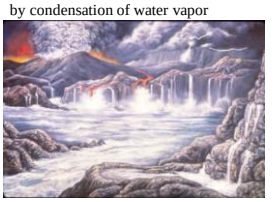
Earth's Changing Landscape Systems

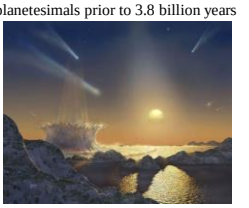
The Oceans, Coastal Processes, and Landforms

Origin Of The Oceans

Outgassing of Earth's interior followed by condensation of water vapor

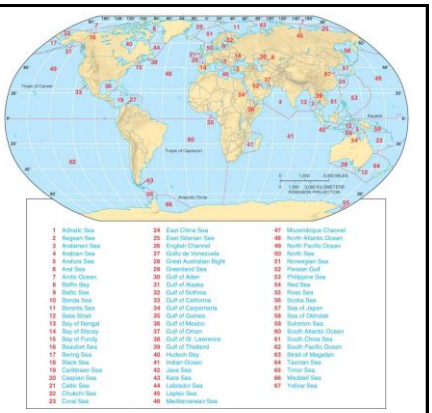


Bombardment of Earth by icy planetesimals prior to 3.8 billion years

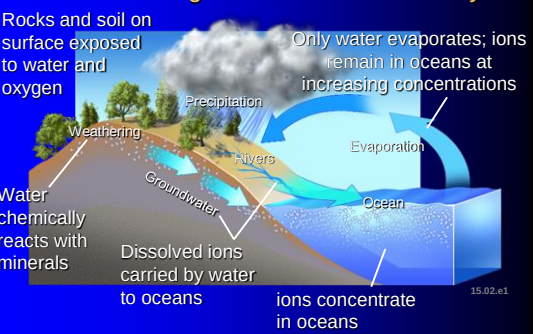


Oxygen isotopes in ancient zircons suggest that water was already present on Earth's surface by ~ 4.3 billion years ago

Principal Oceans And Seas Of The World



How Weathering Makes the Oceans Salty

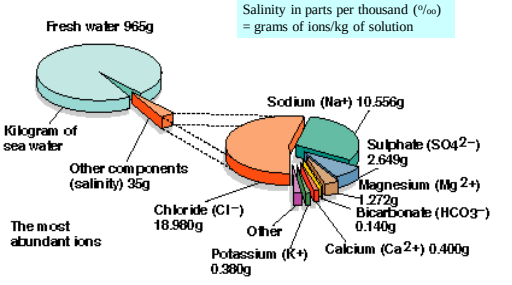


Major Constituents of Seawater

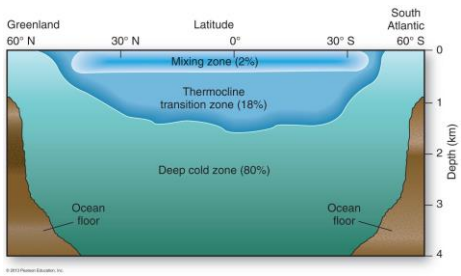
- **Oceans:**
  - **Water H_2O (96.5%)**
  - **Sodium Na^+ (1.1%)**
  - **Chloride Cl^- (1.9%)**
  - **Magnesium Mg^{2+} (0.1%)**
  - **Sulfate SO_4^{2-} (0.3%)**
  - **Calcium Ca^{2+} (0.04%)**
  - **Bicarbonate HCO_3^- (0.01%)**

Common Ions in Sea Water

Salinity in parts per thousand (‰) = grams of ions/kg of solution

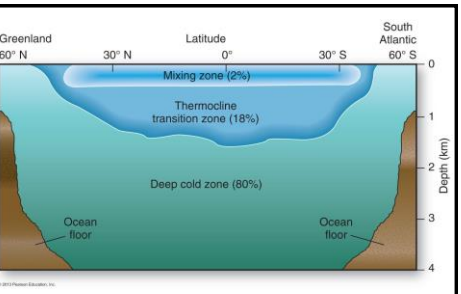


Layers Of The Oceans



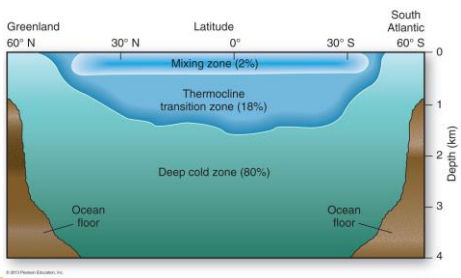
- Mixing zone (Surface layer):
  - Warmed by the Sun
  - Currents are wind driven
  - Variations in temperature and solutes are blended rapidly in a mixing zone

Layers Of The Oceans



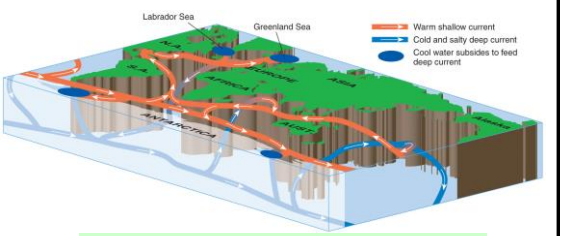
- Thermocline transition zone:
  - Lacks motions of surface water
  - Temperature decreases with depth

Layers Of The Oceans



- Deep cold zone:
  - Begins at depths of 1km - 1.5km below the surface and extends down to the ocean floor
  - Water temperatures near 0ºC, but higher salinity prevents freezing
  - Temperature and salinity values uniform

Thermohaline Circulation Of The Oceans

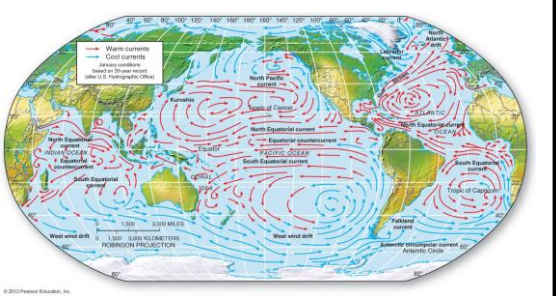


Thermohaline circulation driven by differences in temperature and salinity of ocean water

Surface Waters

- **Surface ocean layer is in direct contact with the atmosphere and warmed by Sun's energy**
- **Temperatures vary with latitude and seasons**
- **Surface layer moves horizontally by wind and wave action:**
  - **Coriolis force deflects currents and creates gyres**

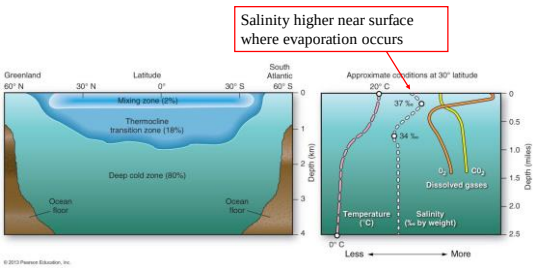
Surface Ocean Currents



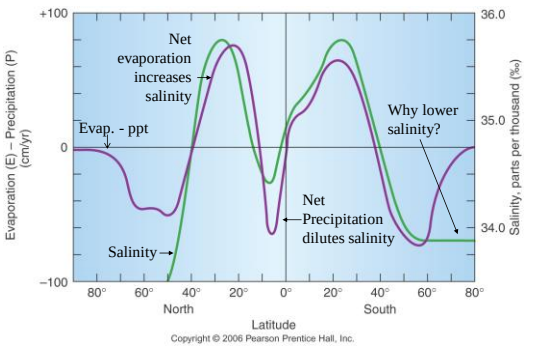
Ocean Salinity

- **Salinity in oceans and seas vary between 34 and 37 parts per thousand**
- **Variations attributable to:**
  - **Atmospheric conditions**
  - **Precipitation and volume of freshwater inflows:**
    - **Equatorial waters: Salinity diluted due to abundant ppt**
    - **High-latitude oceans diluted by meltwater from glaciers and ice**
  - **Rates of evaporation:**
    - **Subtropical oceans have high evaporation rates, increasing salinity**

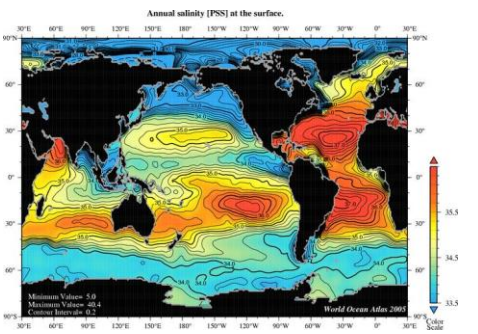
Ocean's Physical Structure



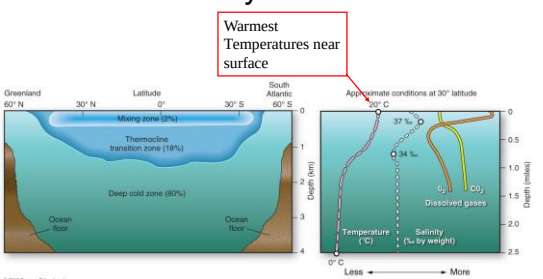
Salinity By Latitude



Annual Salinity Of Ocean Surface Water

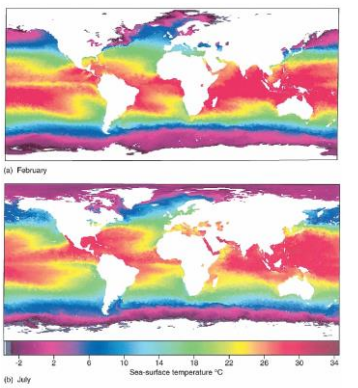


Ocean's Physical Structure



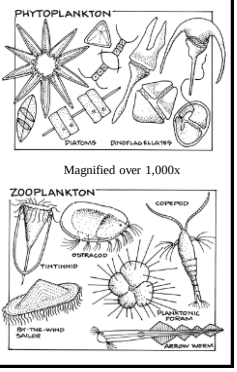
Average Annual Sea-surface Temperatures Vary By Latitude

Pathfinder AVHRR satellite image data



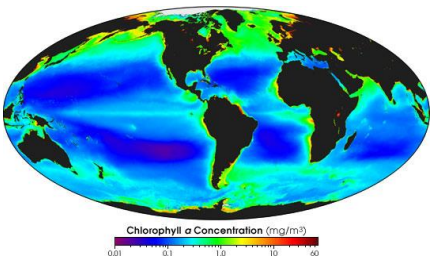
Inhabitants Of The Surface Layer

- Phytoplankton and zooplankton are microscopic organisms that inhabit the surface ocean layer within the euphotic (sunlit) zone
- Phytoplankton (typically diatoms):
  - Photosynthetic; take in CO_2 and release O_2
  - Primary producers in the oceanic food chain
  - Give green discoloration to water due to the presence of chlorophyll
- Zooplankton (foraminiferans and radiolarians) are microscopic organisms that feed on phytoplankton



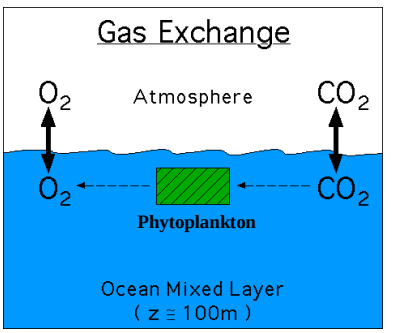
Magnified over 1,000x

Chlorophyll In The Oceans

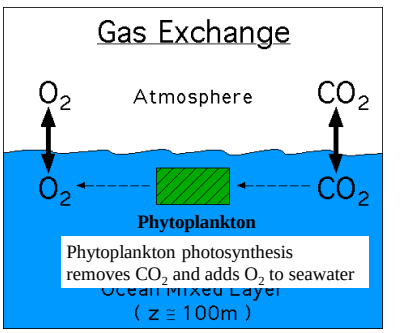


SeaWiFS satellite image from NASA

Surface Ocean Layer Exchanges Oxygen And Carbon-dioxide With Atmosphere

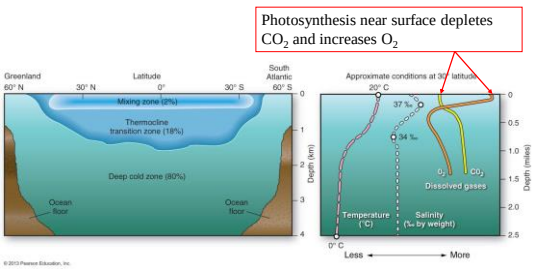


Surface Ocean Layer Exchanges Oxygen And Carbon-dioxide With Atmosphere

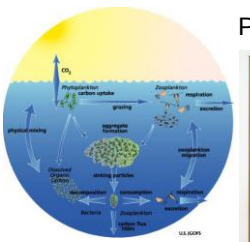


Ocean's Physical Structure

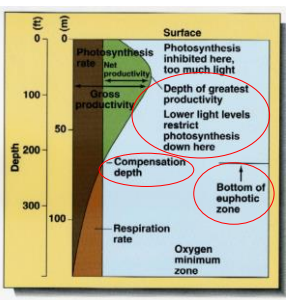
Photosynthesis near surface depletes CO_2 and increases O_2



Phytoplankton And Photosynthesis In Oceans

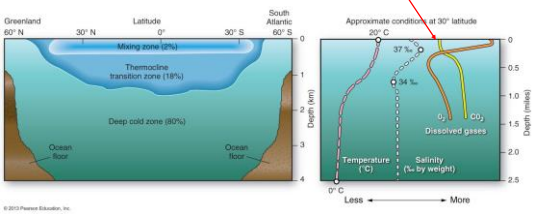


Base of the euphotic (sunlit) zone, below which calcium carbonate dissolves



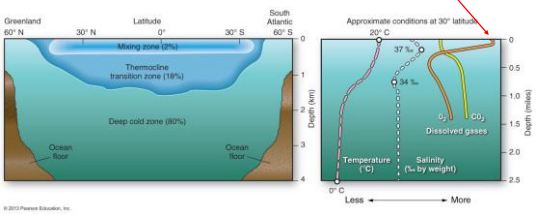
Ocean's Physical Structure

Dissolved CO_2 increases at depth due to reduction of photosynthesis and greater dissolution of carbonate



Ocean's Physical Structure

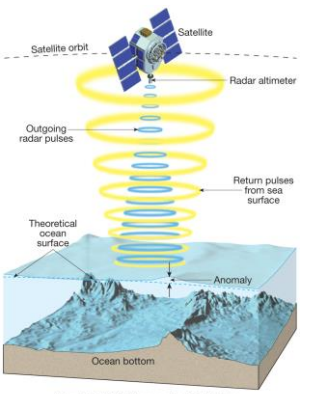
Dissolved O_2 highest near surface and decreases with depth



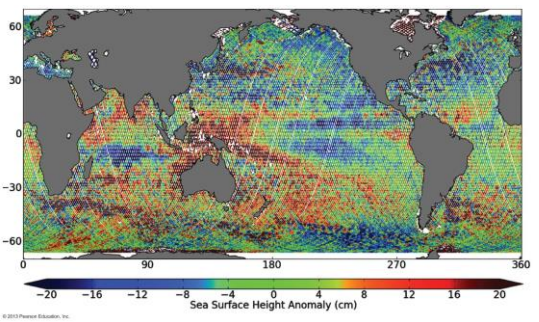
Sea Level

- **Sea level is not a smooth, flat surface but rather is distorted due to several forces:**
  - **Wind**
  - **Tides**
  - **Effects of sea floor bathymetry on local gravity**
- **Sea level is also changed by:**
  - **Water balance in reservoirs (ice caps)**
  - **Shape of ocean basins**

Satellite Radar Altimeter Measures Variations In Sea Surface Elevations



Sea Surface Heights Relative To Earth's Geoid As Recorded By Radar Altimeter

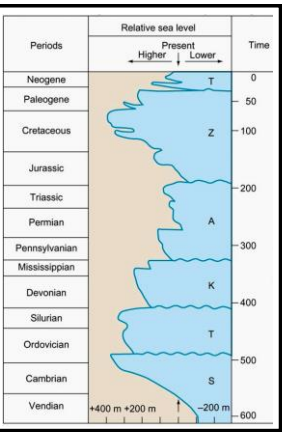


Global Sea Level Changes

Sea Level Has Risen and Fallen on a Global Scale Many Times Over the Last 600 Million Years of Earth History

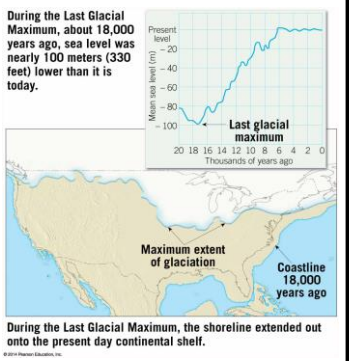
Factors That Affect Sea Level Changes

- Glacial/interglacial cycles (tens of thousands of years)
- Assembly and breakup of supercontinents (tens of millions of years)
- Mountain-building events along continental margins (millions of years)
- Enlargement and shrinking of mid-ocean ridges (millions of years)



Sea Level and Ice Ages

- During Ice Ages, water is removed from oceans and stored on land as glacial ice, causing sea level to drop:
  - During peak of last ice age ~18,000 years ago, sea level was 100m (330ft) lower than today
- When Ice Age ends, continental glaciers melt and water is returned to oceans, causing sea level to rise

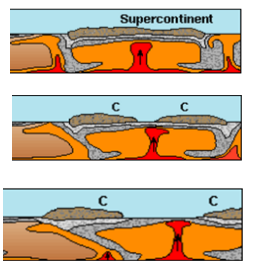


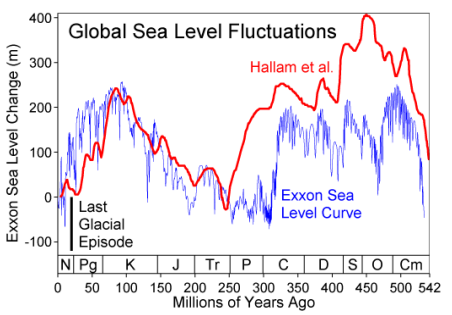
Sea Level And Supercontinents

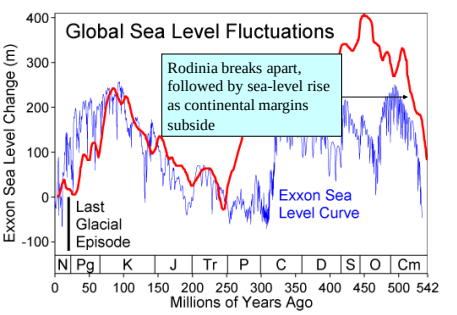
- **Two supercontinents over the last 600 million years:**
  - **Rodinia (~1000 m.y. ago)**
  - **Pangaea (~230 m.y. ago)**
- **Supercontinents would assemble, break apart, and reassemble again over time periods of hundreds of millions of years:**
  - **This has a profound effect on sea level changes**

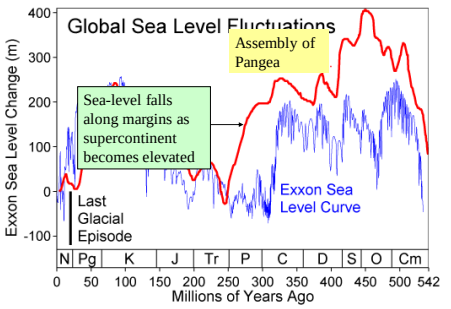
Sea Level And Supercontinents

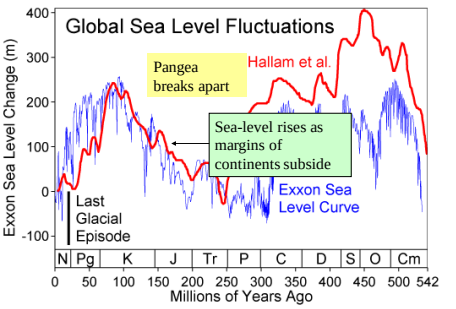
- When continents are assembled into supercontinent:
  - Insulation of supercontinent traps mantle heat below
  - Supercontinent becomes elevated
  - Sea level drops along continental margins
- When supercontinent breaks apart:
  - Margins of continents subside
  - Sea level rises along coastlines

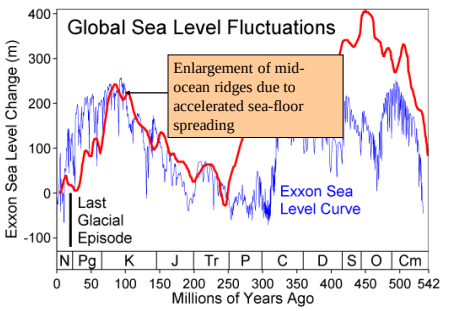


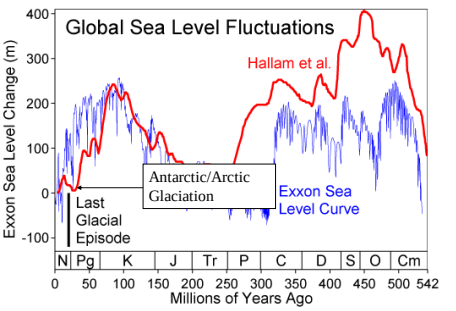












Recent Sea-level Rise

- **Remote Sensing by the Jason-1 and Jason-2 satellites track changing sea-level using radar altimetry**
- **Data indicate there was a rise in global MSL of 4.5 cm (1.7 inches) from 1993 – 2008. Rise attributed to two factors:**
  - **Thermal expansion of seawater due to higher temperatures**
  - **Melting of glacial ice and ice sheets**
- **Scientists estimate that sea-level will rise 1.0 – 1.4 m by the end of this century**

Coastal Inundation with a 1-m Sea-Level Rise

Coastal Inundation with a 1-m Sea-Level Rise

Coastal Inundation with a 1-m Sea-Level Rise

Coastal System Components

- Most of Earth's coastlines are relatively new and constantly changing
- Coasts are sites of interactions among land, ocean, and atmosphere
- These interactions are in the form of tides, currents, and waves
- Interactions result in erosional and depositional features along continental margins
- Rising sea-level will enhance these coastal interactions and lead to significant changes

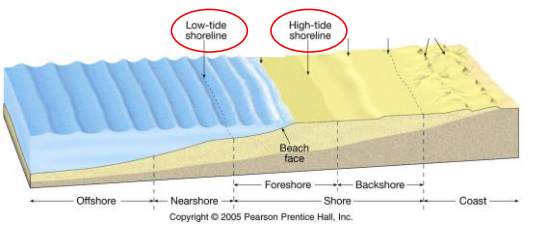
Inputs To The Coastal Environment

- **Solar energy:**
  - Drives the atmosphere and hydrosphere
- **Atmospheric winds:**
  - Generate ocean currents and waves
- **Climatic regimes:**
  - Strongly influence coastal geomorphic processes
- **Nature of coastal rock:**
  - Determines rates of erosion and sediment production
- **Human activities:**
  - Disrupt natural processes

Coastal System Actions

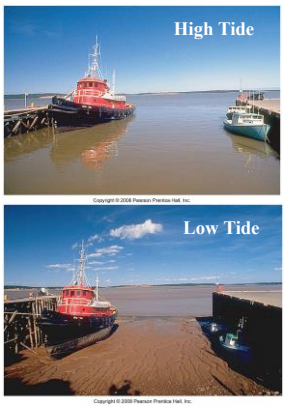
- Tides
- Waves

Tides Rise and Fall Twice Daily Along Most Shorelines



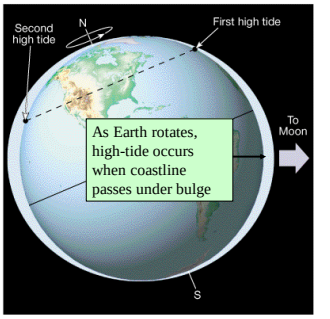
Tidal Bulges

- Tides are the daily rise and fall of ocean waters
- Caused by gravitational attraction of the Moon, and to a lesser extent the Sun, on the Earth:
  - Side of the Earth facing the Moon experiences greater gravitational pull, causing a bulge in the ocean surface
  - On far side, ocean water is pulled less strongly, causing a second bulge



Tides Result From The Moon's Gravitational Pull On The Earth

Tidal bulges on opposite sides of Earth



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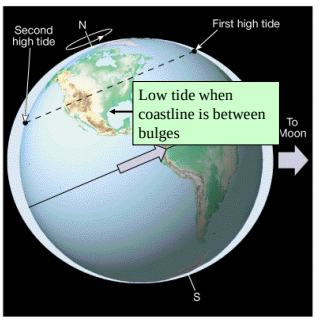

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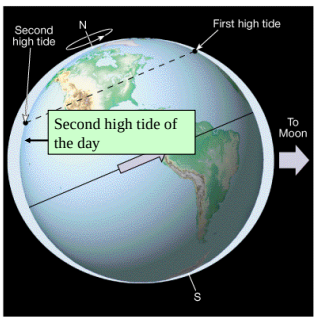
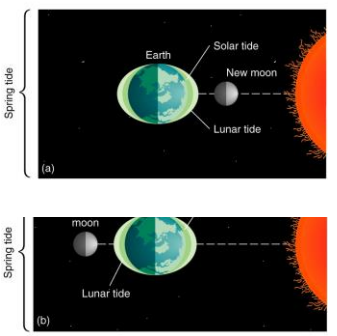


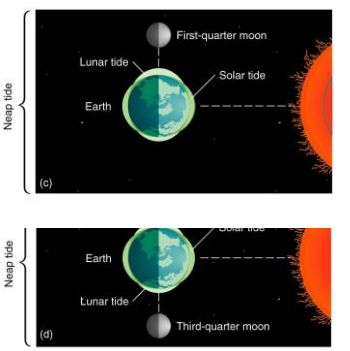
High Tides Are Highest During Spring Tides When Earth, Moon And Sun Are Aligned; This Occurs Approximately Twice A Month

Solar tide (bulge) adds to the lunar tide (bulge); Resulting composite bulge produces the highest tides



High Tides Are Lowest During Neap Tides When The Moon And Sun Are At Right Angles To Earth; This Also Occurs Approximately Twice A Month

Solar tide (bulge) is separate from lunar tide (bulge), diminishing the height of high tide



Tidal Cycle