Oceanography, An Invitation to Marine Science | 9e
Tom Garrison

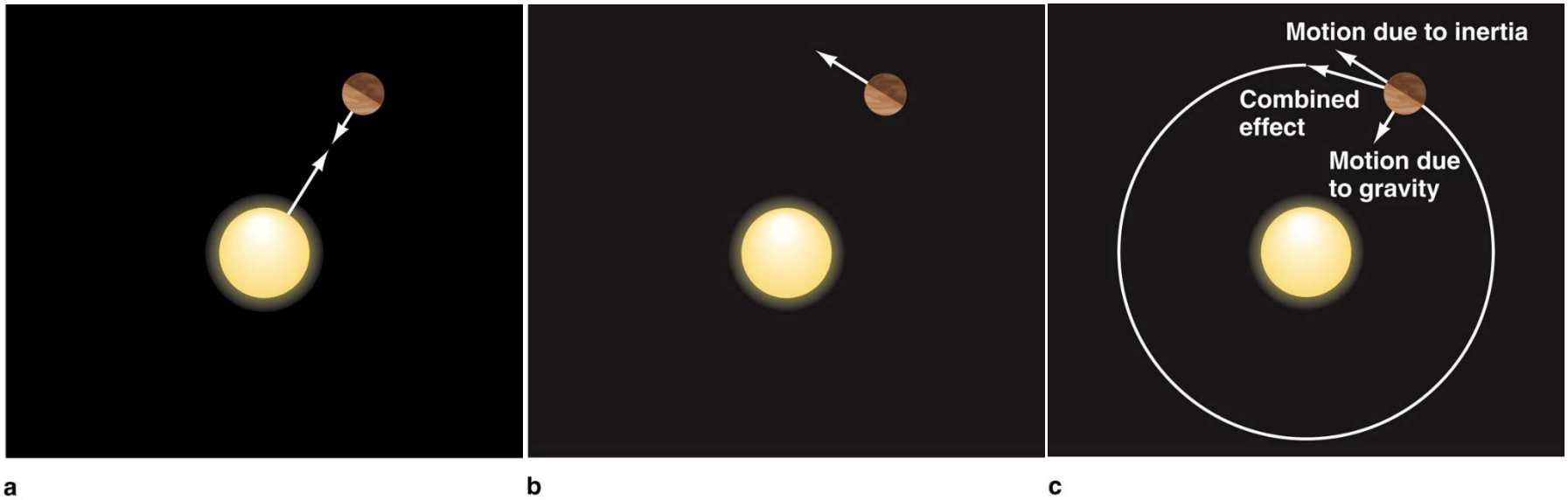
11

Chapter Title

Tides Are the Longest of All Ocean Waves

- Tides – periodic short-term changes in height of ocean surface at a particular place
- Caused by:
  - Gravity from the sun and moon
  - Motion of Earth
  - Inertia of water
- Forced wave
- **Equilibrium theory** of tides explains tides by examining the balance of and effects of forces that allow our planet to stay in orbit around the sun, or the moon to orbit Earth.

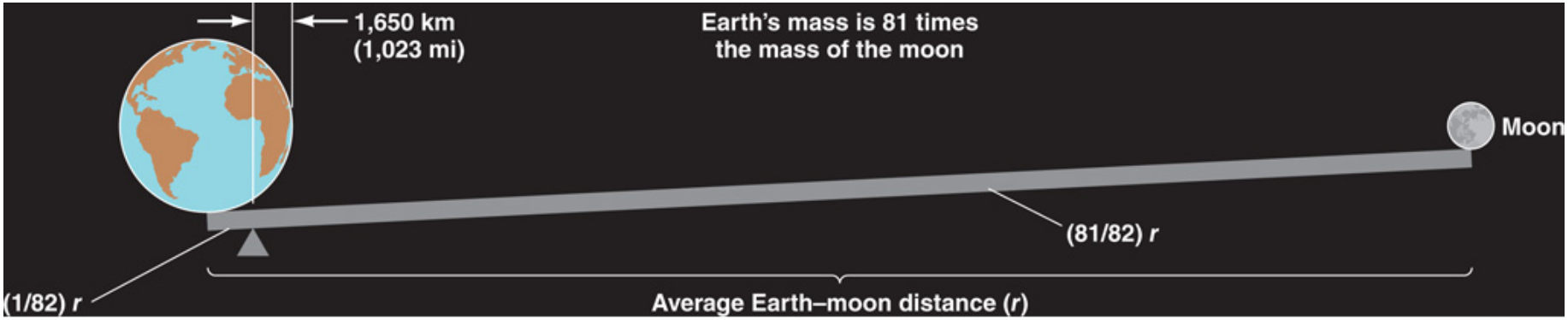
The Movement of the Moon Generates Strong Tractive Forces



A planet orbits the sun in balance between gravity and inertia. (a) If the planet is not moving, gravity will pull it into the sun. (b) If the planet is moving, the inertia of the planet will keep it moving in a straight line. (c) In a stable orbit, gravity and inertia together cause the planet to travel in a fixed path around the sun.

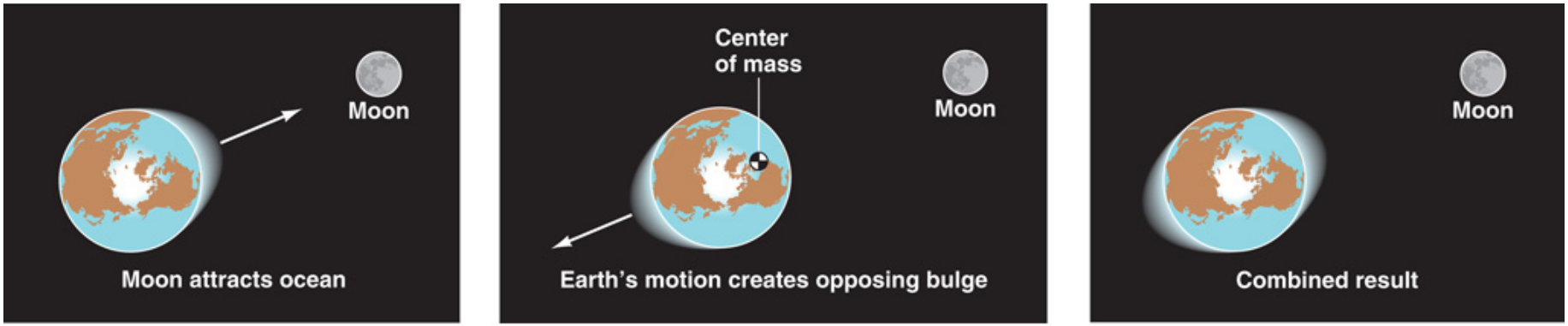
Tides: Forced Waves Formed by Gravity and Inertia

Moon does not revolve around the center of Earth. Earth and moon together—the Earth–moon system—revolve around a common center of mass about 1,650 kilometers (1,023 miles) beneath Earth's surface.



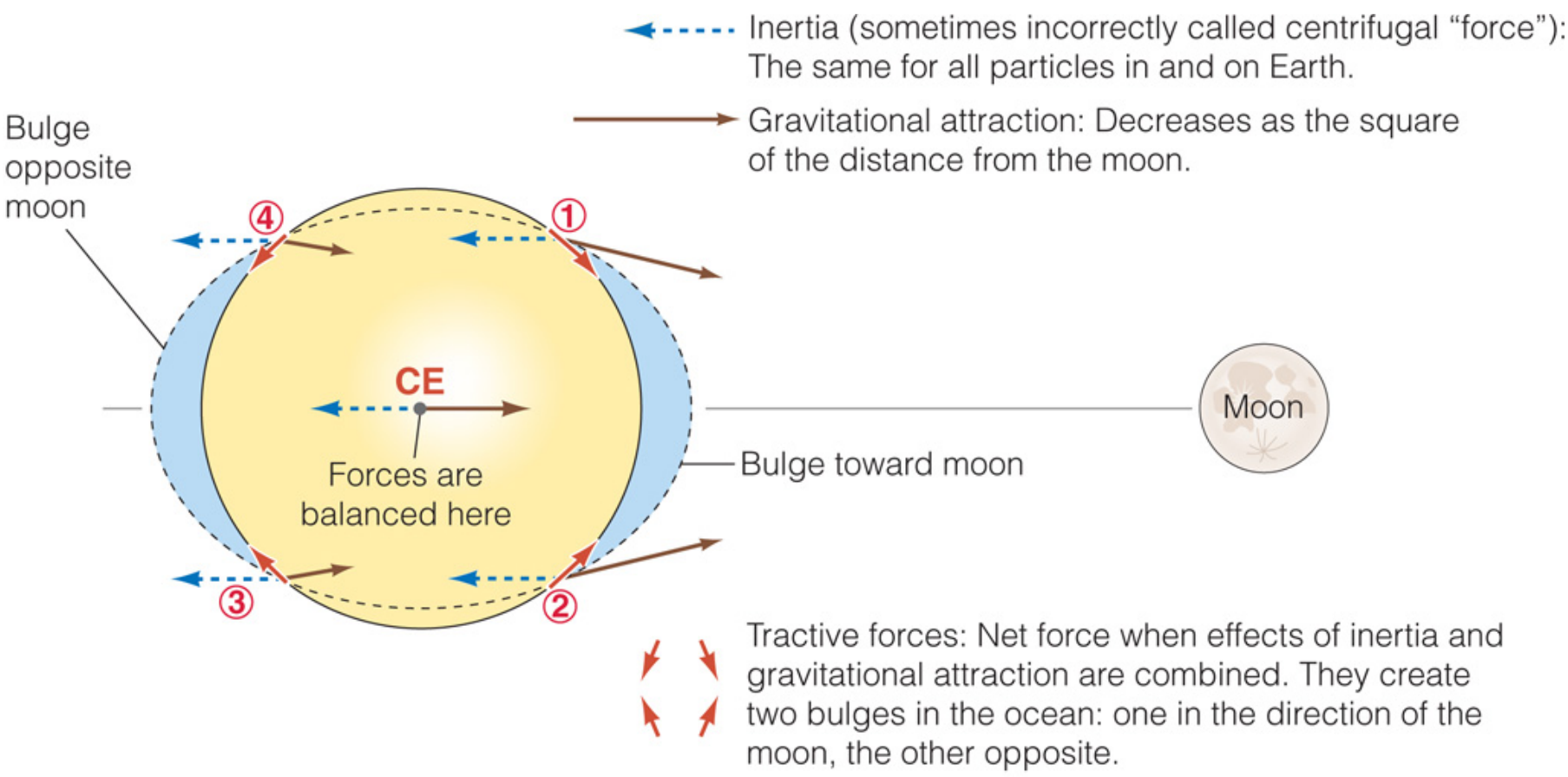
© Cengage Learning

Tides: Forced Waves Formed by Gravity and Inertia



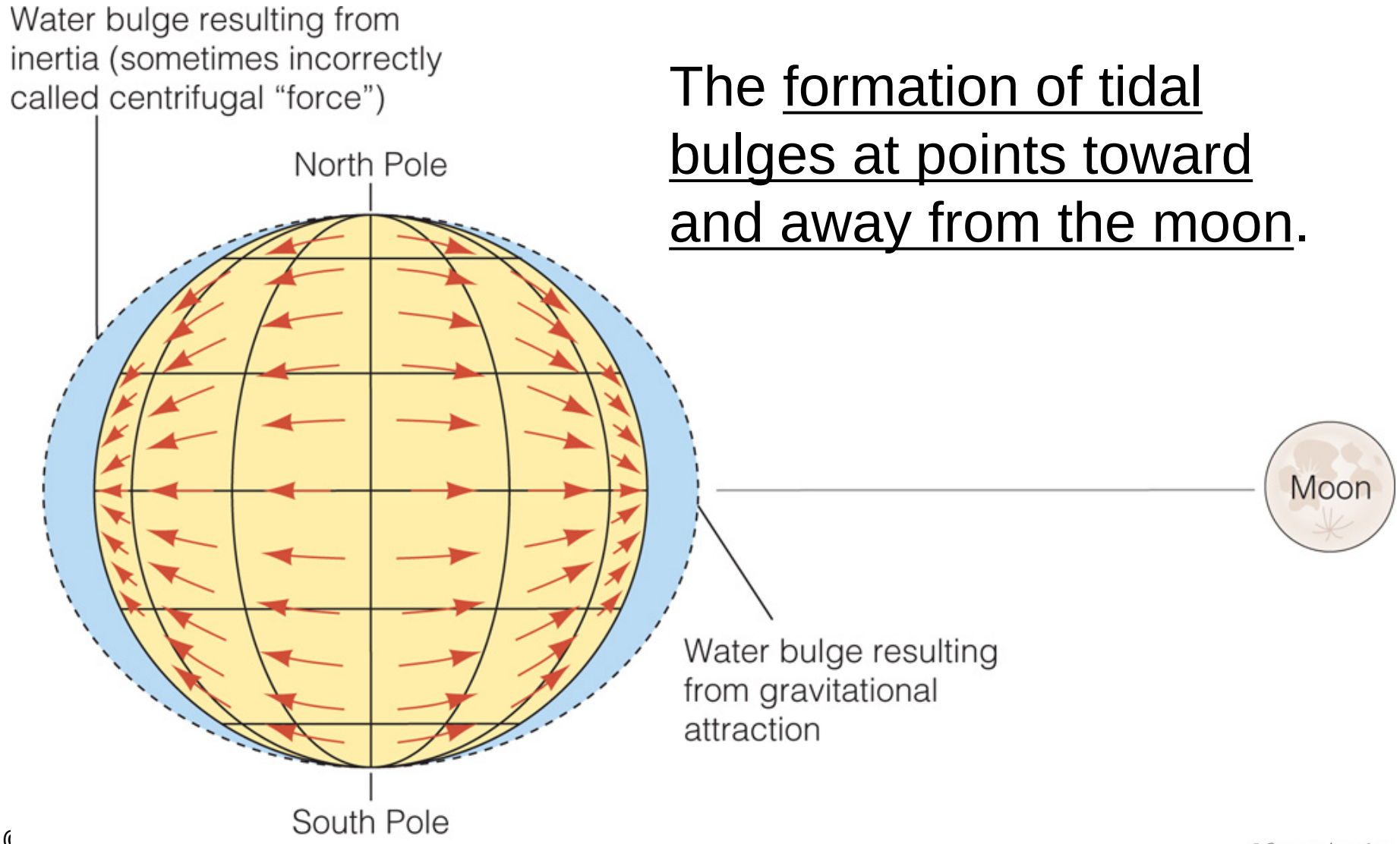
The moon's gravity attracts the ocean toward it. The motion of Earth around the center of mass of the Earth–moon system throws up a bulge on the side of Earth opposite the moon. The combination of the two effects creates two tidal bulges.

Tides Are Formed by Gravity and Inertia



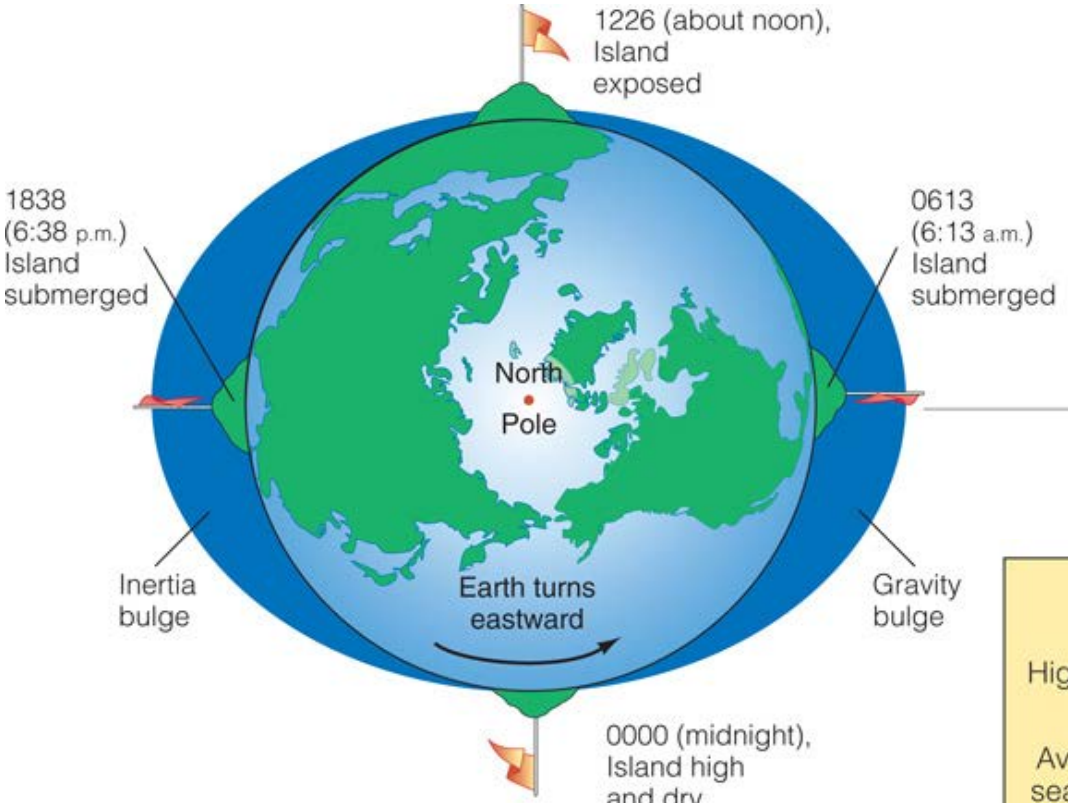
The two forces that can move the ocean—inertia and gravitational attraction—are precisely equal in strength but opposite in direction, and thus balanced, only at the center of Earth (point **CE**).

Tides Are Formed by Gravity and Inertia

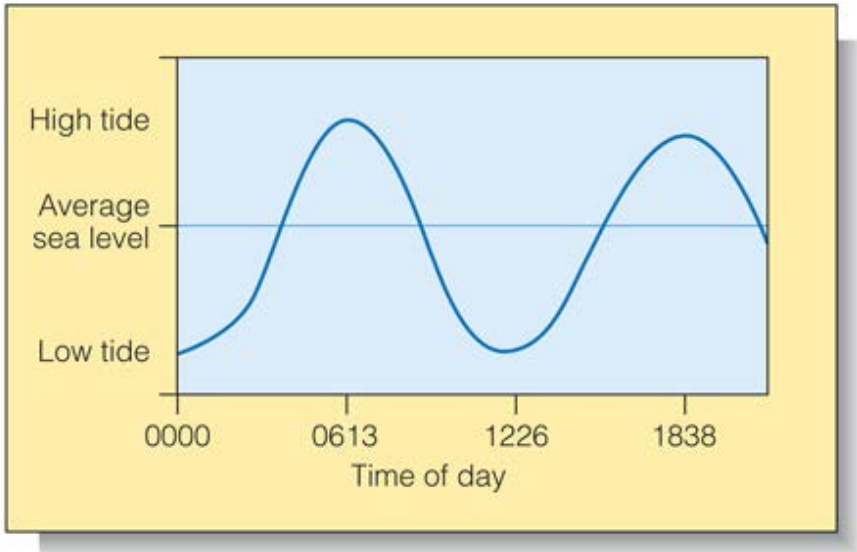


The formation of tidal bulges at points toward and away from the moon.

How Earth's Rotation Beneath the Tidal Bulges Produces High and Tow Tides

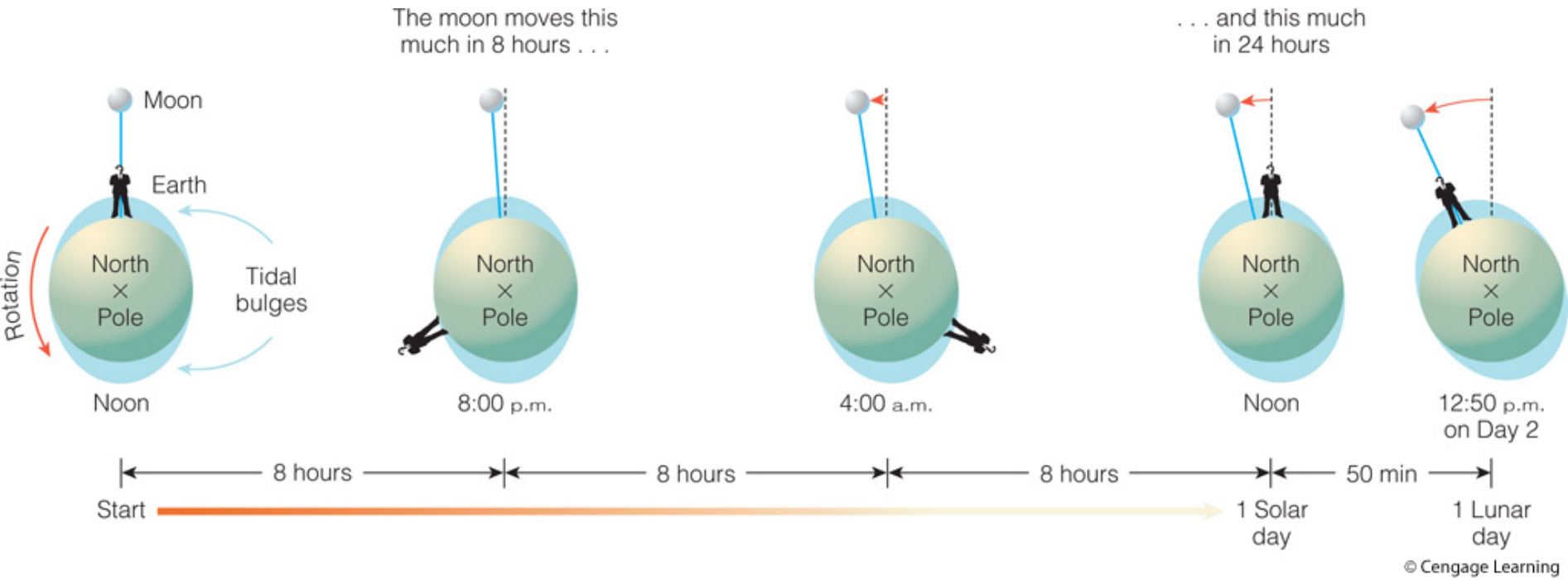


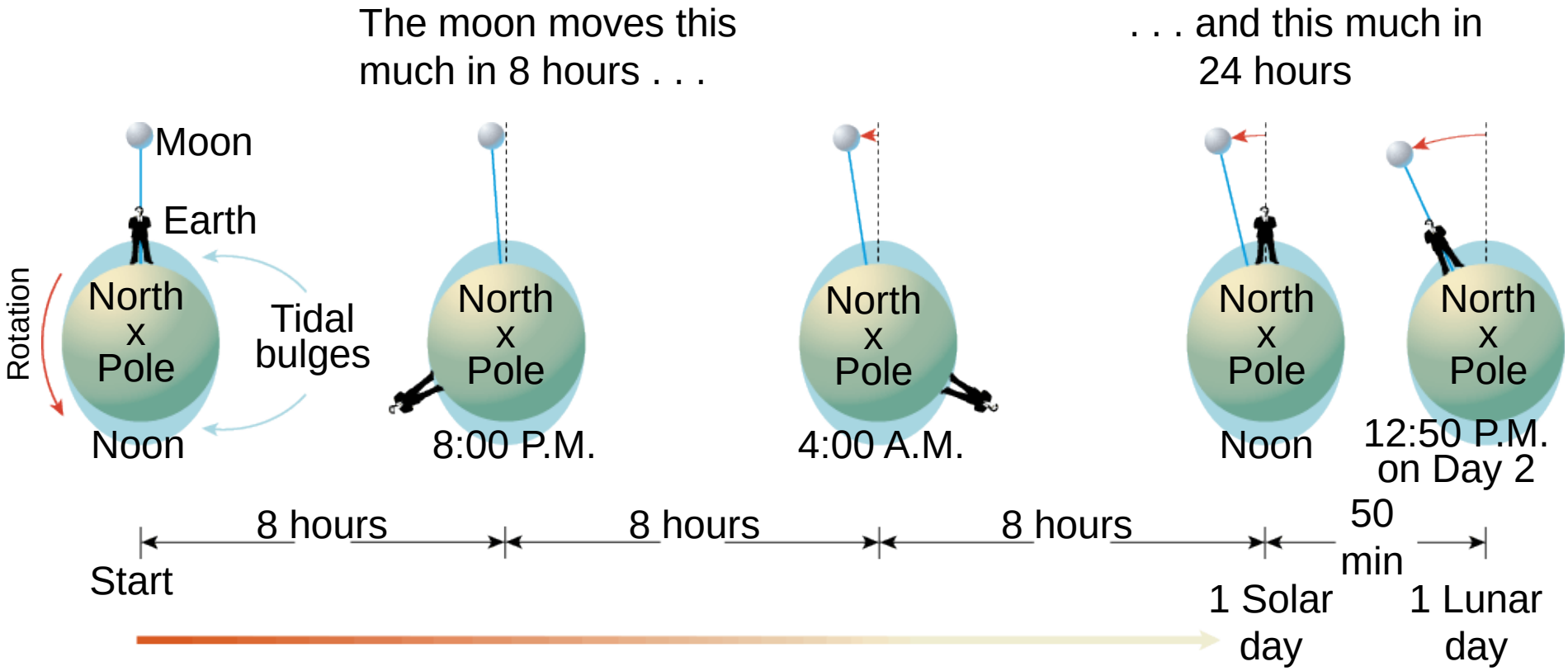
Notice that the tidal cycle is 24 hr 50 min long because the moon rises 50 min later each day.



Movement of the Moon Generates Strong Tractive Forces

Lunar day is longer than solar day. Lunar day is time that elapses between when moon is highest in the sky and next time it is highest in the sky. In 24-hour solar day, moon moves eastward and Earth must rotate, takes 50 extra min. A Lunar day is 24 hr 50 min long.

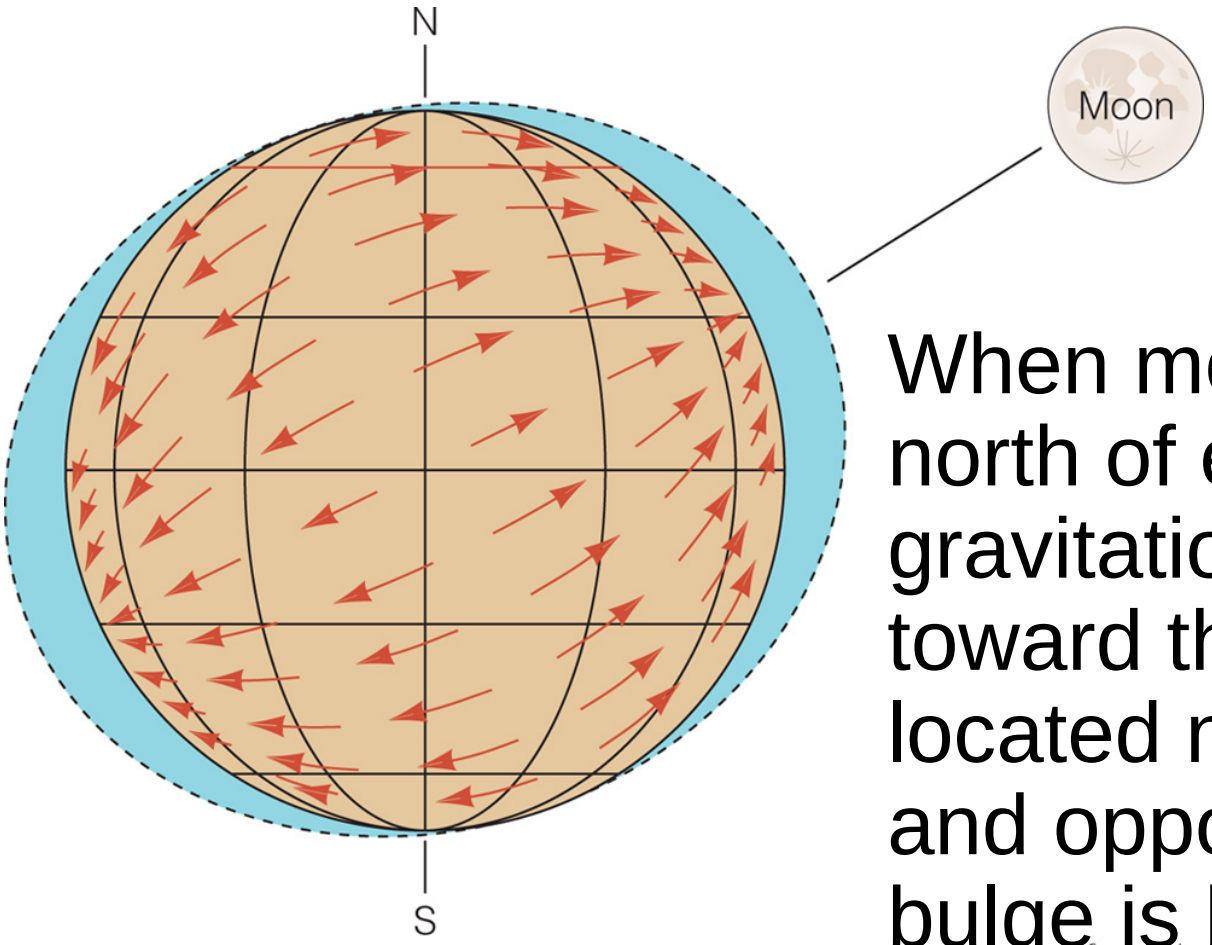




Stepped Art

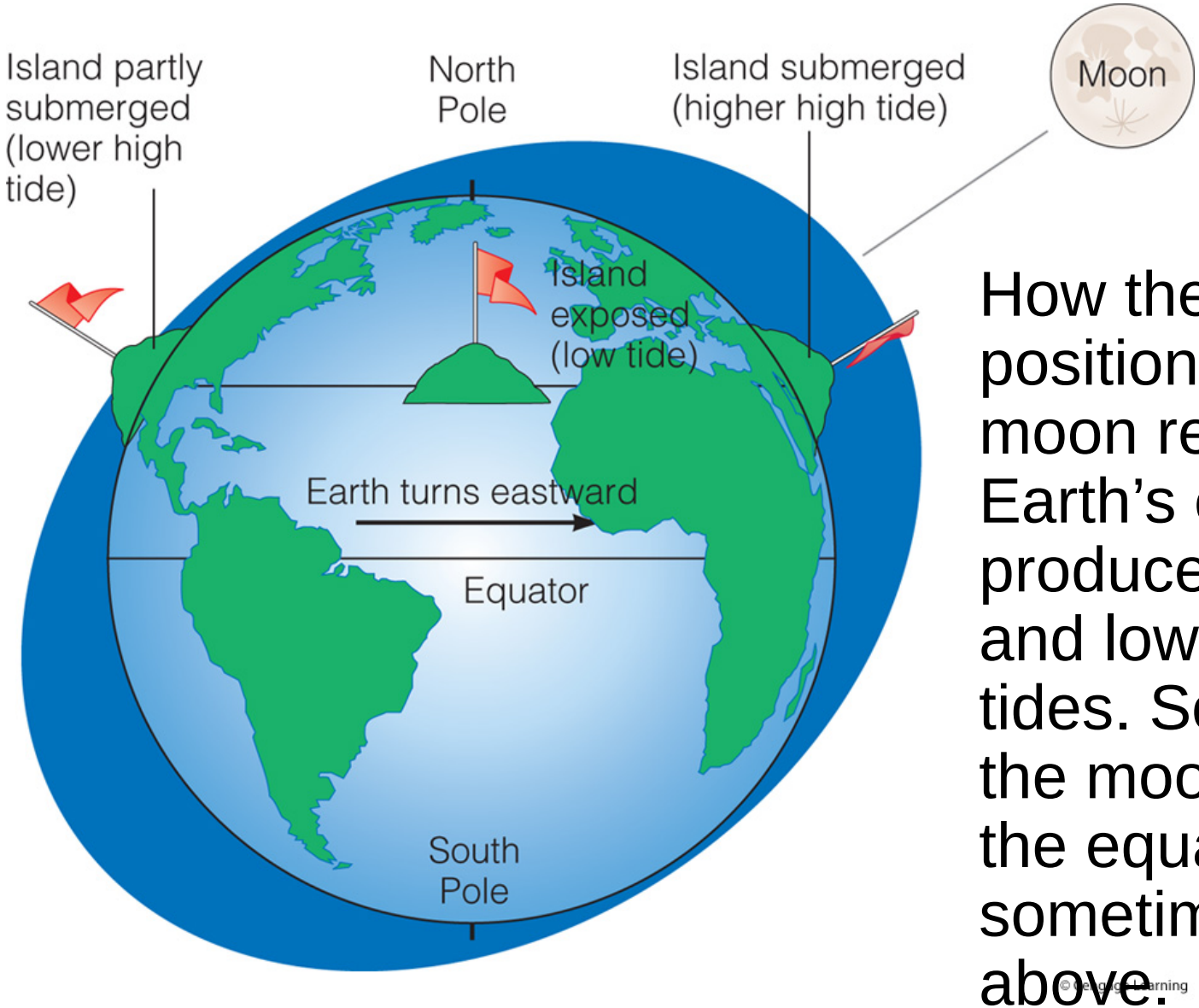
Figure 11-8 p336

Tides Bulges Follow the Moon



When moon's position is north of equator, gravitational bulge toward the moon is also located north of equator and opposite inertia bulge is below the equator.

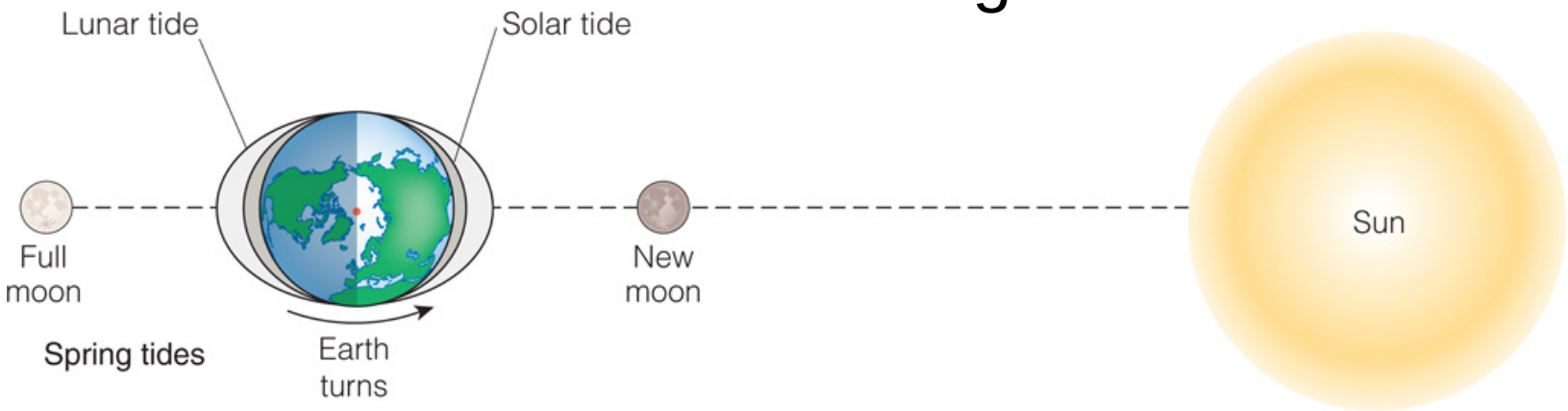
High and Low Tides



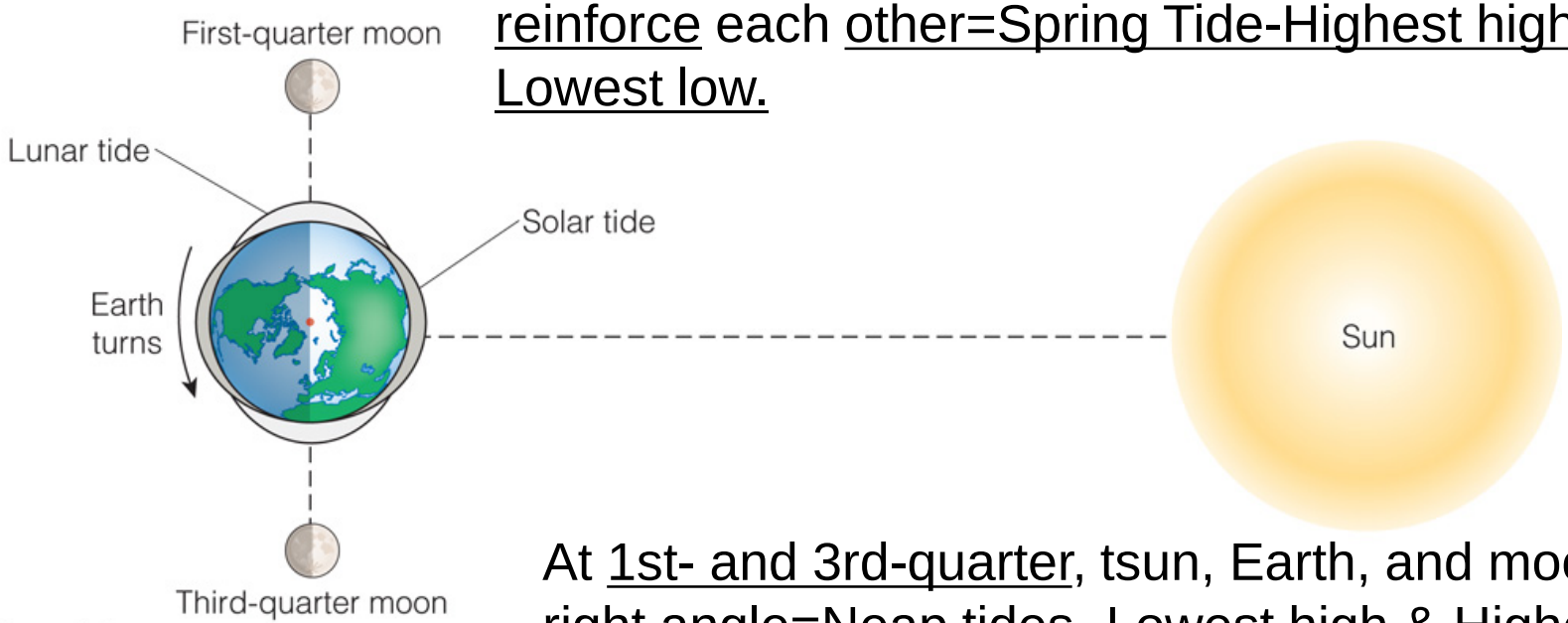
How the changing position of the moon relative to Earth's equator produces higher and lower high tides. Sometimes the moon is below the equator, and sometimes it is above.

Sun and Moon Influence Tides Together

- The sun also generates tractive forces

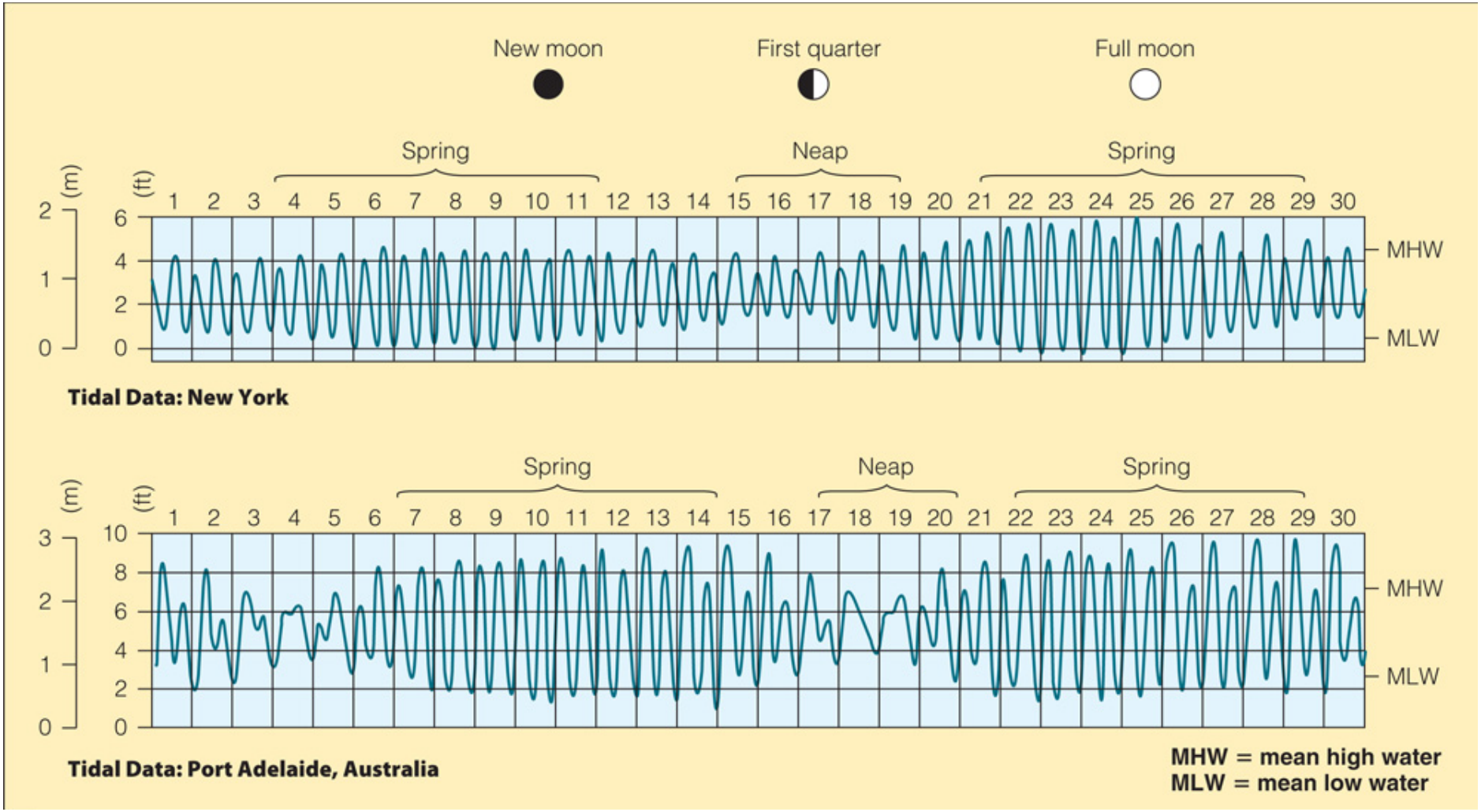


At new and full moons, the solar and lunar tides reinforce each other=Spring Tide-Highest high & Lowest low.



At 1st- and 3rd-quarter, tsun, Earth, and moon form right angle=Neap tides- Lowest high & Highest low.

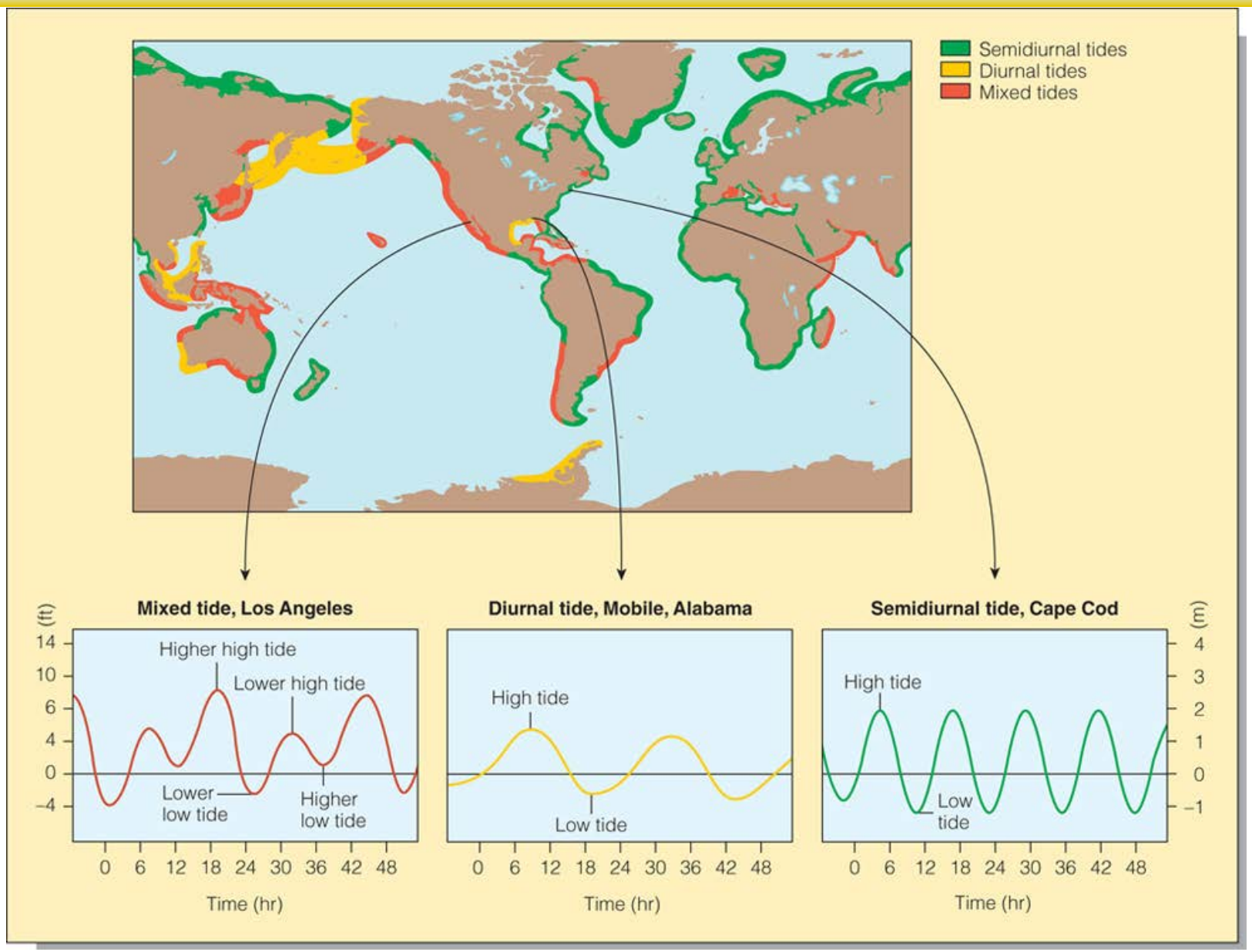
Spring Tides and Neap Tides



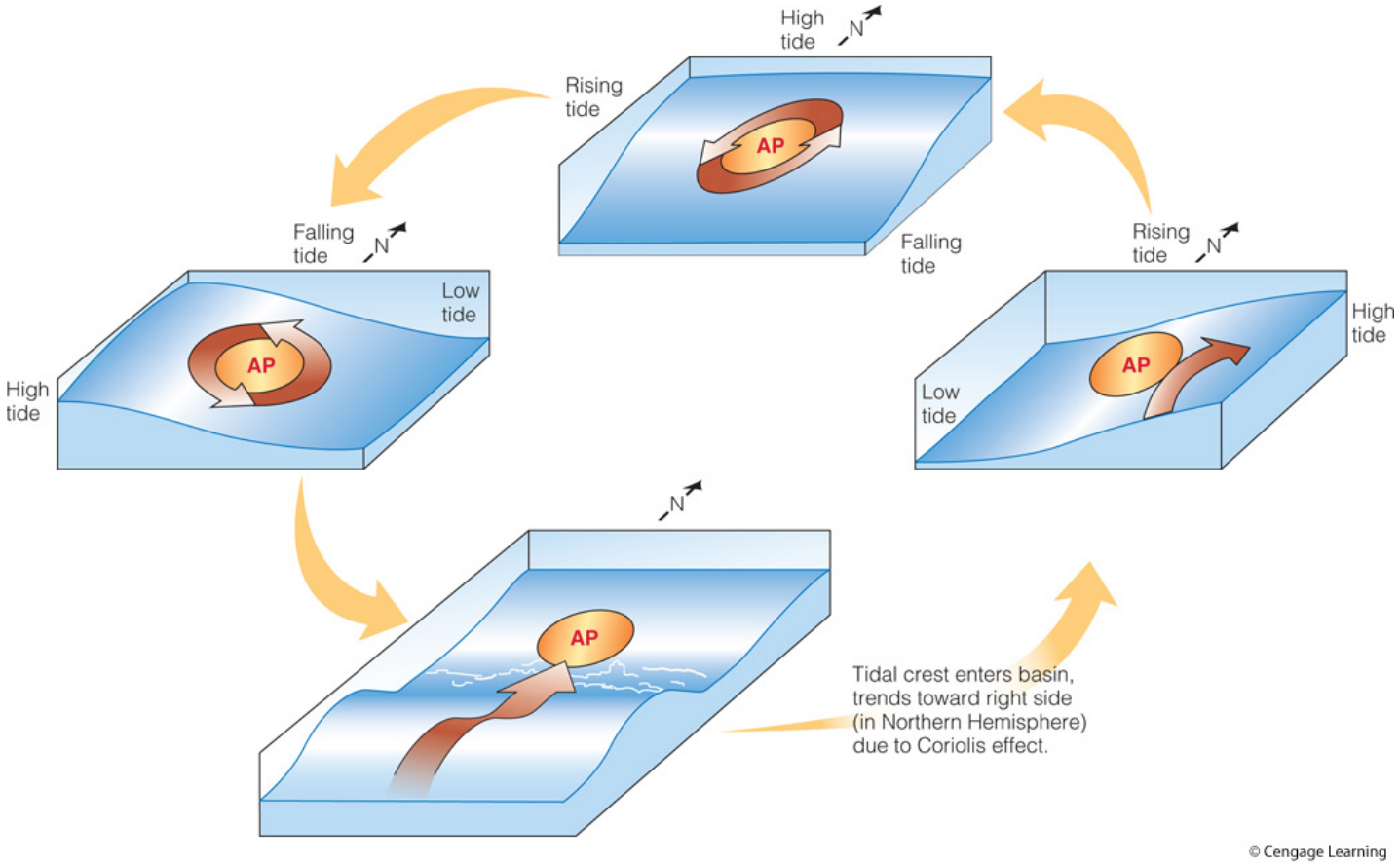
Dynamic Theory of Tides Adds Fluid Motion Dynamics

- Dynamic theory – adds charachteristics of fluid motion to celestial mechanics to the equilibrium theory
- Common tidal patterns
  - Semidiurnal tides – occur twice in a lunar day
  - Diurnal tides – occur once in a lunar day
  - Mixed tides-describe a tidal pattern of significantly different heights through the cycle
- Amphidromic point – nodes at center of basin
  - No tides

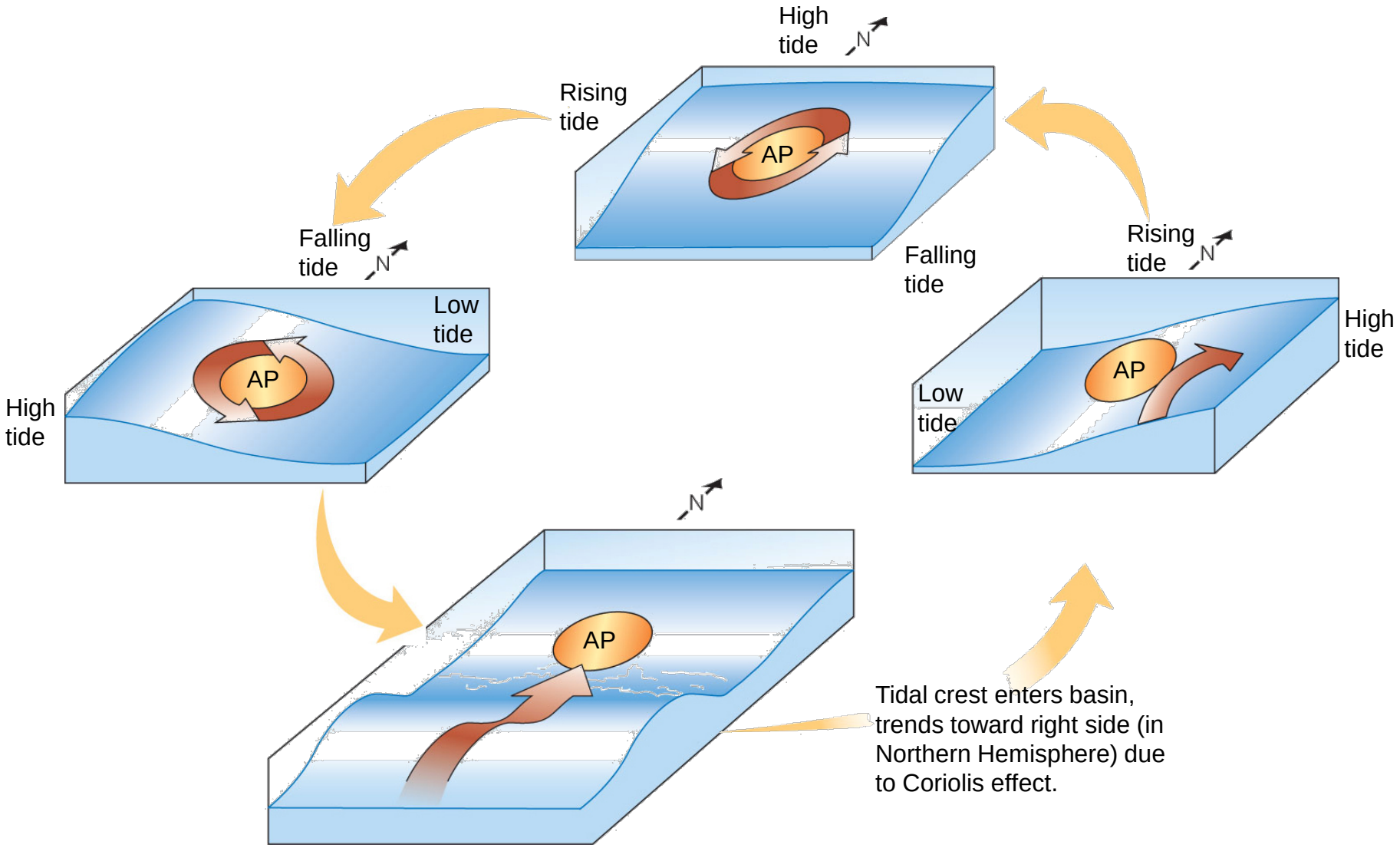
Tide Curves For Three Common Types of Tides



Development of Amphidromic Circulation



(a) Tide wave crest enters ocean basin in Northern Hemisphere and trends to the right because of Coriolis effect (b), causing high tide on basin's eastern shore. Unable to continue turning right because of interference of the shore, the crest moves northward, following the shoreline (c) and causes a high tide on the basin's northern shore. The wave continues its progress around the basin in a counterclockwise direction (d), forming a high tide on the western shore and completing the circuit. The point around which the crest moves is an amphidromic point (AP).

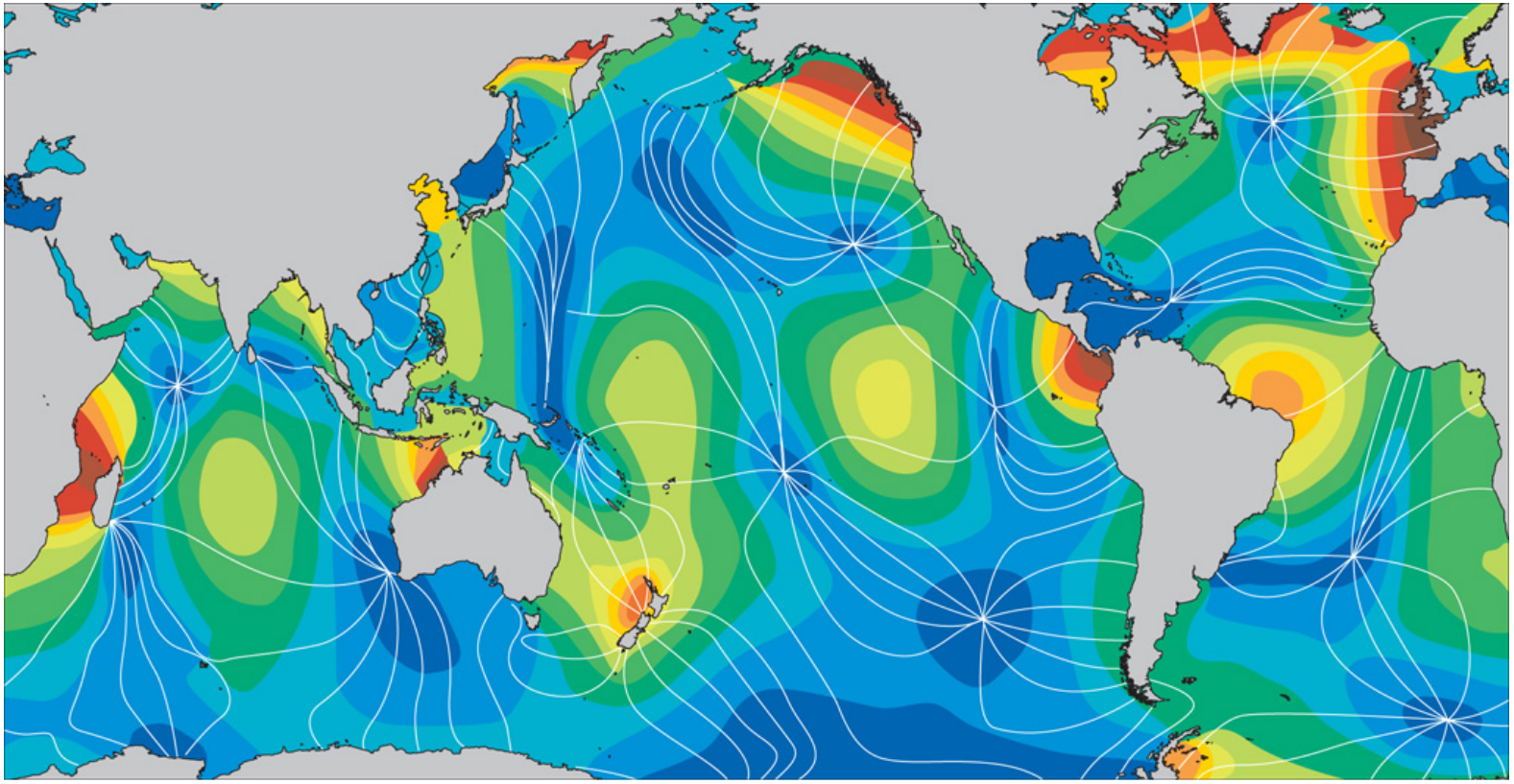


Stepped Art

Figure 11-14 p341

Amphidromic Points in the World Ocean

- Tidal ranges increase with distance from amphidromic points

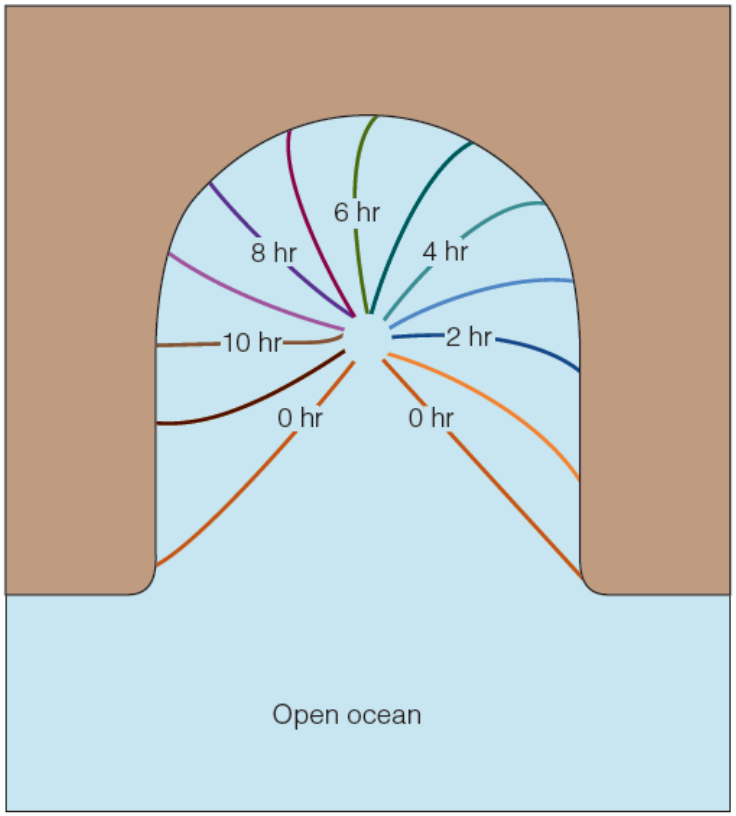


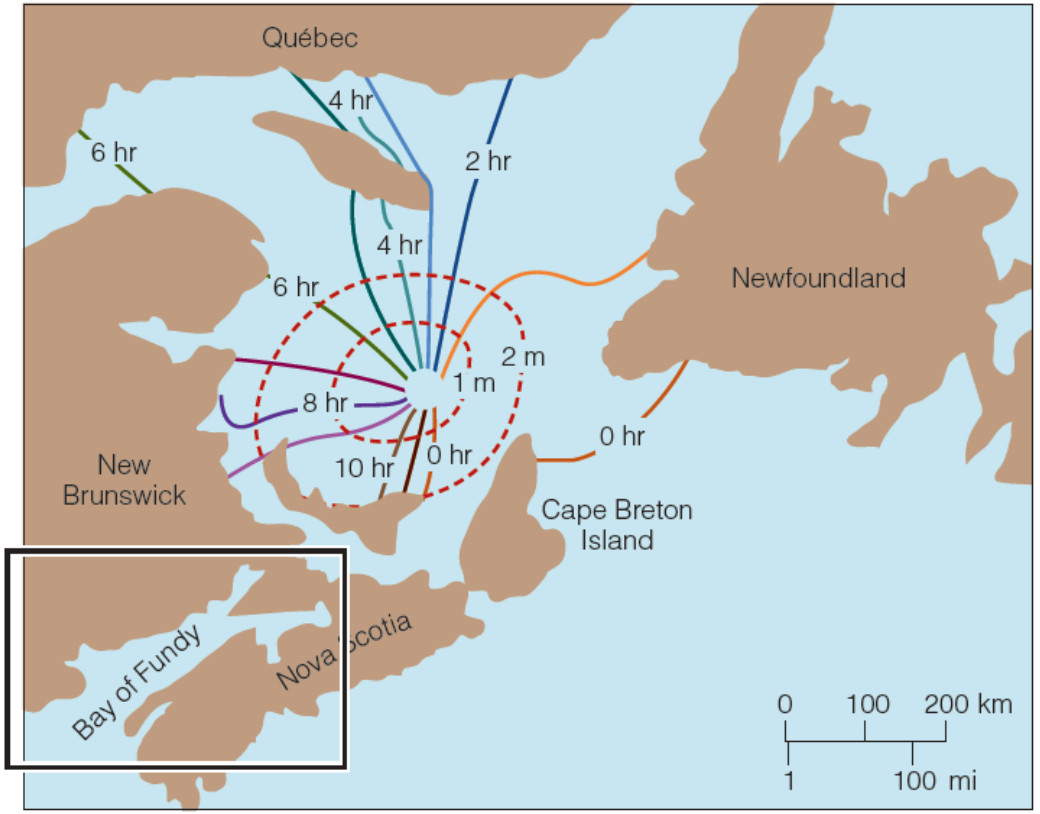
Tidal Datum, Range, and Bore

- Tidal datum – reference point for tidal height
  - Not always mean sea level
- Tidal range – high- to low-water height difference
  - Differs with basin configuration
- Tidal bore (wave) – steep wave moving upstream at some inlets

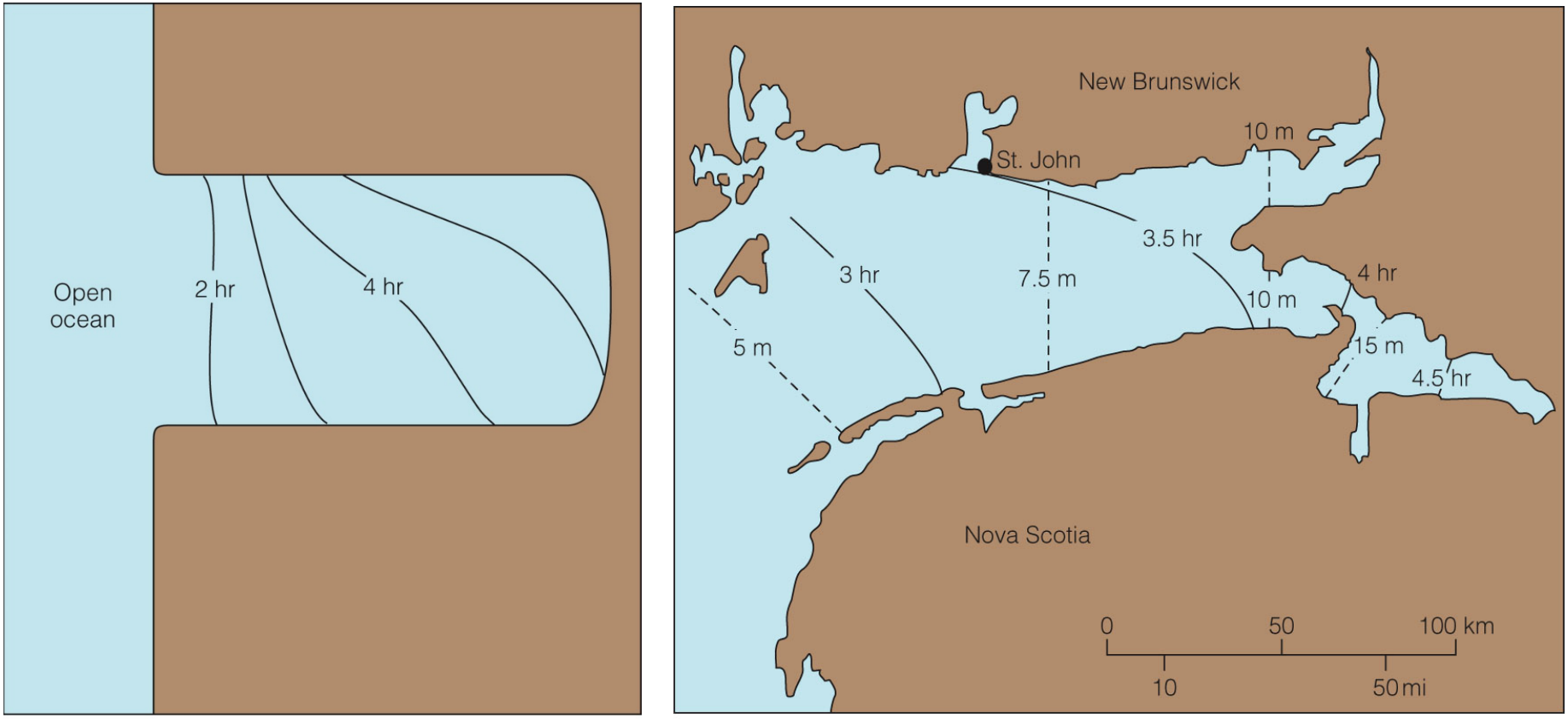
Tidal range is determined by basin configuration

Imaginary amphidromic system in a broad, shallow basin. The numbers indicate the hourly positions of tide crests as a cycle progresses.
Amphidromic system for Gulf of St. Lawrence. Dashed lines show the tide heights when the tide crest is passing.





Tides in a narrow basin



True amphidromic systems do not develop in narrow basins because there is no space for rotation. (b) Tides in the Bay of Fundy, Nova Scotia, are extreme because water in the bay naturally resonates (seiche) at the same frequency as the lunar tide.

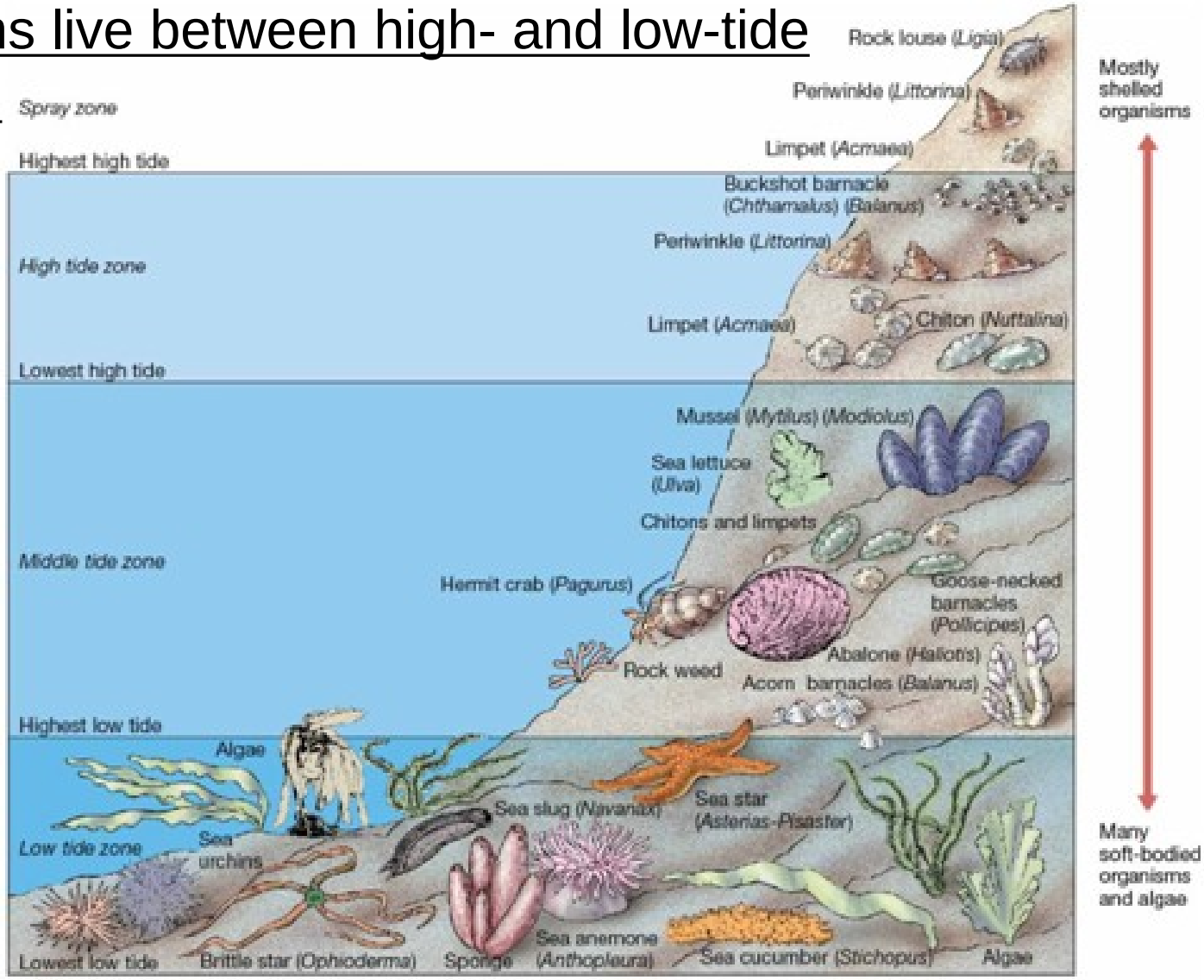
Most Tides Can Be Accurately Predicted

- Meteorological tides
  - Weather related alterations to tides
  - Storm surge
  - Tsunami
  - Strong on-shore wind

Tidal Patterns Can Affect Marine Organisms

Some organisms live between high- and low-tide (intertidal zone)

- Sorted into sub-zones within the intertidal zone

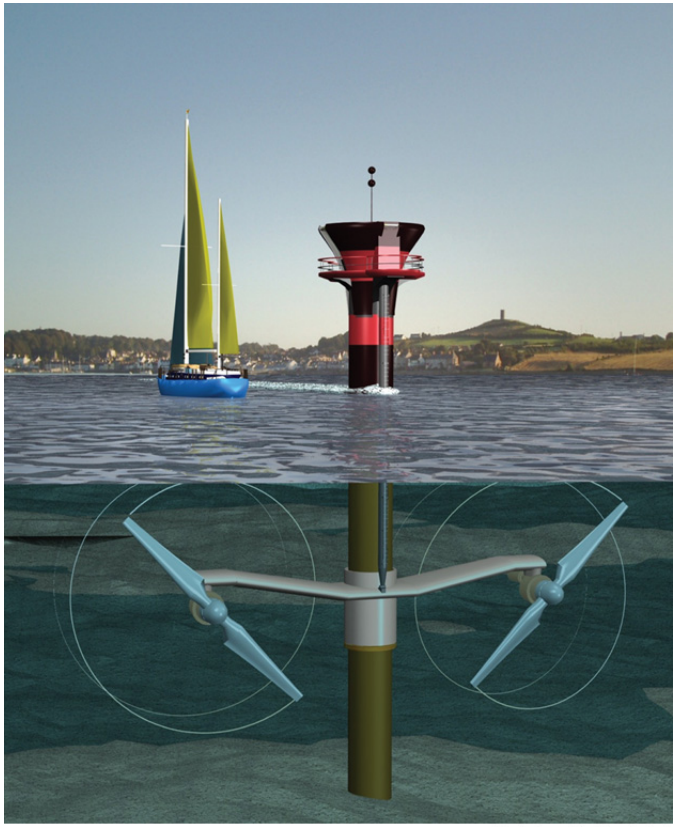


Power Can Be Extracted From Tidal Motion

Tidal currents are being exploited to provide electrical power.

- First major tidal power station – France 1966
- New technologies

Courtesy of Marine Current Turbines Limited



Marine Current Turbines Limited

Chapter in Perspective

- Tides have the longest wavelength of Earth's ocean waves
- Cause by combination of gravitational forces, Earth's motion, fluid motion
- Basin resonances cause different tidal patterns at different coasts
- Tides can be used to generate electrical power