Earth Science, 11e

The Dynamic Ocean
Chapter 15

Ocean water movements

- Surface circulation
  - Ocean currents are masses of water that flow from one place to another
  - Surface currents develop from friction between the ocean and the wind that blows across the surface
  - Huge, slowly moving gyres

Ocean water movements

- Surface circulation
  - Five main gyres
    - North Pacific Gyre
    - South Pacific Gyre
    - North Atlantic Gyre
    - South Atlantic Gyre
    - Indian Ocean Gyre
  - Related to atmospheric circulation

Average ocean surface currents in February-March

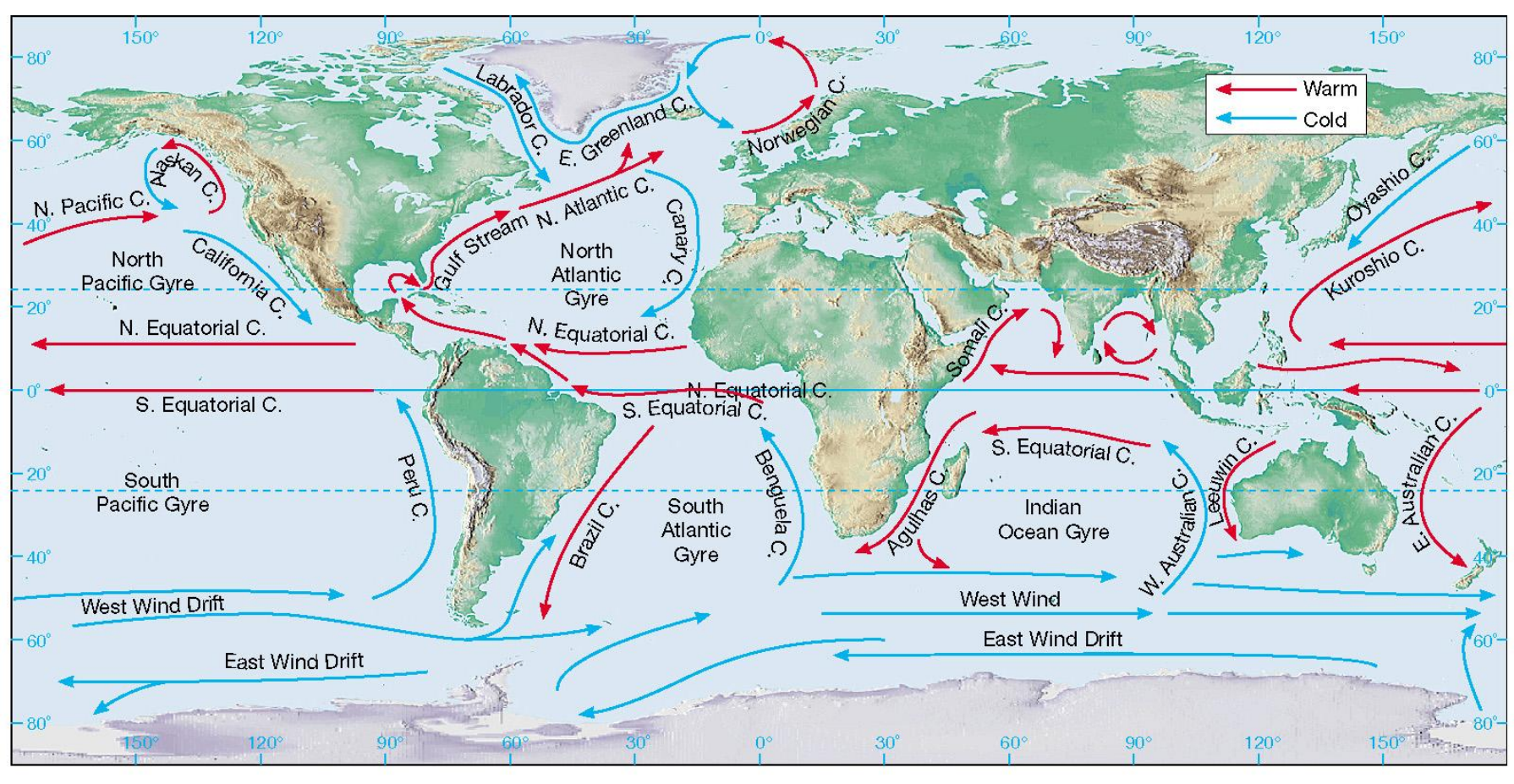


Figure 15.2

Ocean water movements

- Surface circulation
  - Deflected by the Coriolis effect
    - To the right in the Northern Hemisphere
    - To the left in the Southern Hemisphere
  - Four main currents generally exist within each gyre
  - Importance of surface currents
    - Climate
      - Currents from low latitudes into higher latitudes (warm currents) transfer heat from warmer to cooler areas

Ocean water movements

- Surface circulation
  - Importance of surface currents
    - Climate
      - Influence of cold currents is most pronounced in the tropics or during the summer months in the middle latitudes
    - Upwelling
      - The rising of cold water from deeper layers
      - Most characteristic along west coasts of continents
      - Brings greater concentrations of dissolved nutrients to the ocean surface

Ocean water movements

- Deep-ocean circulation
  - A response to density differences
  - Factors creating a dense mass of water
    - Temperature – cold water is dense
    - Salinity – density increases with increasing salinity
  - Called thermohaline circulation

Ocean water movements

- Deep-ocean circulation
  - Most water involved in deep-ocean currents begins in high latitudes at the surface
  - A simplified model of ocean circulation is similar to a conveyor belt that travels from the Atlantic Ocean, through the Indian and Pacific Oceans and back again

Idealized "conveyor belt" model of ocean circulation

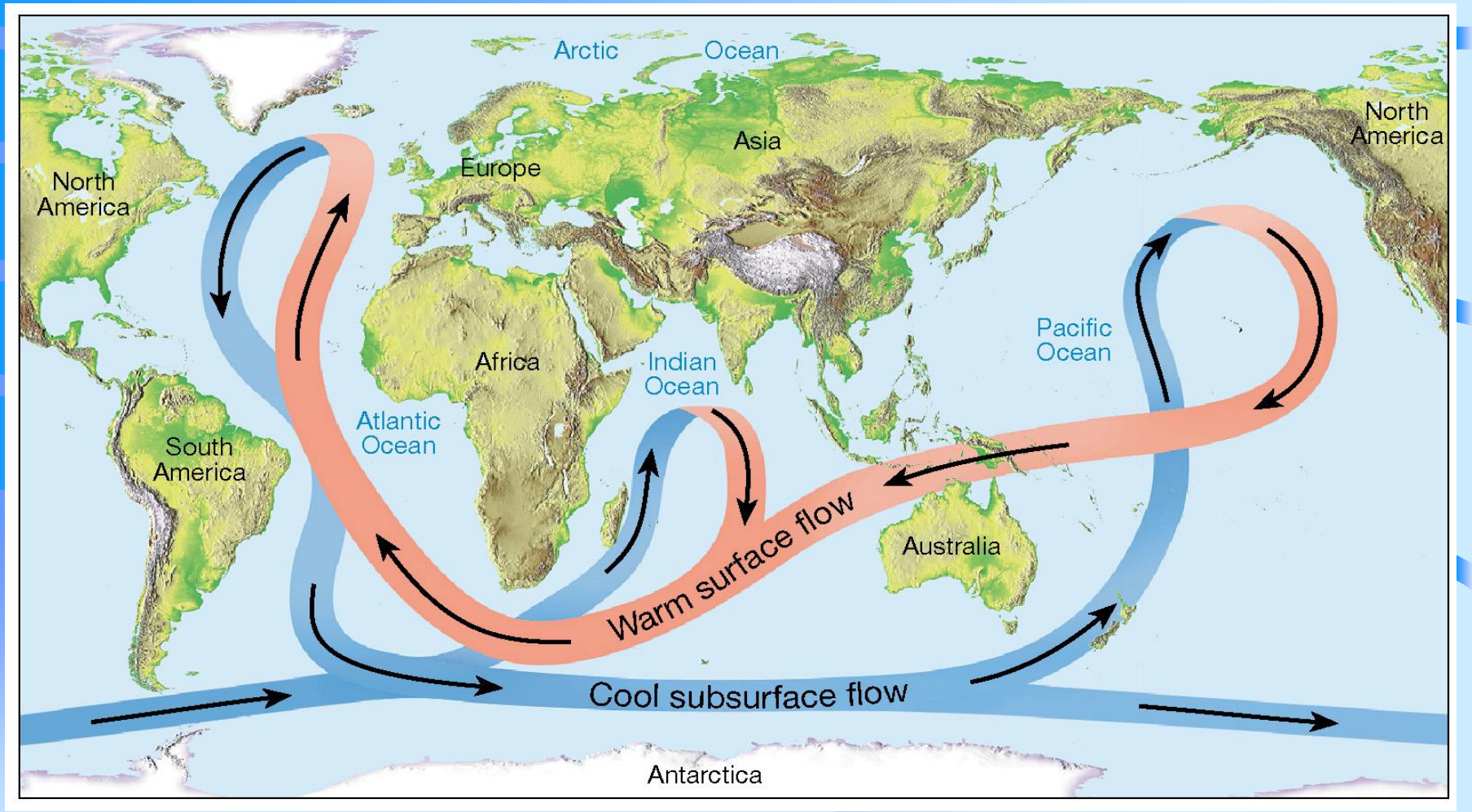


Figure 15.6

The coastal zone

- The land-sea boundary
  - Shoreline – contact between land and sea
  - Shore – area between lowest tidal level and highest areas affected by storm waves
  - Coastline – the seaward edge of the coast
  - Beach – accumulation of sediment along the landward margin of the ocean

The coastal zone

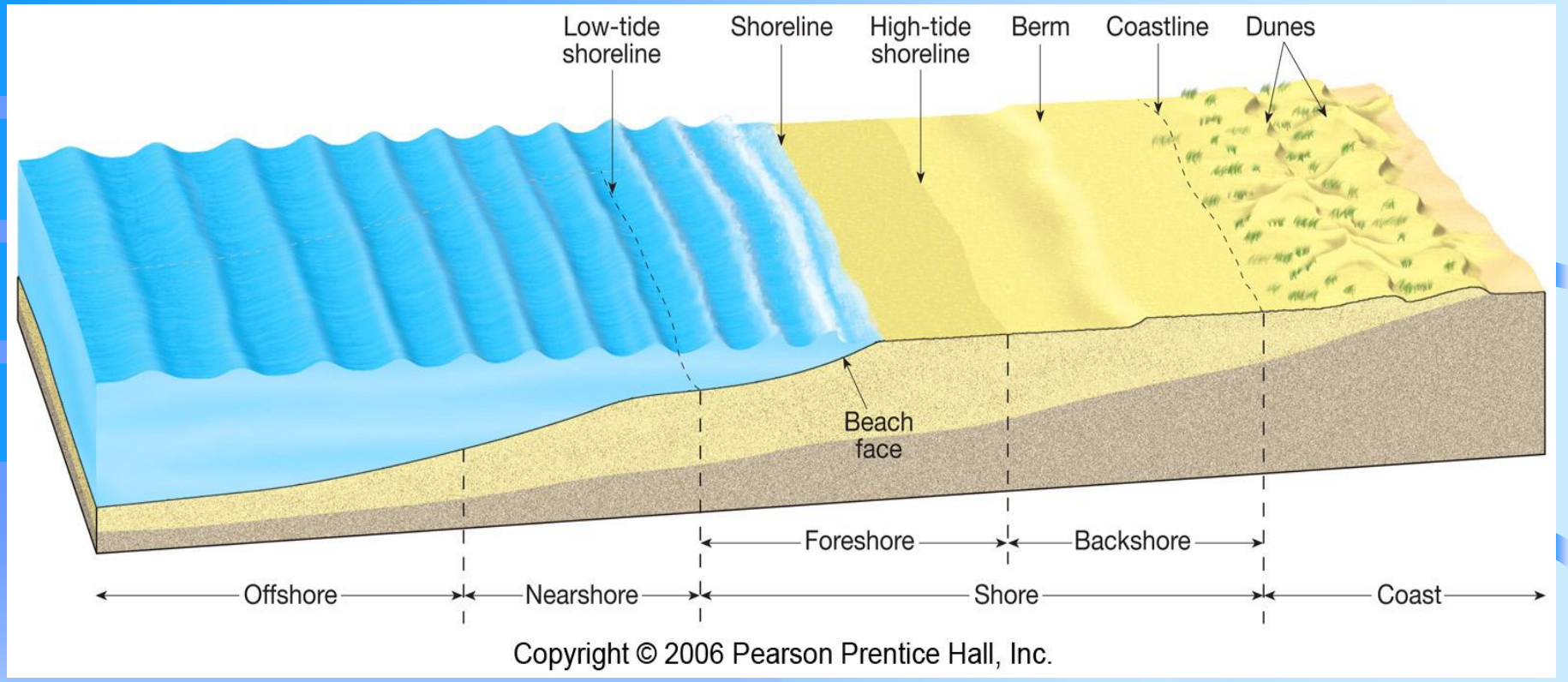


Figure 15.7

Ocean water movements

- Waves
  - Energy traveling along the interface between ocean and atmosphere
  - Derive their energy and motion from wind
  - Parts
    - Crest
    - Trough

Ocean water movements

- Waves
  - Measurements of a wave
    - Wave height – the distance between a trough and a crest
    - Wavelength – the horizontal distance between successive crests (or troughs)
    - Wave period – the time interval for one full wave to pass a fixed position

The basic parts and movement of a non-breaking wave

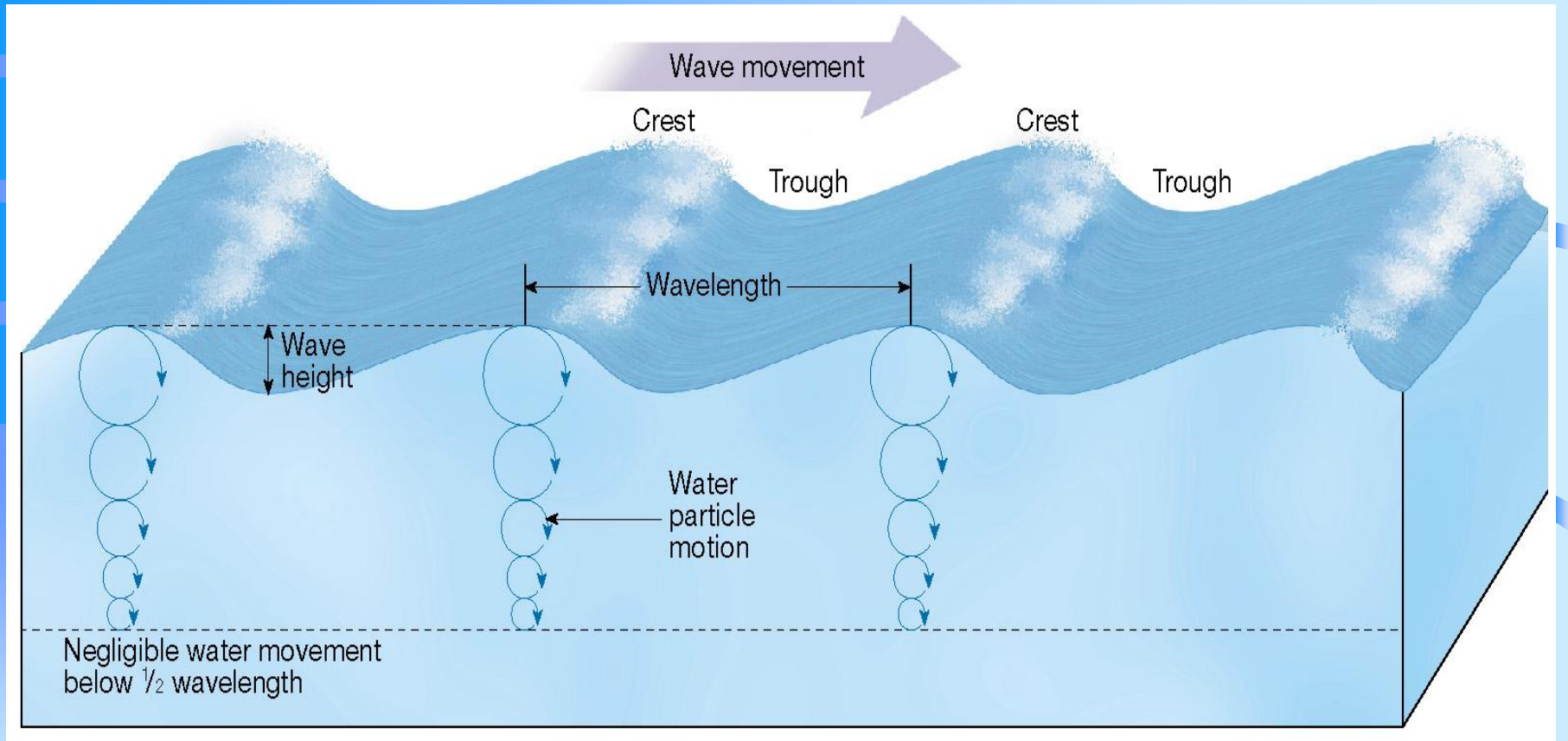
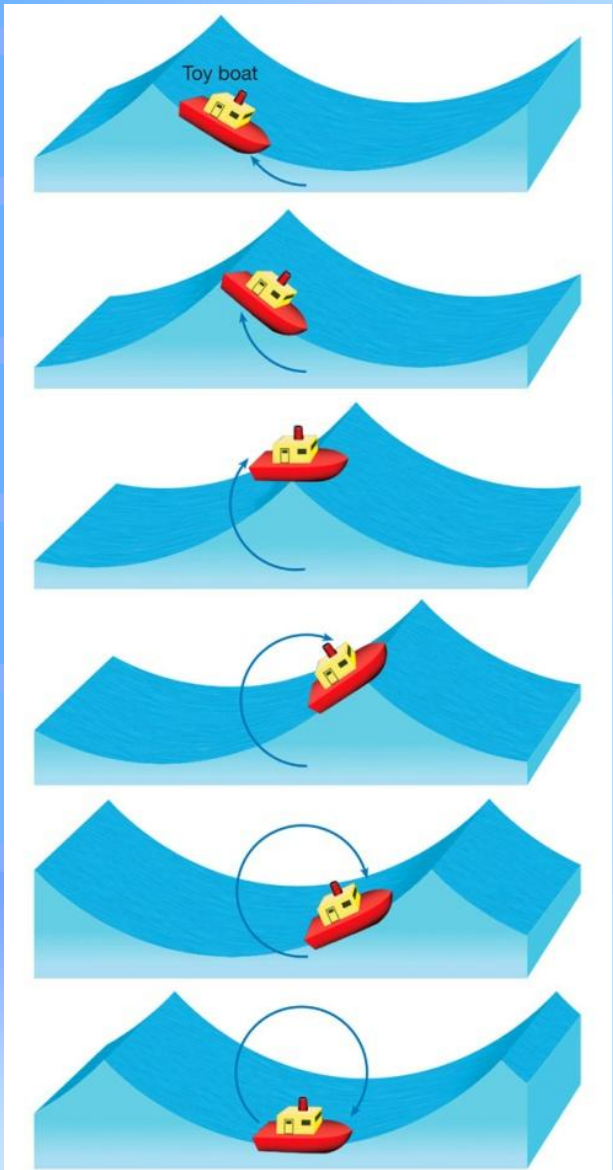


Figure 15.8

Ocean water movements

- Waves
  - Wave height, length, and period depend on
    - Wind speed
    - Length of time the wind blows
    - Fetch – the distance that the wind travels
  - As the wave travels, the water passes energy along by moving in a circle
    - Waveform moves forward
    - At a depth of about one-half the wavelength, the movement of water particles becomes negligible (the wave base)

Circular motion of water waves



Changes that occur when a wave moves onto shore

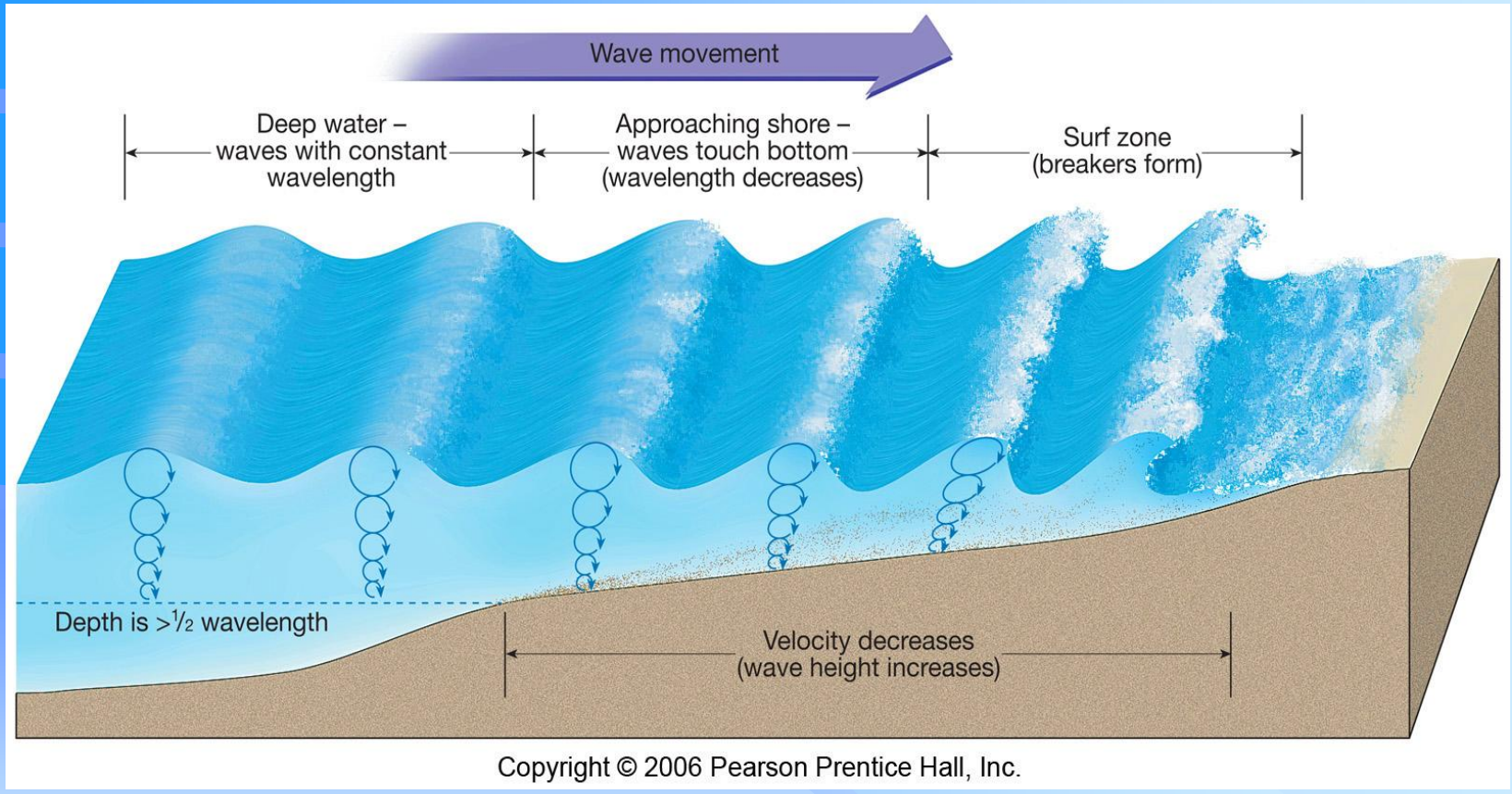


Figure 15.10

Wave erosion

- Wave erosion
  - Caused by
    - Wave impact and pressure
    - Breaks down rock material and supplies sand to beaches
    - Abrasion – sawing and grinding action of water armed with rock fragments

Sand movement on the beach

- Beaches are composed of whatever material is available
  - Some beaches have a significant biological component
  - Material does not stay in one place
    - Wave energy moves large quantities of sand parallel and perpendicular to the shoreline

Beaches and shoreline processes

- Wave refraction
  - Bending of a wave
  - Wave arrives parallel to shore
  - Results
    - Wave energy is concentrated against the sides and ends of headland
    - Wave erosion straightens an irregular shoreline

Wave refraction along an irregular coastline

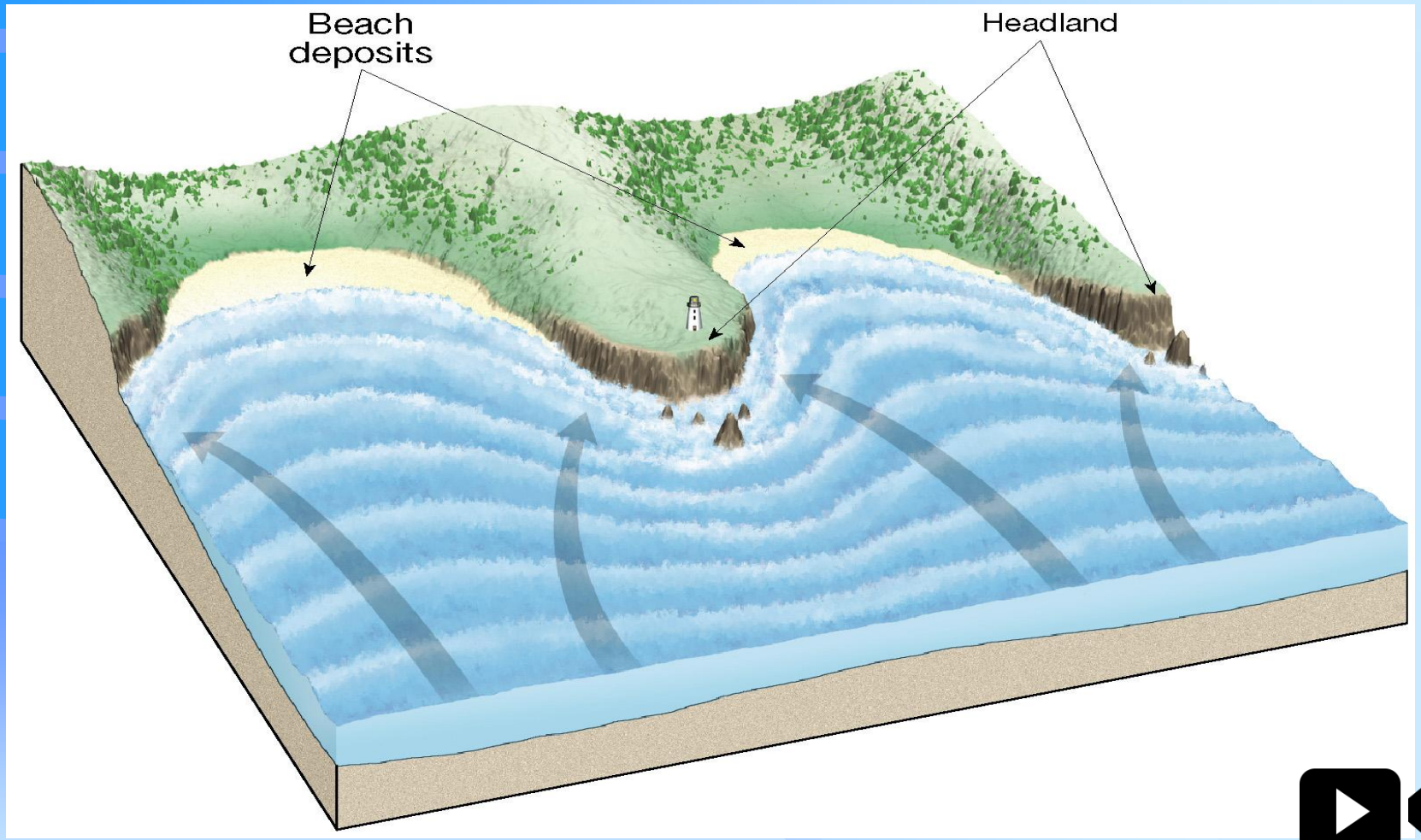


Figure 15.13

Beaches and shoreline processes

- Longshore transport
  - Beach drift – sediment moves in a zigzag pattern along the beach face
  - Longshore current
    - Current in surf zone
    - Flows parallel to the shore
    - Moves substantially more sediment than beach drift

Beach drift and longshore currents

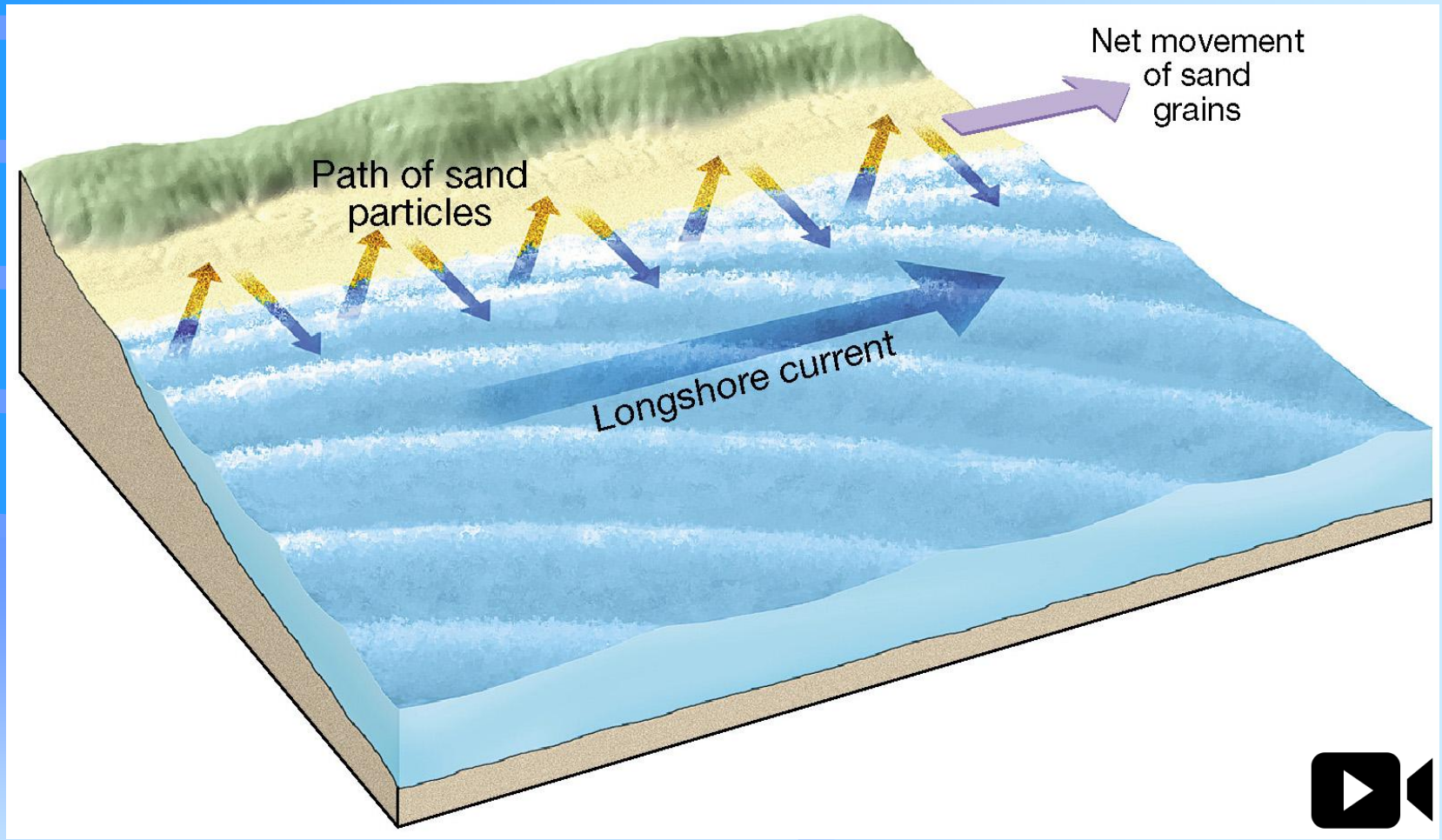


Figure 15.14

Shoreline features

- Erosional features
  - Wave-cut cliff
  - Wave-cut platform
  - Marine terraces
  - Associated with headlands
    - Sea arch
    - Sea stack

Sea arch

Sea arch

Figure 15.19 A

Sea stack

Sea stack

Shoreline features

- Depositional features
  - Spit – a ridge of sand extending from the land into the mouth of an adjacent bay with an end that often hooks landward
  - Baymouth bar – a sand bar that completely crosses a bay
  - Tombolo – a ridge of sand that connects an island to the mainland

Aerial view of a spit and baymouth bar along the Massachusetts coastline

Figure 15.17

Spit

Spit

Figure 15.19 C

Baymouth bar

Baymouth bar

Tombolo

Tombolo

Figure 15.19 B

Shoreline features

- Depositional features
  - Barrier islands
    - Mainly along the Atlantic and Gulf Coastal Plains
    - Parallel the coast
    - Originate in several ways

Stabilizing the shore

- Shoreline erosion is influenced by the local factors
  - Proximity to sediment-laden rivers
  - Degree of tectonic activity
  - Topography and composition of the land
  - Prevailing wind and weather patterns
  - Configuration of the coastline

Stabilizing the shore

- Responses to erosion problems
  - Hard stabilization - building structures
    - Types of structures
      - Groins - barriers built at a right angle to the beach that are designed to trap sand
      - Breakwaters - barriers built offshore and parallel to the coast to protect boats from breaking waves
      - Seawalls - Armors the coast against the force of breaking waves
    - Often these structures are not effective

Stabilizing the shore

- Responses to erosion problems
  - Alternatives to hard stabilization
    - Beach nourishment by adding sand to the beach system
    - Relocating buildings away from beach
- Erosion problems along U.S. Coasts
  - Shoreline erosion problems are different along the opposite coasts

Miami Beach before beach nourishment

A.

Figure 15.23 A

Miami Beach after beach nourishment

B.

Figure 15.23 B

Stabilizing the shore

- Erosion problems along U.S. Coasts
  - Atlantic and Gulf Coasts
    - Development occurs mainly on barrier islands
      - Face open ocean
      - Receive full force of storms
    - Development has taken place more rapidly than our understanding of barrier island dynamics

Stabilizing the shore

- Erosion problems along U.S. Coasts
  - Pacific Coast
    - Characterized by relatively narrow beaches backed by steep cliffs and mountain ranges
    - Major problem is the narrowing of the beaches
      - Sediment for beaches is interrupted by dams and reservoirs
      - Rapid erosion occurs along the beaches

Coastal classification

- Shoreline classification is difficult
- Classification based on changes with respect to sea level
  - Emergent coast
    - Caused by
      - Uplift of the land, or
      - A drop in sea level

Coastal classification

- Classification based on changes with respect to sea level
  - Emergent coast
    - Features of an emergent coast
      - Wave-cut cliffs
      - Marine terraces

Coastal classification

- Classification based on changes with respect to sea level
  - Submergent coast
    - Caused by
      - Land adjacent to sea subsides, or
      - Sea level rises
    - Features of a submergent coast
      - Highly irregular shoreline
      - Estuaries – drowned river mouths

Major estuaries along the East Coast of the United States

Figure 15.24

Tides

- Changes in elevation of the ocean surface
- Caused by the gravitational forces exerted upon the Earth by the
  - Moon, and to a lesser extent by the
  - Sun

Idealized tidal bulges on Earth

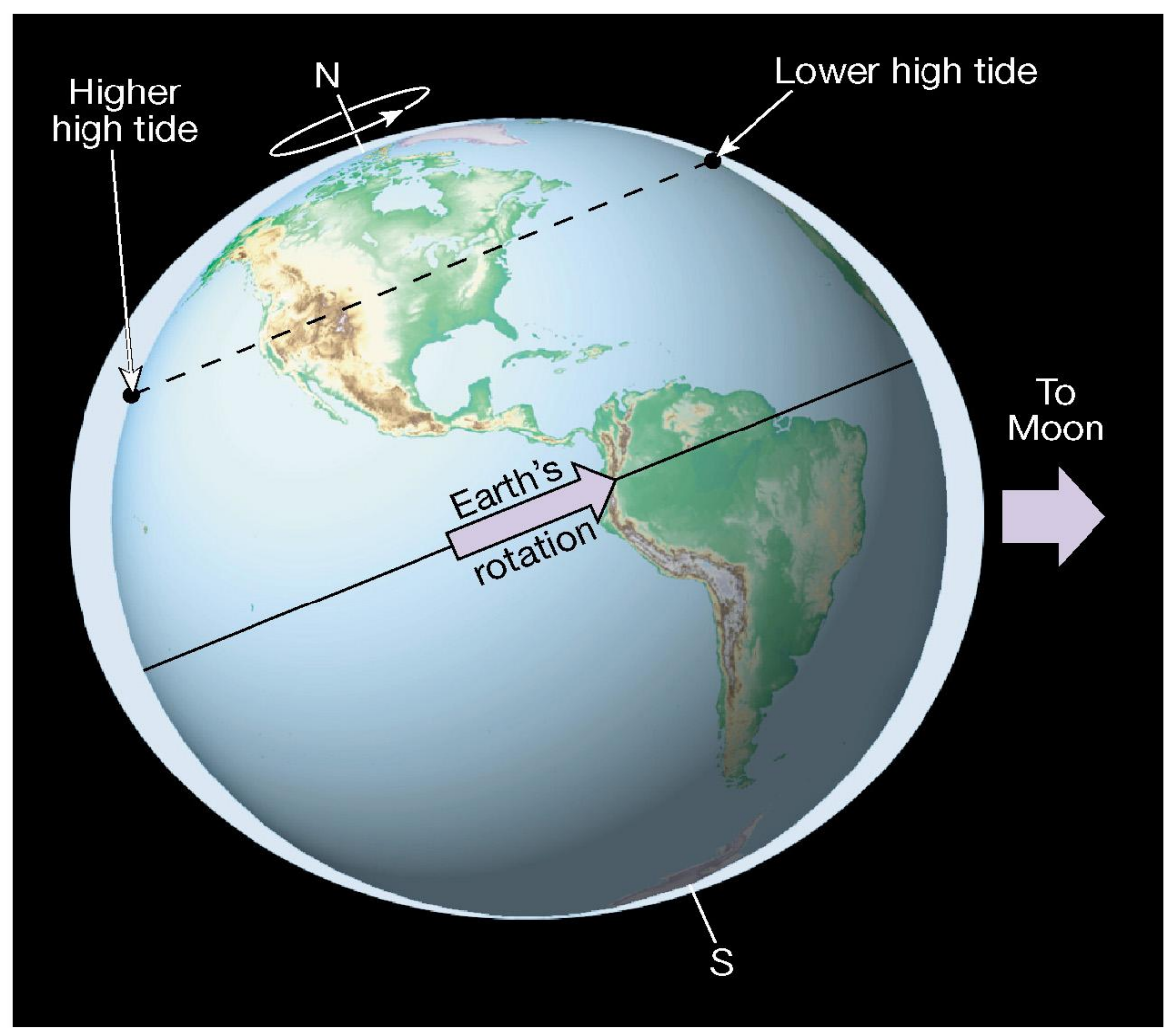


Figure 15.26

Tides

- Monthly tidal cycle
  - Spring tide
    - During new and full moons
    - Gravitational forces added together
    - Especially high and low tides
    - Large daily tidal range

Earth-Moon-Sun positions during the Spring tide

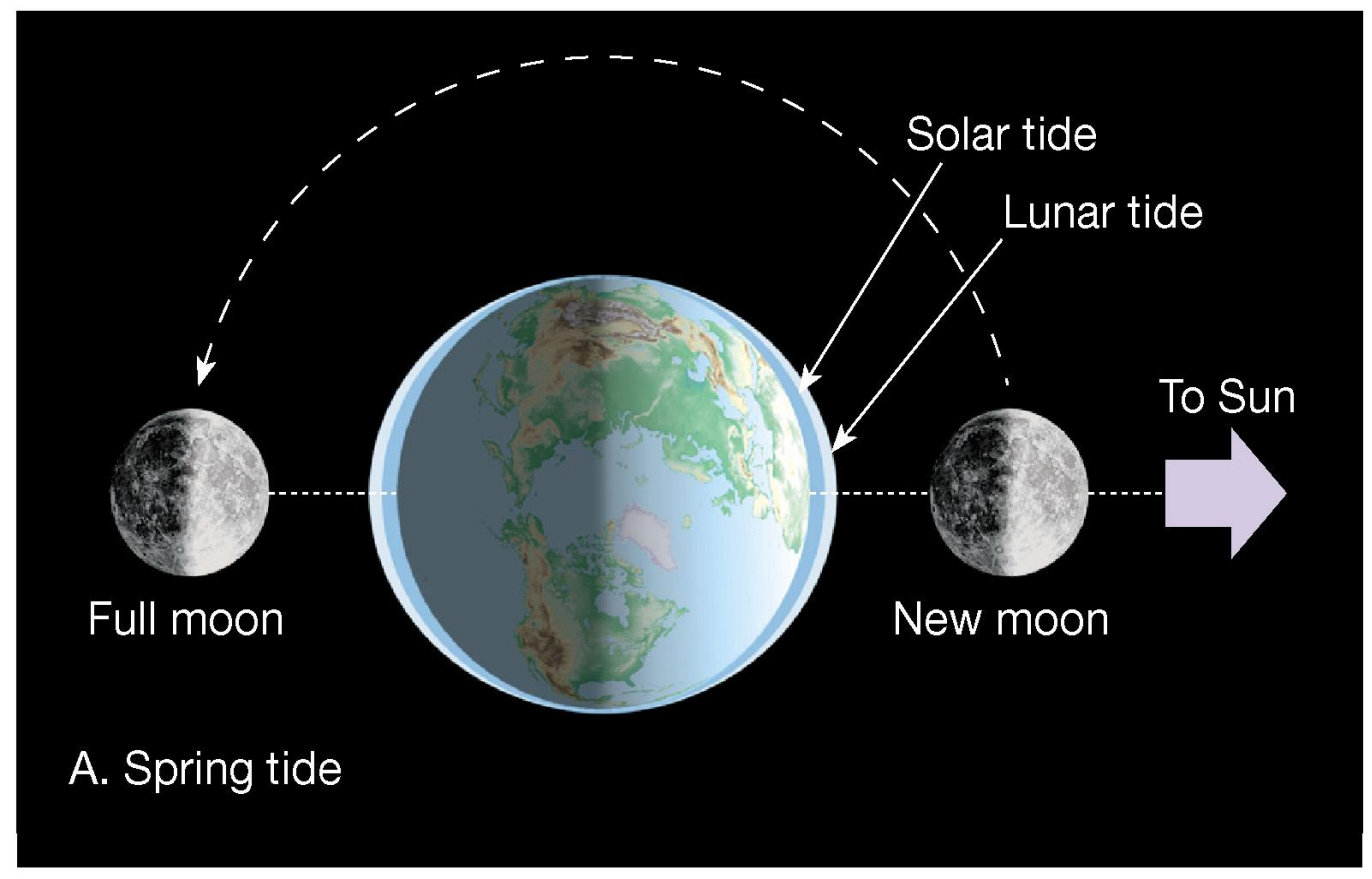


Figure 15.27 A

Earth-Moon-Sun positions during the Neap tide

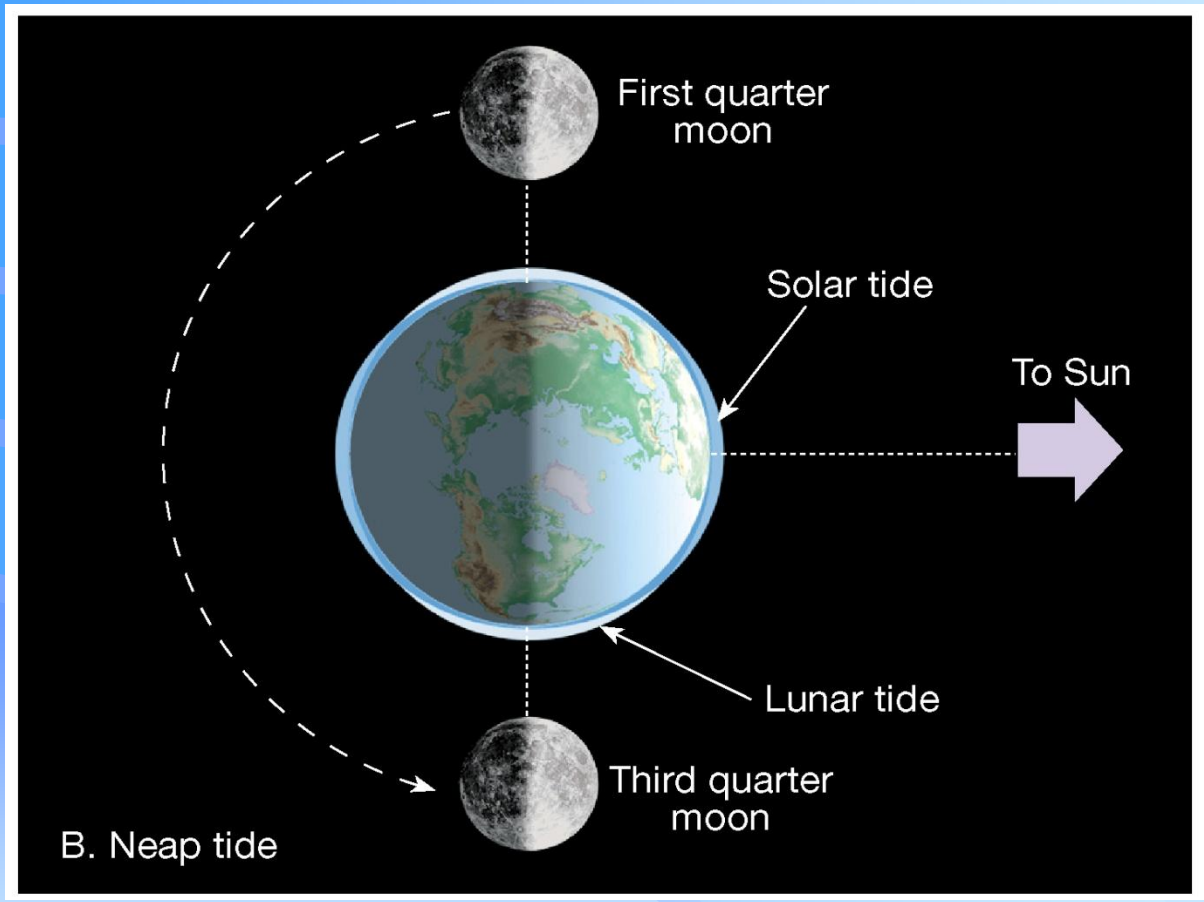


Figure 15.27 B

Tides

- Monthly tidal cycle
  - Neap tide
    - First and third quarters of the Moon
    - Gravitational forces are offset
    - Daily tidal range is least
- Tidal patterns
  - Many factors influence the tides
    - Shape of the coastline
    - Configuration of the ocean basin
    - Water depth

High tide in the Bay of Fundy along the Nova Scotia coast

Figure 15.25 A

Low tide in the Bay of Fundy along the Nova Scotia coast

Figure 15.25 B

Tides

- Tidal patterns
  - Main tidal patterns
    - Diurnal tidal pattern
      - A single high and low tide each tidal day
      - Occurs along the northern shore of the Gulf of Mexico
    - Semidiurnal tidal pattern
      - Two high and two low tides each tidal day
      - Little difference in the high and low water heights
      - Common along the Atlantic Coast of the U.S.

Tides

- Tidal patterns
  - Main tidal patterns
    - Mixed tidal pattern
      - Two high and two low waters each day
      - Large inequality in high water heights, low water heights, or both
      - Prevalent along the Pacific Coast of the U.S.

Tides

- Tidal patterns
  - Tidal currents
    - Horizontal flow accompanying the rise and fall of tides
    - Types of tidal currents
      - Flood current – advances into the coastal zone
      - Ebb current – seaward moving water
    - Sometimes tidal deltas are created by tidal currents

Features associated with tidal currents

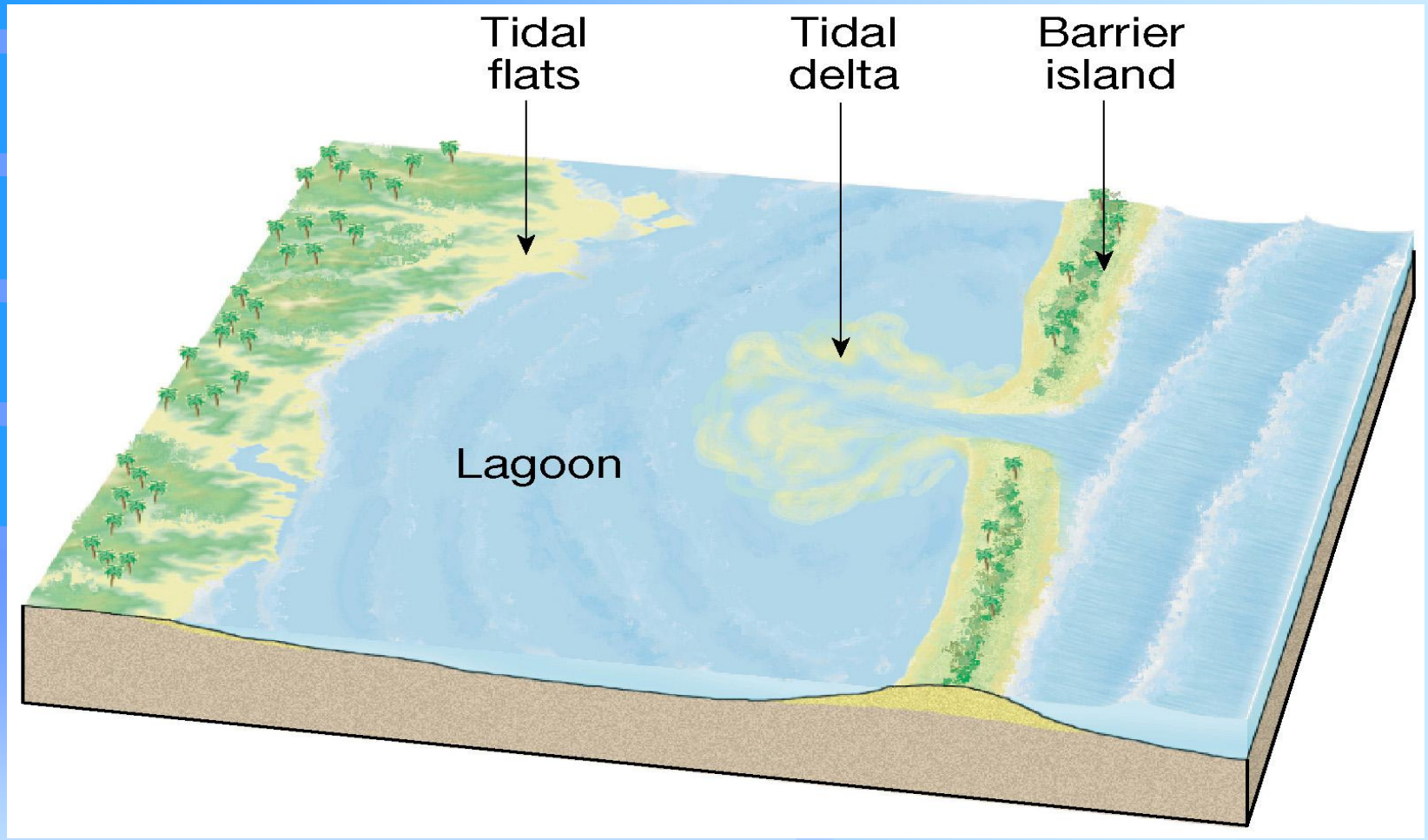


Figure 15.29

End of Chapter 15