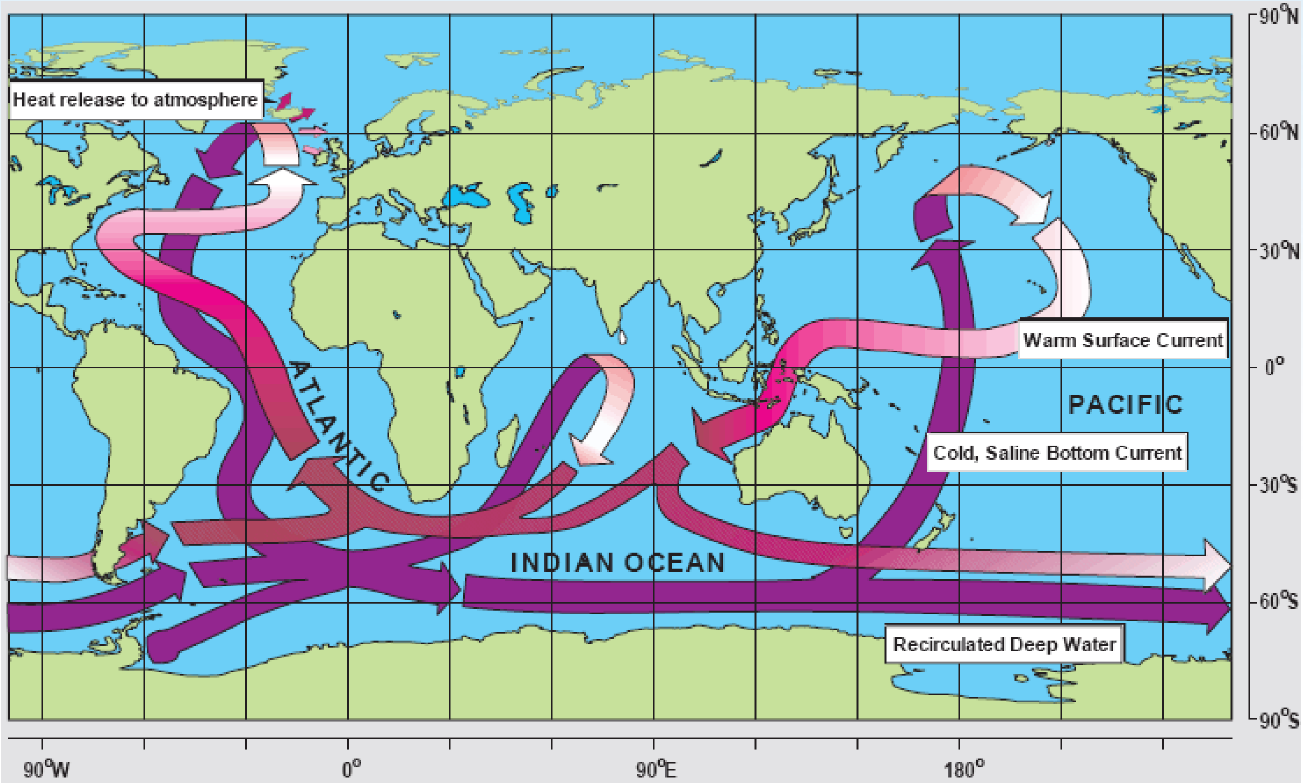
Vertical Water Movements

- Vertical circulation of ocean water results from density-driven sinking processes.

The Ocean in Motion – Vertical Water Movements

ones and Bartlett Publishers, LLC (www.jbpub.com)

Vertical Mixing



thermohaline circulation – mixing by differences in temp & salinity

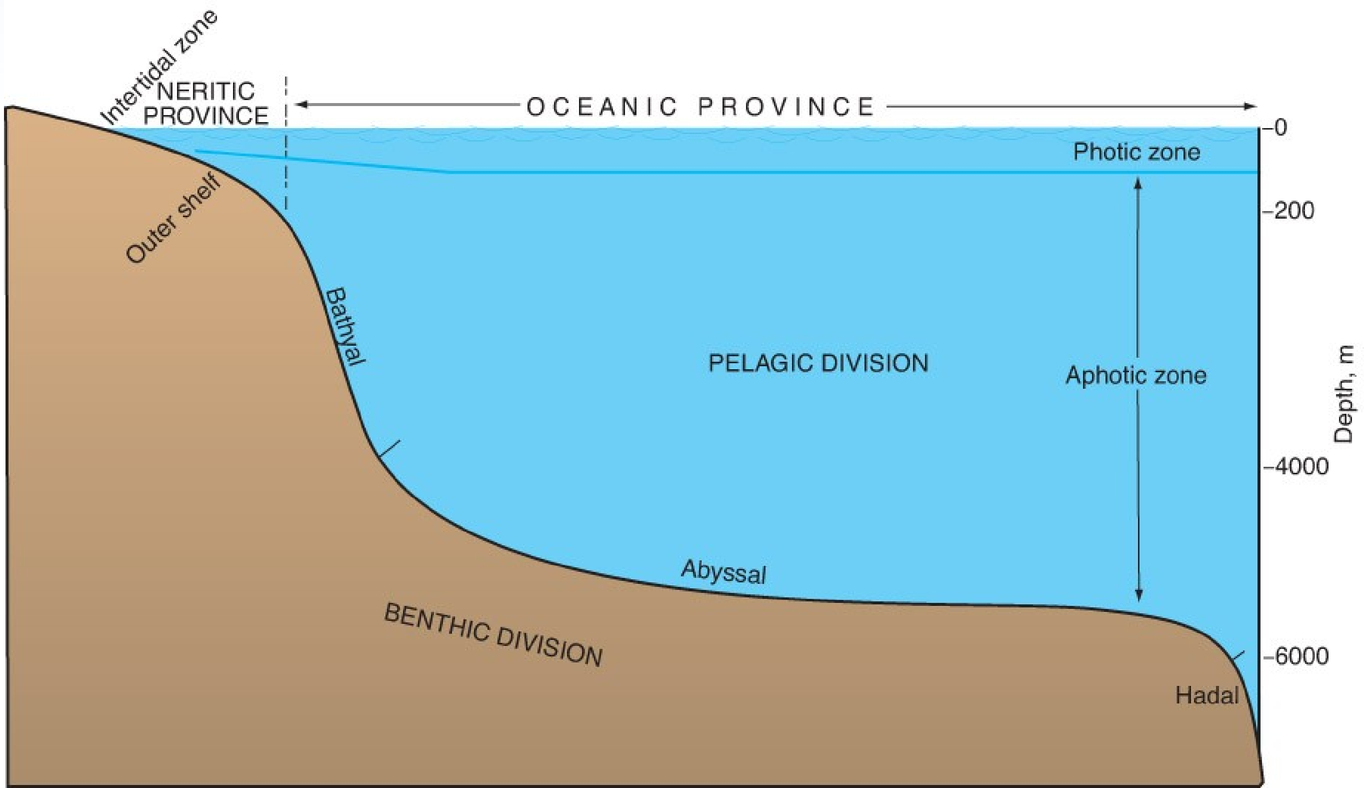
Classification of the Marine Environment

- Energy from the sun:
  - warms the sea's surface
  - creates winds

- Winds result in a two-layered world ocean, with:
  - a shallow, well-mixed, warm, sunlit layer overlaying
  - a much deeper, cold, dark, high-pressure layer of slowly moving water below

Classification of the Marine Environment

- The three-dimensional marine environment can be separated into two broad divisions:
  - the benthic realm of the sea floor (bathyal, abyssal, hadal)
  - and the pelagic water column (neritic, oceanic)



Classification of the Marine Environment

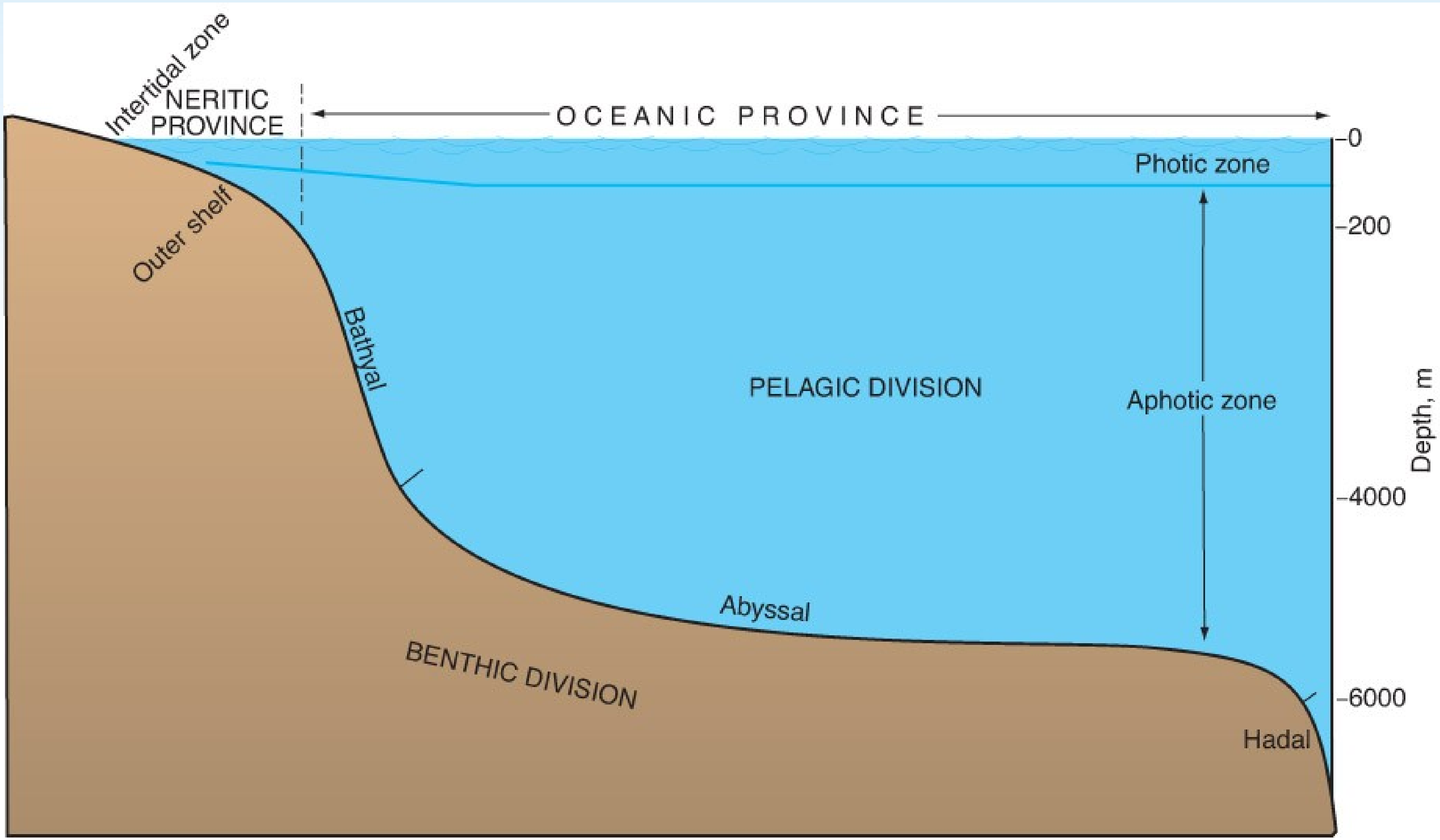


Fig. 1.46 A system for classifying the marine environment.

Adapted from J. W. Hedgpeth, ed. Treatise on Marine Ecology and Paleoecology. 2 vols. Geological Society of America, 1966.