Courtesy Hubbard Brook Experimental Forest

4 Ecosystems and the Physical Environment

Overview of Chapter 4

- Cycling of Materials within Ecosystems
- Solar Radiation
- The Atmosphere
- The Global Ocean
- Weather and Climate
- Internal Planetary Processes

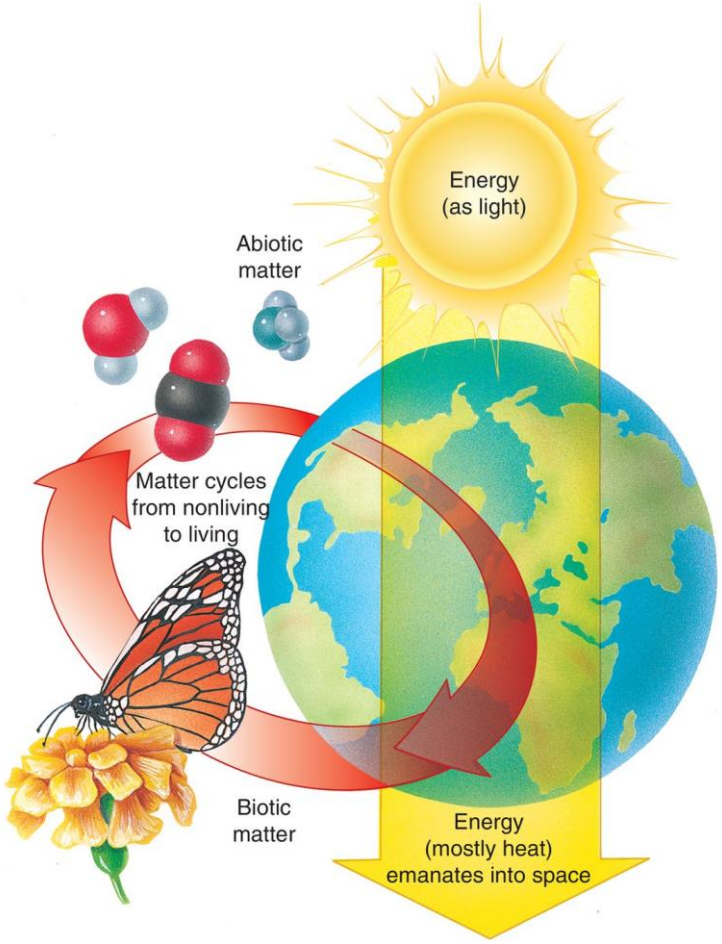
Hubbard Brook Experimental Forest

- Experimental area in White Mountains, 1950s
- Long-term ecological data
  - Data on salamanders since 1970
  - Effects of deforestation
    - Measured chemistry of stream water after forest was logged and compared to control catchment (unlogged)

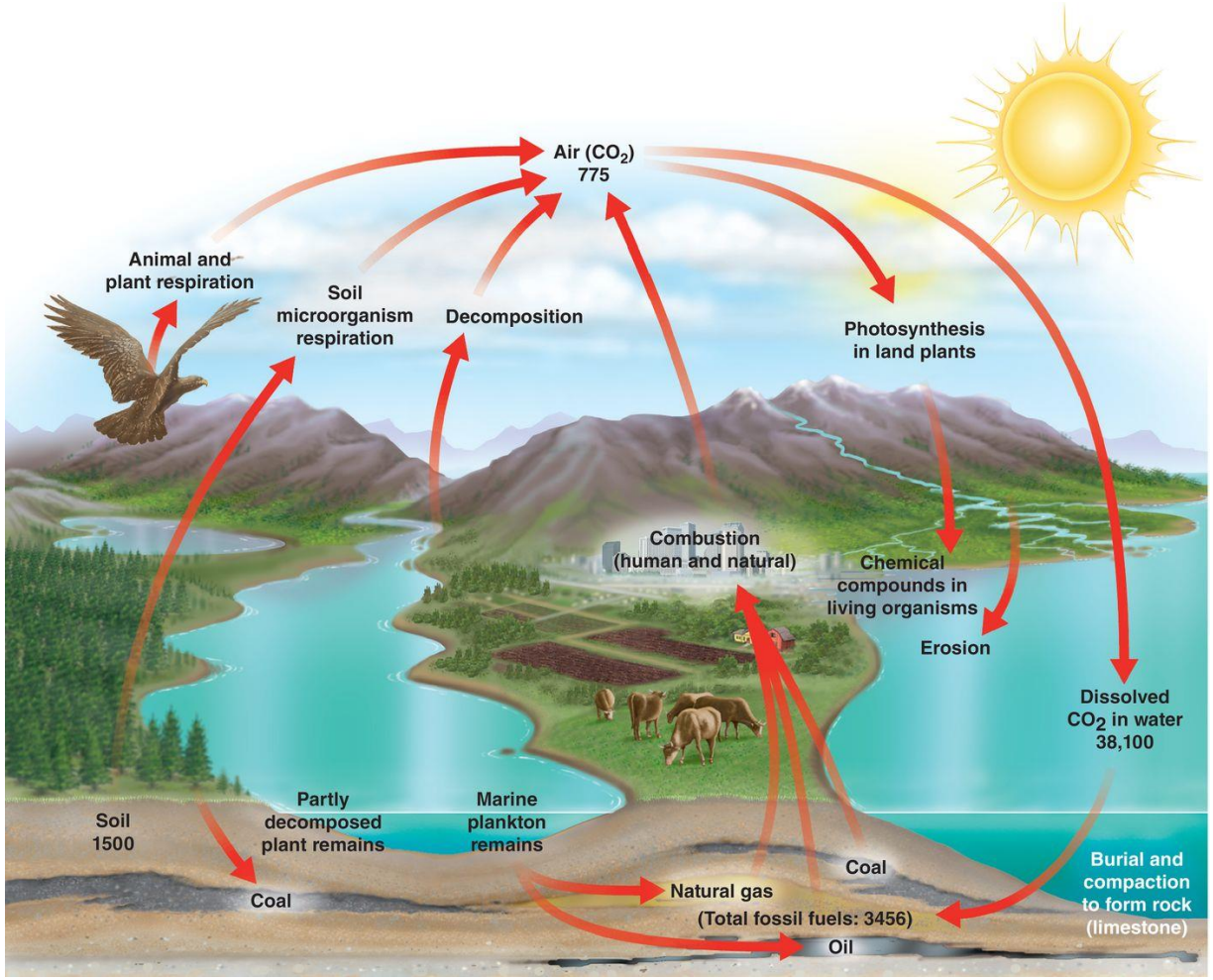
Courtesy Hubbard Brook Experimental Forest

Cycling of Materials

- Matter moves among organisms, ecosystems, and the abiotic environment
- Biogeochemical cycling
  - Interactions between biological, geological, and chemical aspects of environment
- Five major cycles:
  - Carbon, Nitrogen, Phosphorus, Sulfur, and Water (Hydrologic)

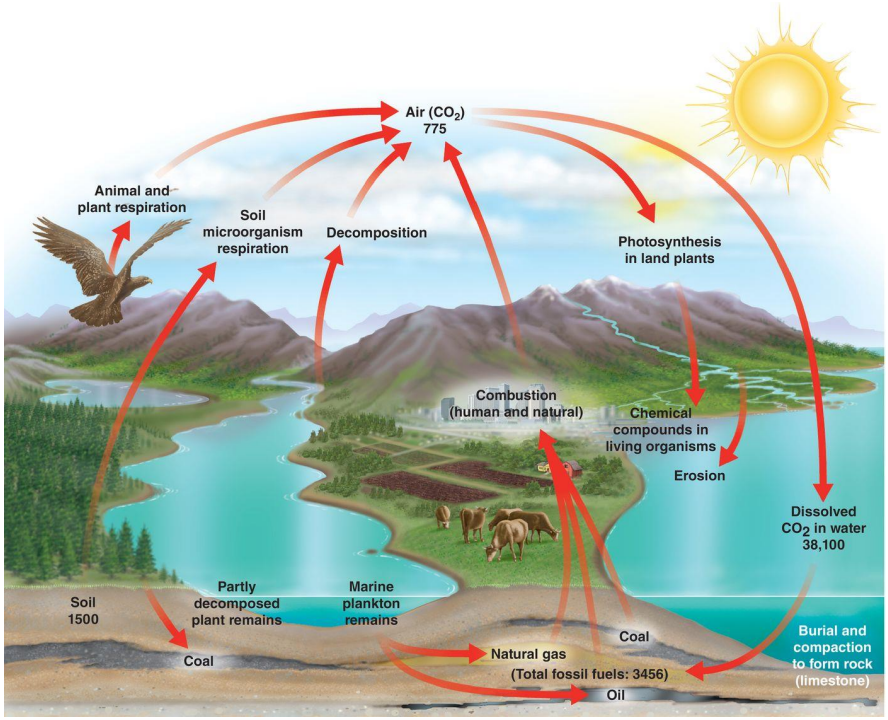


The Carbon (C) Cycle



The Carbon (C) Cycle

- Global circulation of C between living and non-living environment
- Major processes
  - Photosynthesis
  - Respiration
    - Soil, in particular
  - Combustion of fossil fuels
  - CO_2 dissolving into ocean

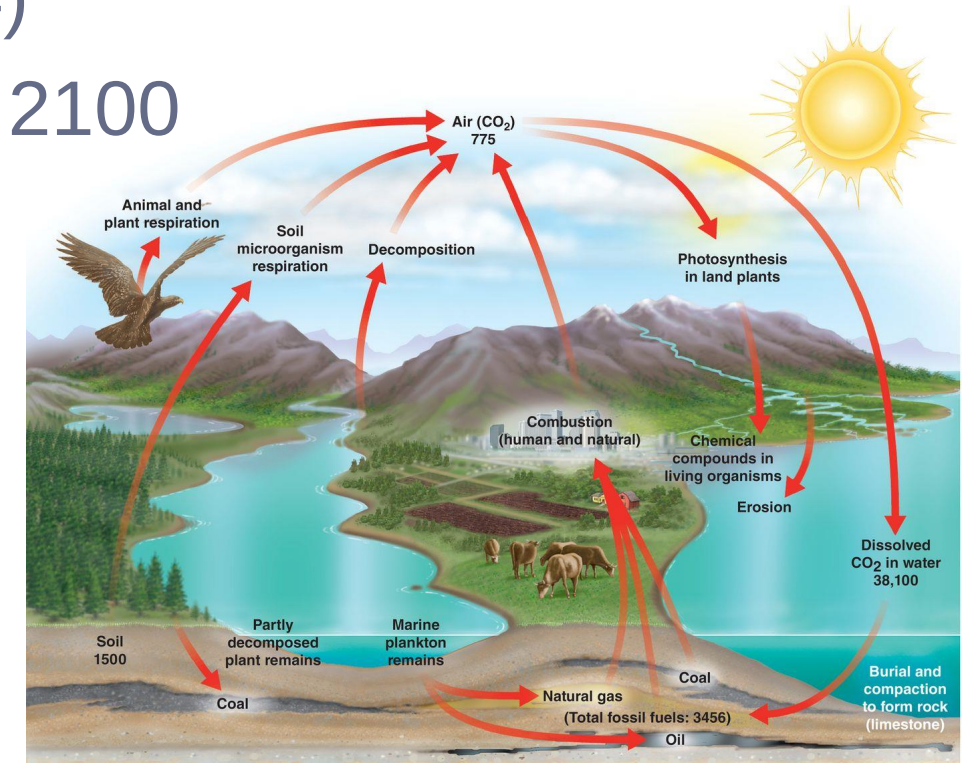


The Carbon-Silicate Cycle

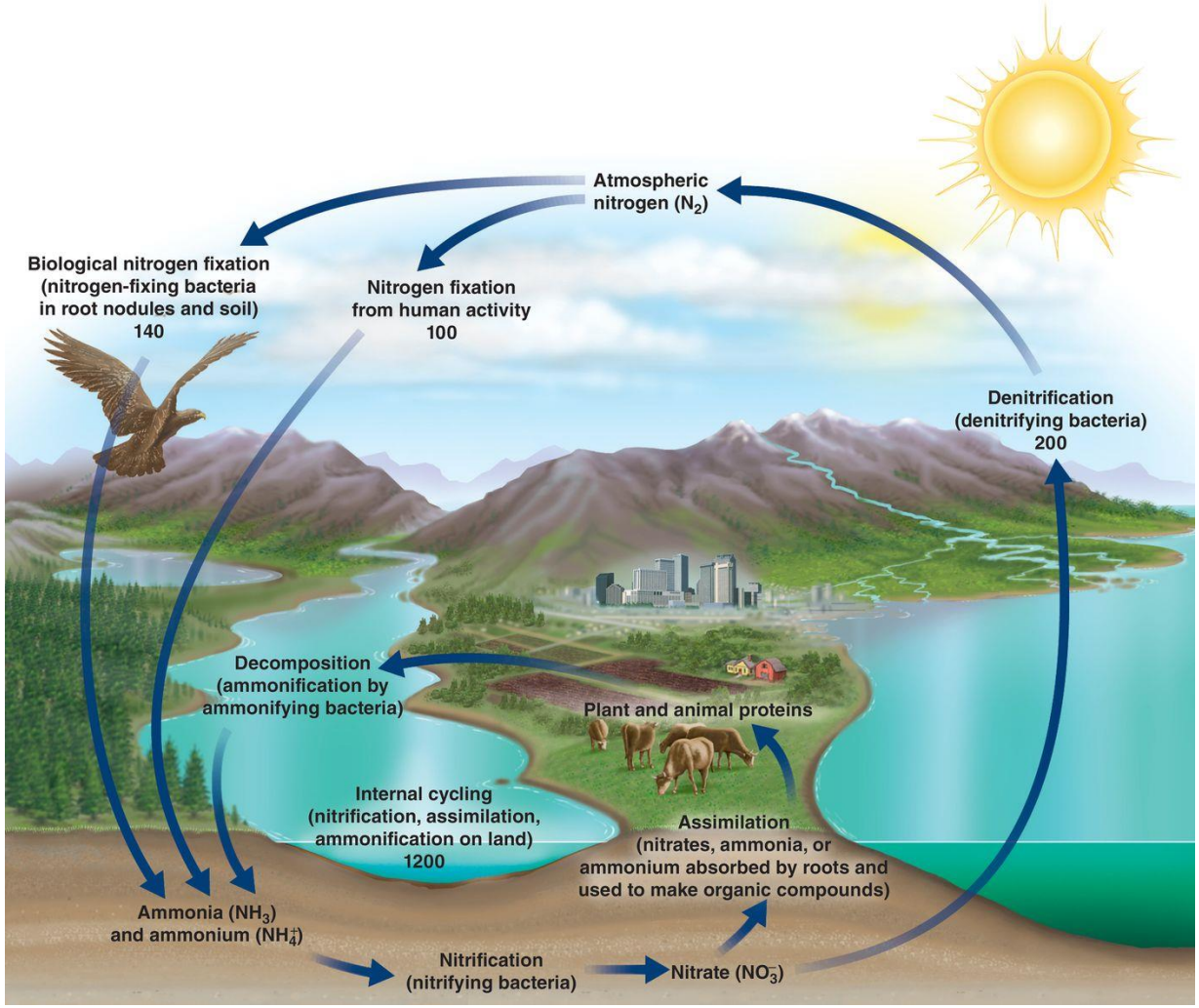
- Over millions of years, C will interact with silicate cycle
- CO_2 with rainwater becomes H_2CO_3 and will slowly weather silicate rich rocks
  - Calcium minerals also released
- Ocean organisms use Ca^{2+} and Si^{4+} to form shells
- When die, shells become buried and over time formed into limestone
- Geologic uplift or subduction

Human Affects on C Cycle

- CO_2 was 0.029% of atmosphere (1700s)
- CO_2 is 0.04% (2014)
- Expected 0.06% by 2100
- Higher CO_2 creates lots of feedbacks in environment
  - > CO_2 dissolved in ocean

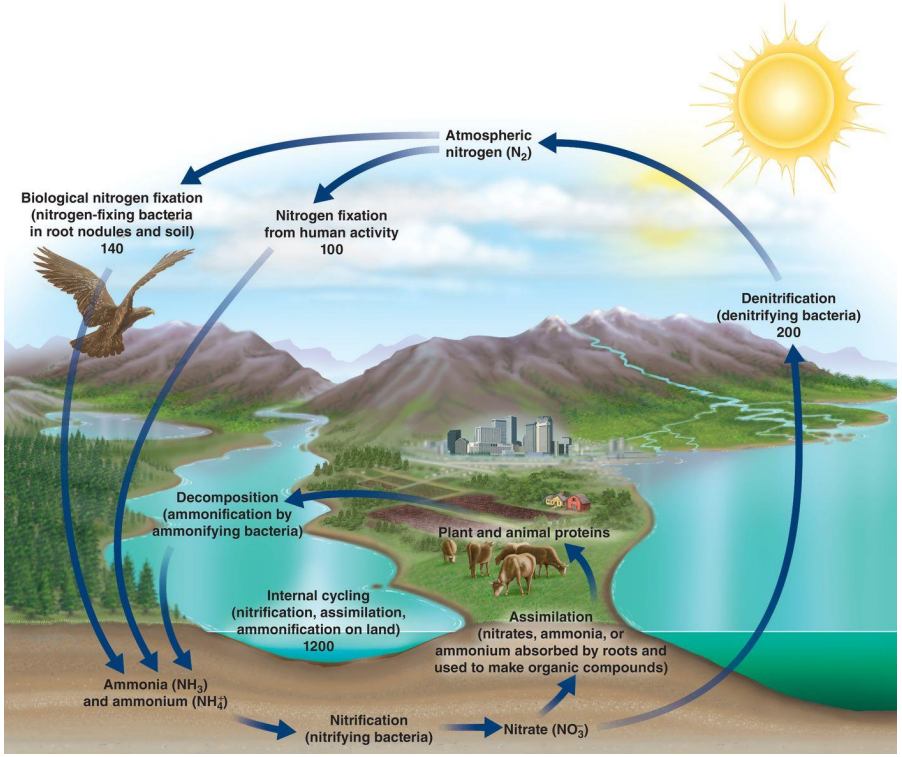


The Nitrogen (N) Cycle



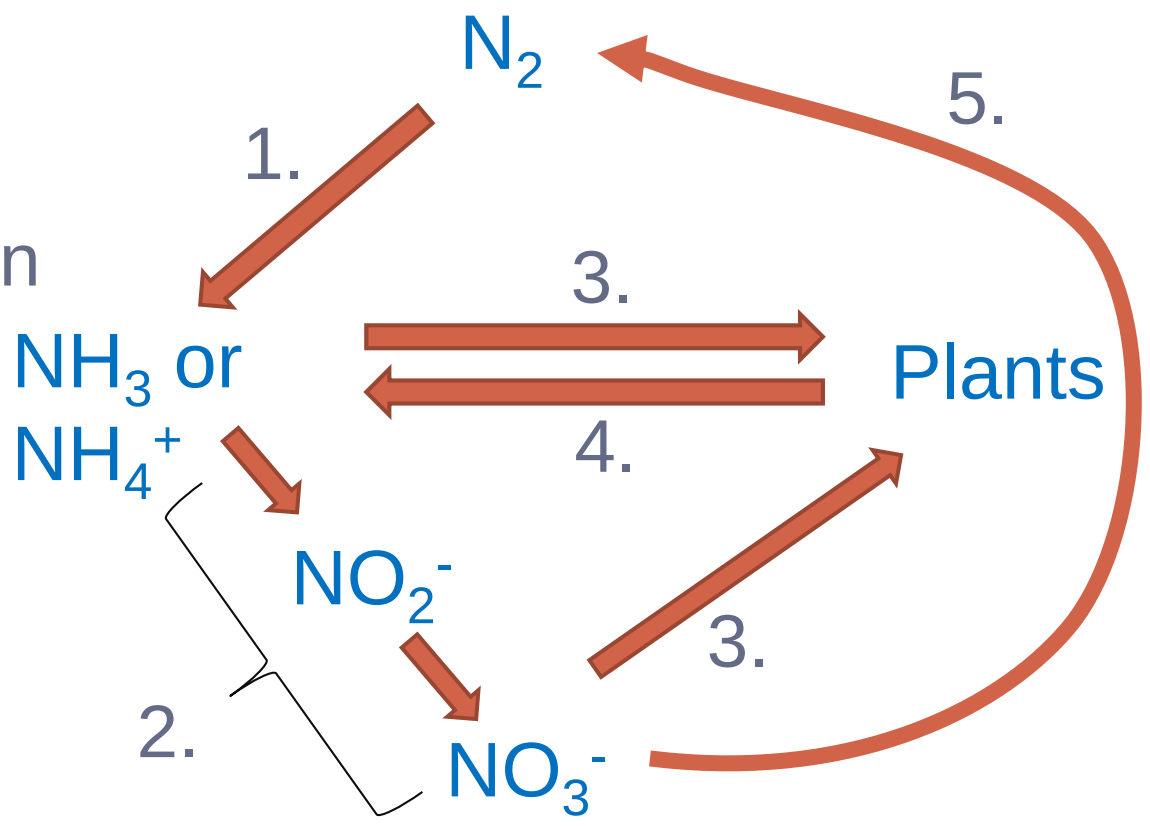
The Nitrogen (N) Cycle

- N needed for proteins and nucleic acids (DNA)
- Atmosphere is 78% N_2, but most cannot use this form
- Five steps
  - Nitrogen fixation
  - Nitrification
  - Assimilation
  - Ammonification
  - Denitrification



The Nitrogen (N) Cycle

1. Nitrogen fixation
2. Nitrification
3. Assimilation
4. Ammonification
5. Denitrification



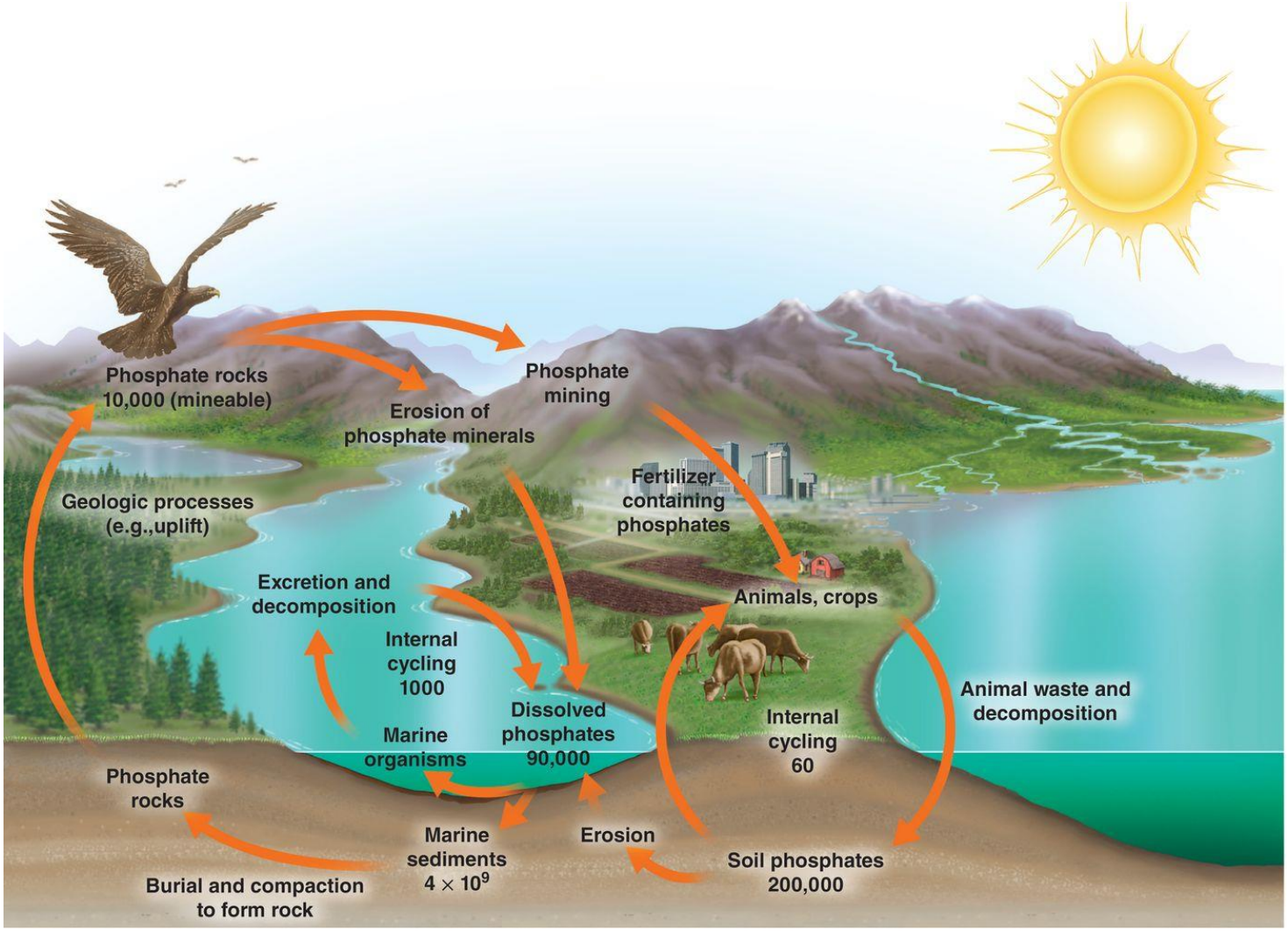
The Nitrogen (N) Cycle

- Nitrogen fixation
  - By bacteria (via nitrogenase enzyme), lightening, volcanoes, industrial processes
- Nitrification
  - Soil bacteria convert to NO_2^- then NO_3^-
- Assimilation
  - Plants absorb NO_3, NH_3, or NH_4^+, moves into food web
- Ammonification
  - Bacteria convert organic N into NH_3 or NH_4^+
- Denitrification
  - Bacteria convert NO_3^- into N_2

Human Affect on N Cycle

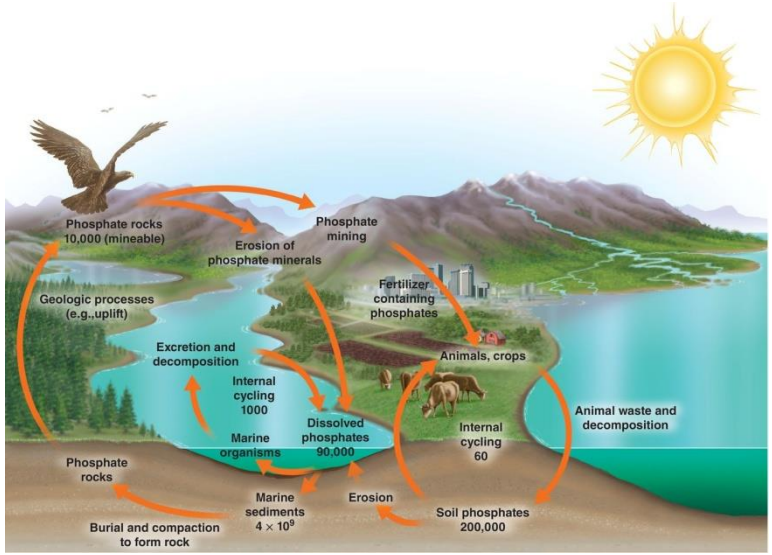
- Humans have doubled N fixation
  - Haber- Bosch process sped fertilizer production
  - Great for efficiently growing vegetables
  - N pollution in natural environments causes eutrophication, over fertilization of forests
- Combustion of fossil fuels
  - Produces photochemical smog
  - Increases production of acid rain

The Phosphorus (P) Cycle



The Phosphorus (P) Cycle

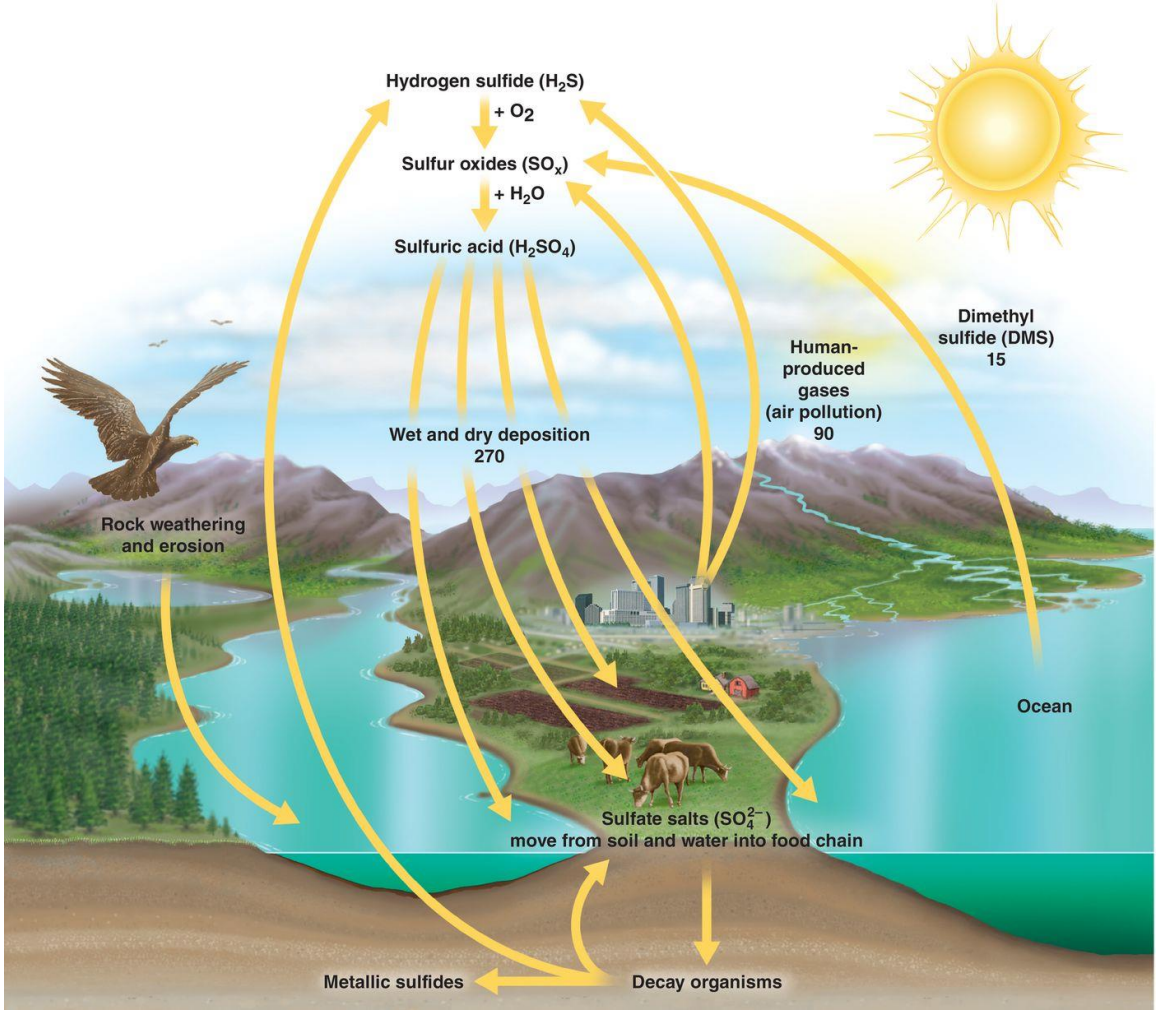
- P cycles from land to ocean sediments and back to land
- No gaseous phase, dust storms can blow P forms into atmosphere
- Weathering of P-rich rock into soils as PO_4^{3-}
- Plants absorb (ex: ATP)
- Eventually carried to ocean and sedimented



Human Affect on P Cycle

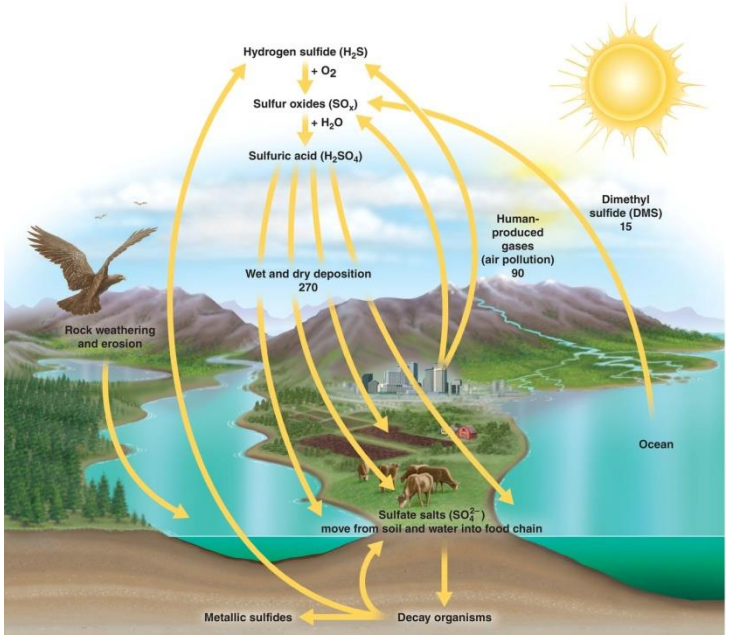
- P fertilizers
  - One of primary limiting nutrients for plant growth
- Waste water treatment plants (WWTP) do not remove
  - Can cause eutrophication
  - Ex: Lake Washington example (Chapter 1)
- 2014 – 7 commercial WWTP recycling P and other nutrients from treated sewage
  - Business opportunities abound in environmental fields

The Sulfur (S) Cycle

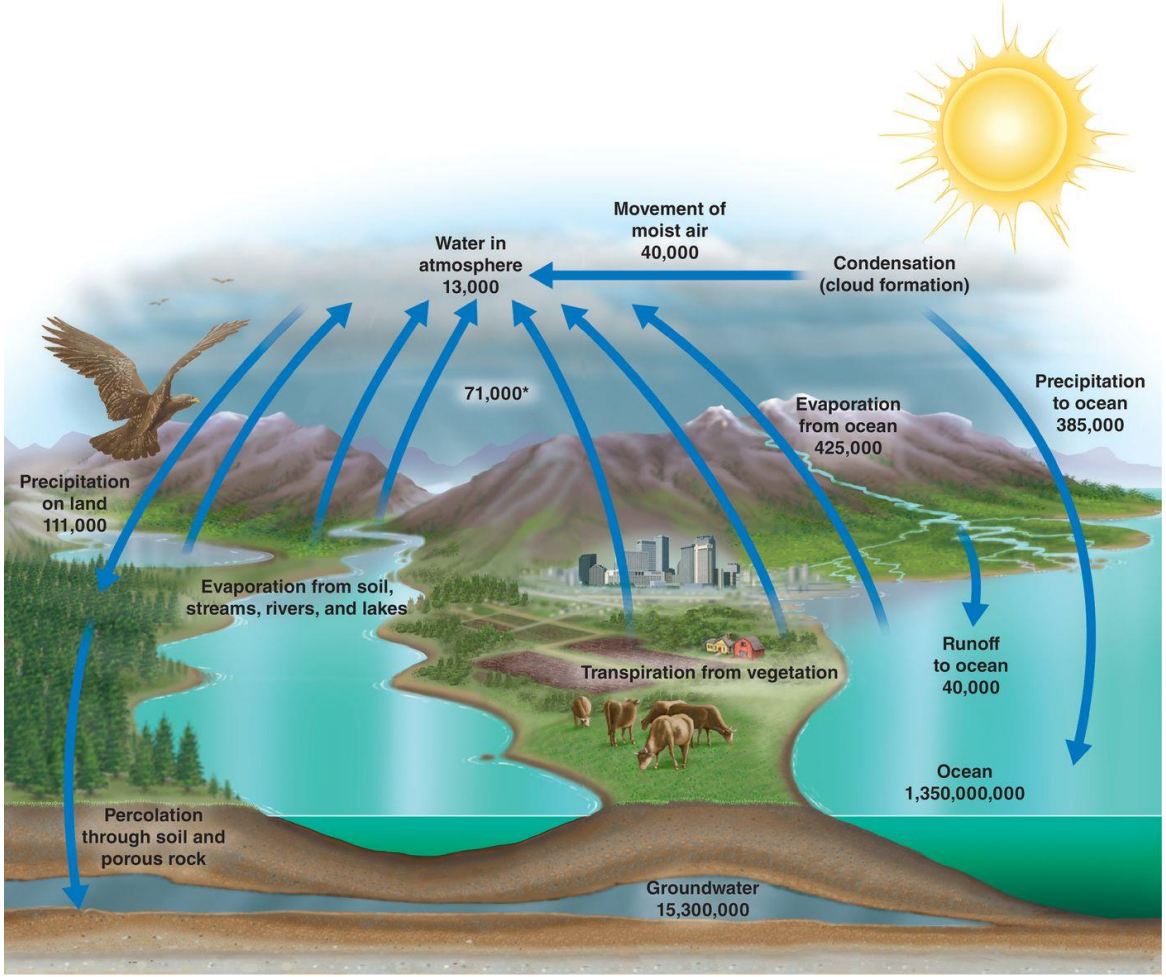


The Sulfur (S) Cycle

- Still not fully understood
- Sulfur primarily in sedimentary rock, which can weather
- Sea spray, dust storms, volcanoes cycle S
- Main biotic cyclers are bacteria
  - Ocean, Salt marsh - rotten egg smell
- Fossil Fuels – S greenhouse gas

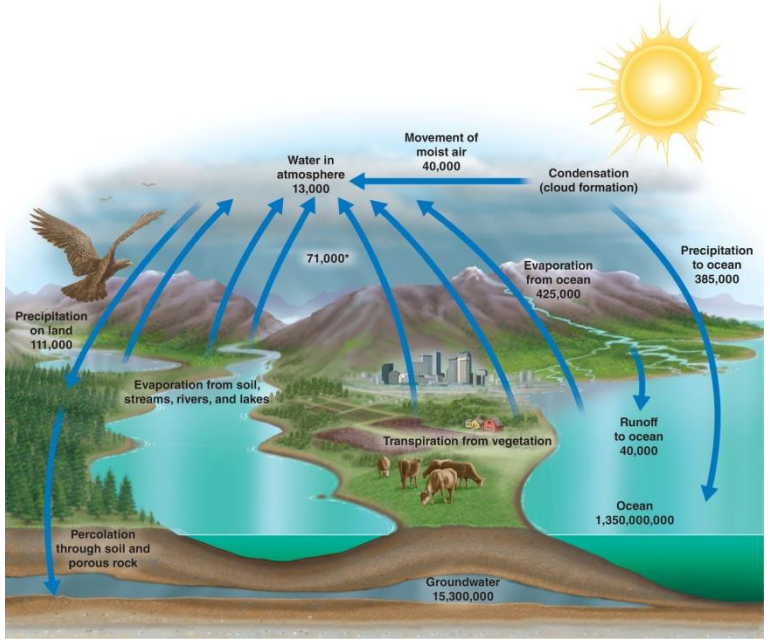


The Water (Hydrologic) Cycle



The Water (Hydrologic) Cycle

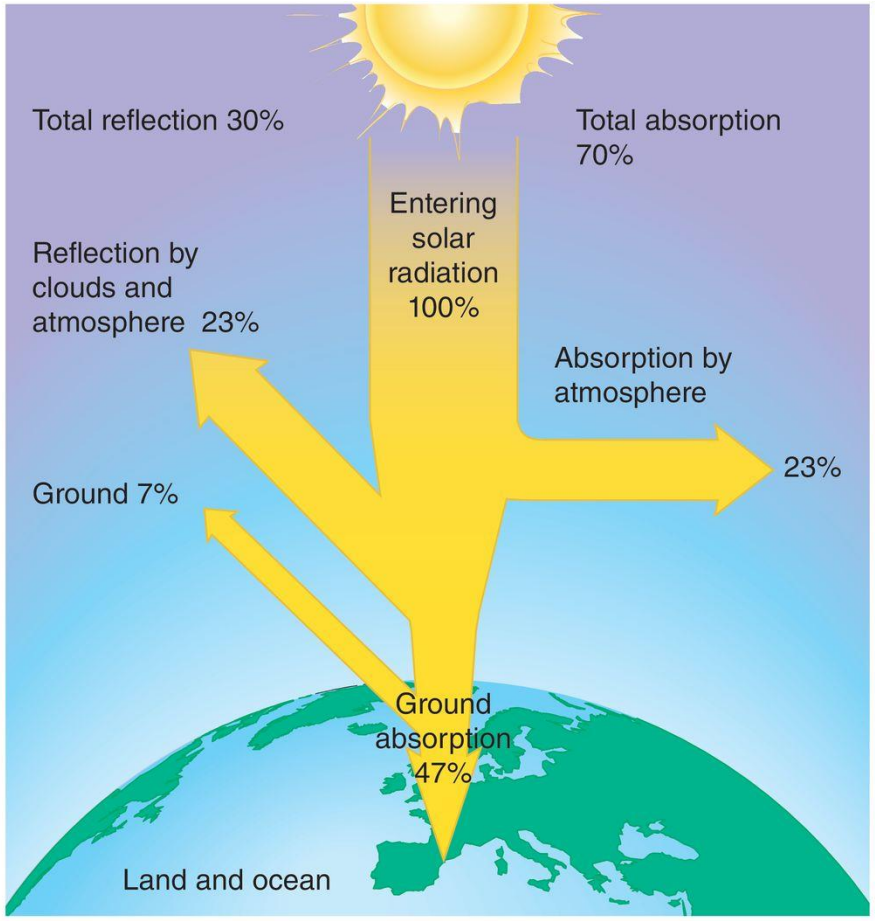
- Cycles among organisms, atmosphere, land, and ocean
  - All organisms use water
- Transpiration
  - Loss of water vapor from land plants
  - 97% of plant water can be lost this way
  - Important in deserts



Human Affect on Water Cycle

- Air pollution may decrease precipitation
- Pumping, diverting surface and groundwater for irrigation
- Climate change – warming temperatures are melting polar ice caps
  - Sea level rise
  - Greater frequency of storms predicted

Solar Radiation



- Sun provides energy for life, powers biogeochemical cycles, and determines climate
- Albedo
  - The reflectance of solar energy off earth's surface
  - Dark colors = low albedo
    - Forests and ocean
  - Light colors = high albedo
    - Ice caps

Temperature Changes with Latitude

- Solar energy does not hit earth uniformly
  - Due to earth's spherical shape and tilt

Equator (a)

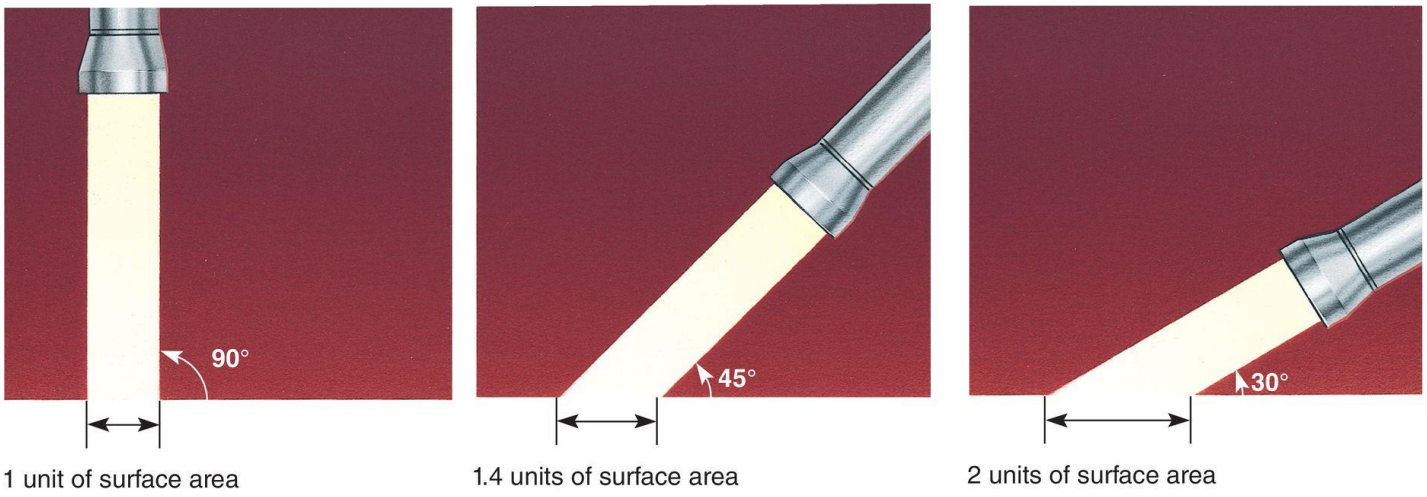
High concentration
Little Reflection
High Temperature

From (a) to (c)

In diagram below

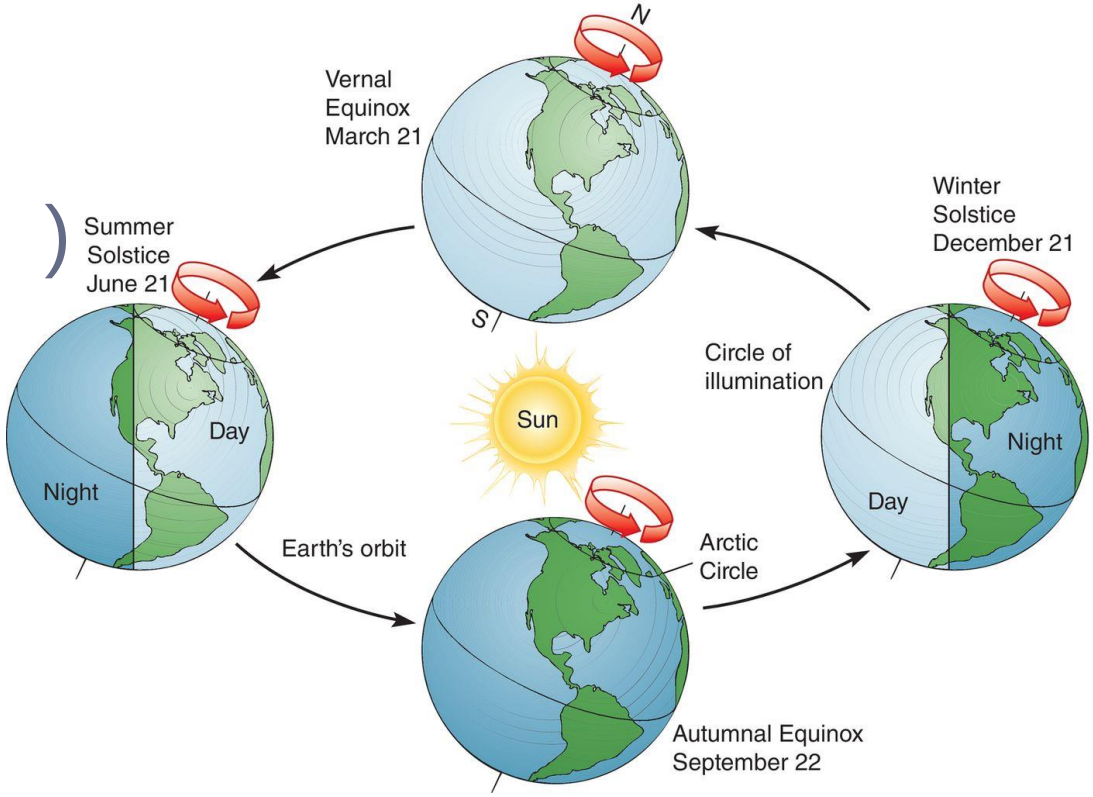
Closer to Poles (c)

Low concentration
Higher Reflection
Low Temperature



Temperature Changes with Season

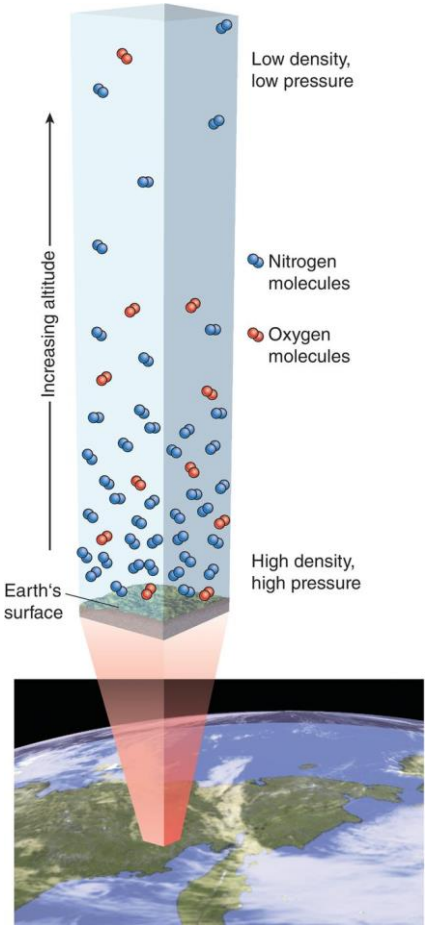
- Seasons determined by earth's tilt (23.5˚))
- Causes each hemisphere to tilt toward the sun for half the year



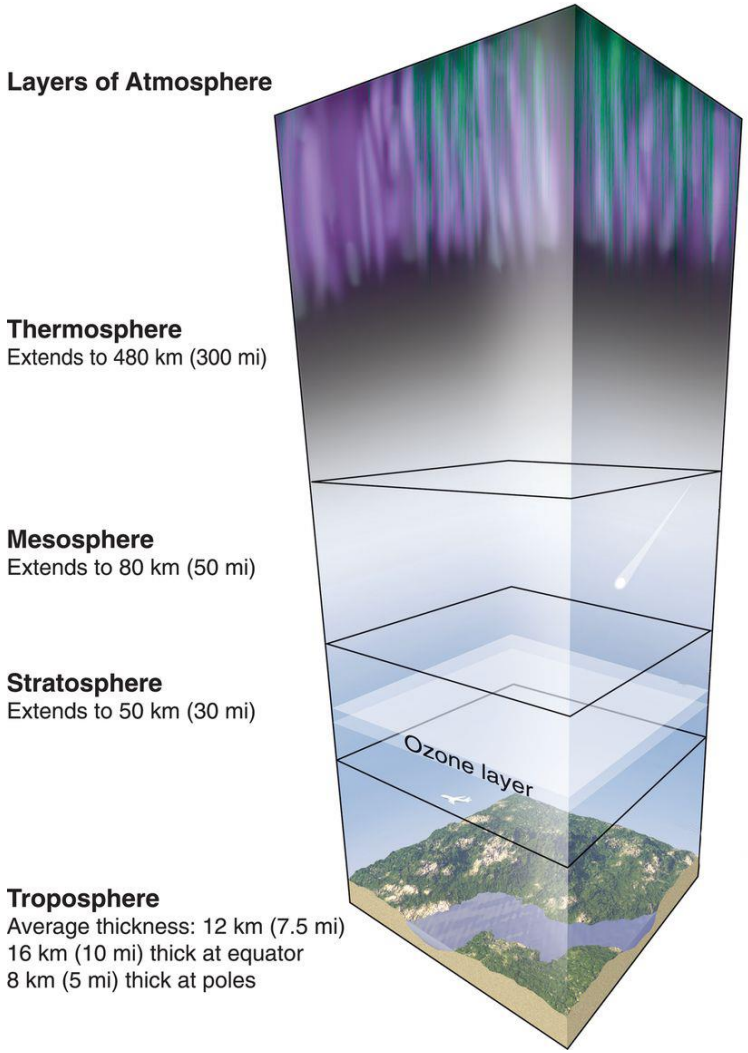
- Northern Hemisphere tilts towards the sun from March 21– September 22 (warm season)

The Atmosphere

- Content
  - 21% Oxygen
  - 78% Nitrogen
  - 1% Argon, Carbon dioxide, Neon and Helium
  - Greenhouse gases (CFCs, CO_2, CH_4)
- Density decreases with distance from earth
- Shields earth from high energy radiation

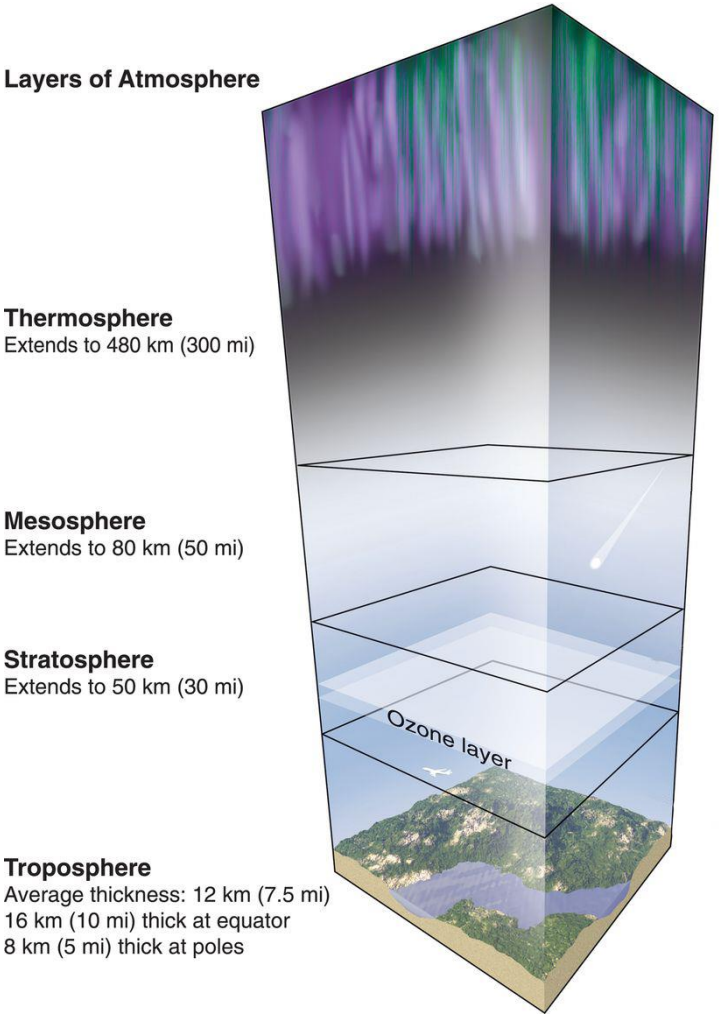


Atmospheric Layers



- Troposphere (0-12km)
  - Where weather occurs
  - Temperature decreases with altitude
- Stratosphere (12-50km)
  - Temperature increases with altitude- very stable
  - Ozone layer absorbs UV
  - Where jets fly
- Mesosphere (50-80km)
  - Temperature decreases with altitude

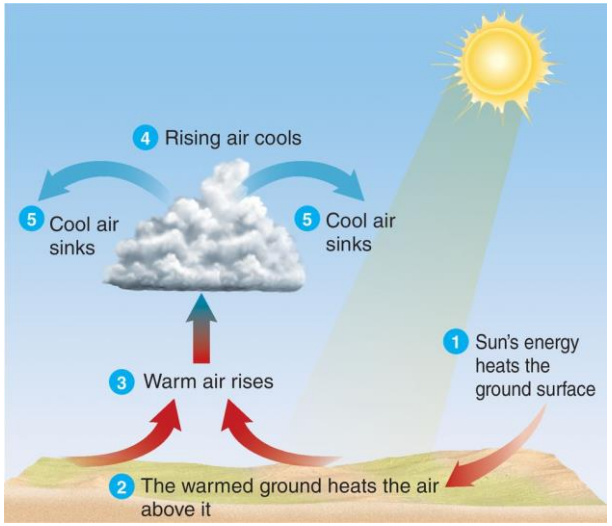
Atmospheric Layers

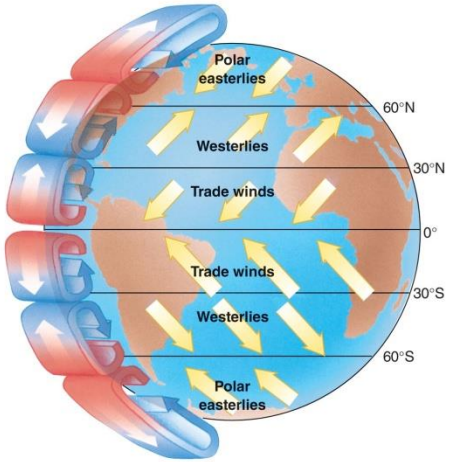


- Thermosphere (80–480km)
  - Gases in thin air absorb x-rays and short-wave UV radiation = very hot
  - Source of aurora
  - Reflects radio waves with need for satellites
- Exosphere (500km and up)
  - Outermost layer
  - Atmosphere continues to thin until converges with interplanetary space

Atmospheric Circulation

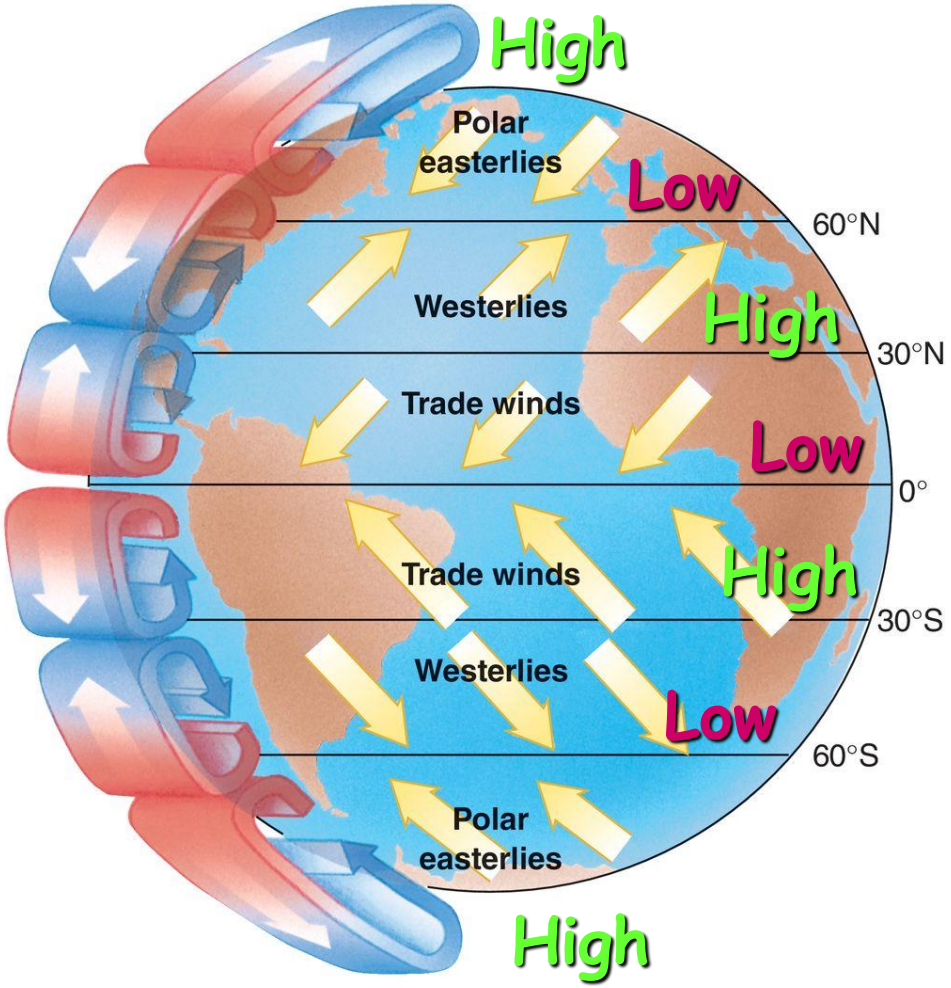
- Near Equator
  - Warm air rises, cools and splits to flow towards the poles
  - At ~30ºN and 30ºS air sinks back to surface
  - Air moves along surface back towards equator
- This occurs at higher latitudes as well
  - Moves heat from equator to the poles





Surface Winds

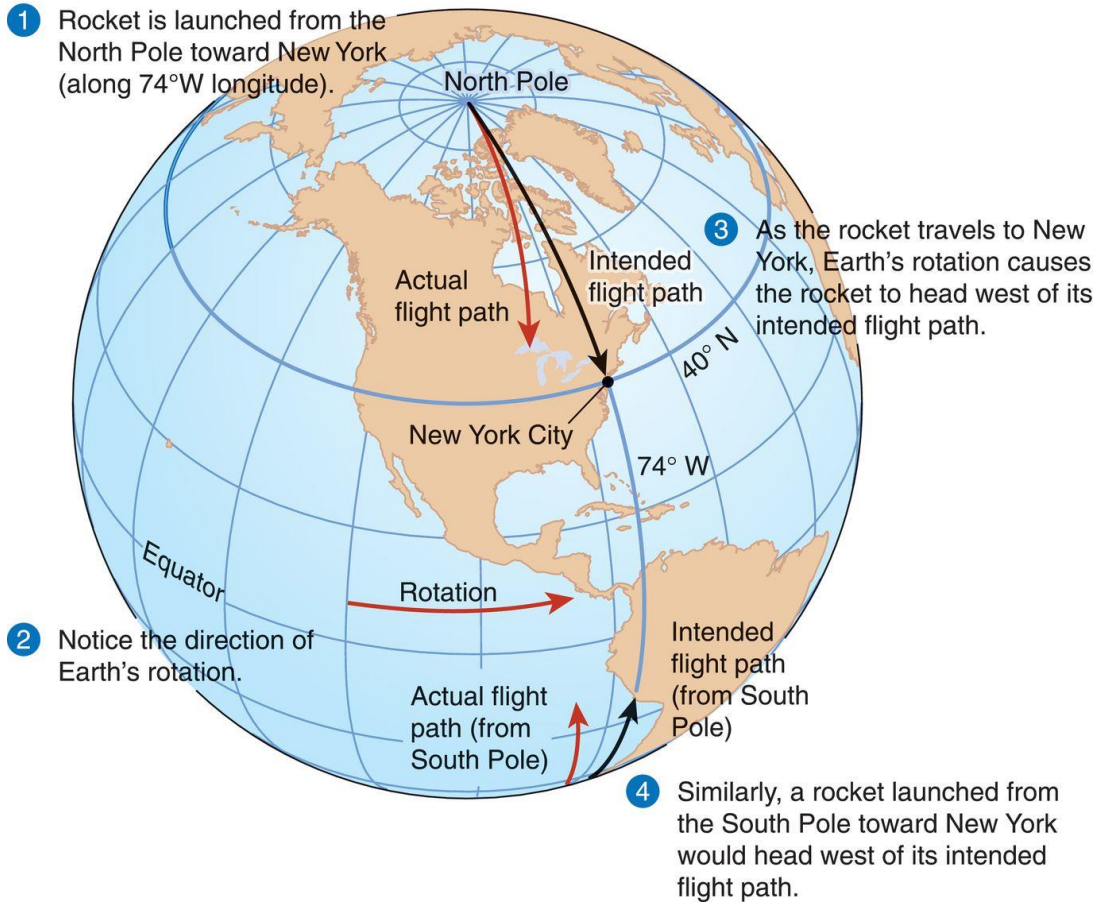
- Large winds due in part to pressures caused by global circulation of air
  - Left side of diagram
- Winds blow from high to low pressure
  - Right side of diagram



Coriolis Effect

- Earth's rotation influences direction of wind
  - Earth rotates from East to West
  - Deflects wind from straight-line path
- Coriolis Effect (due to Earth's tilt)
  - Influence of the earth's rotation on movement of air and fluids
  - Turns them **Right** in the Northern Hemisphere
  - Turns them **Left** in the Southern Hemisphere

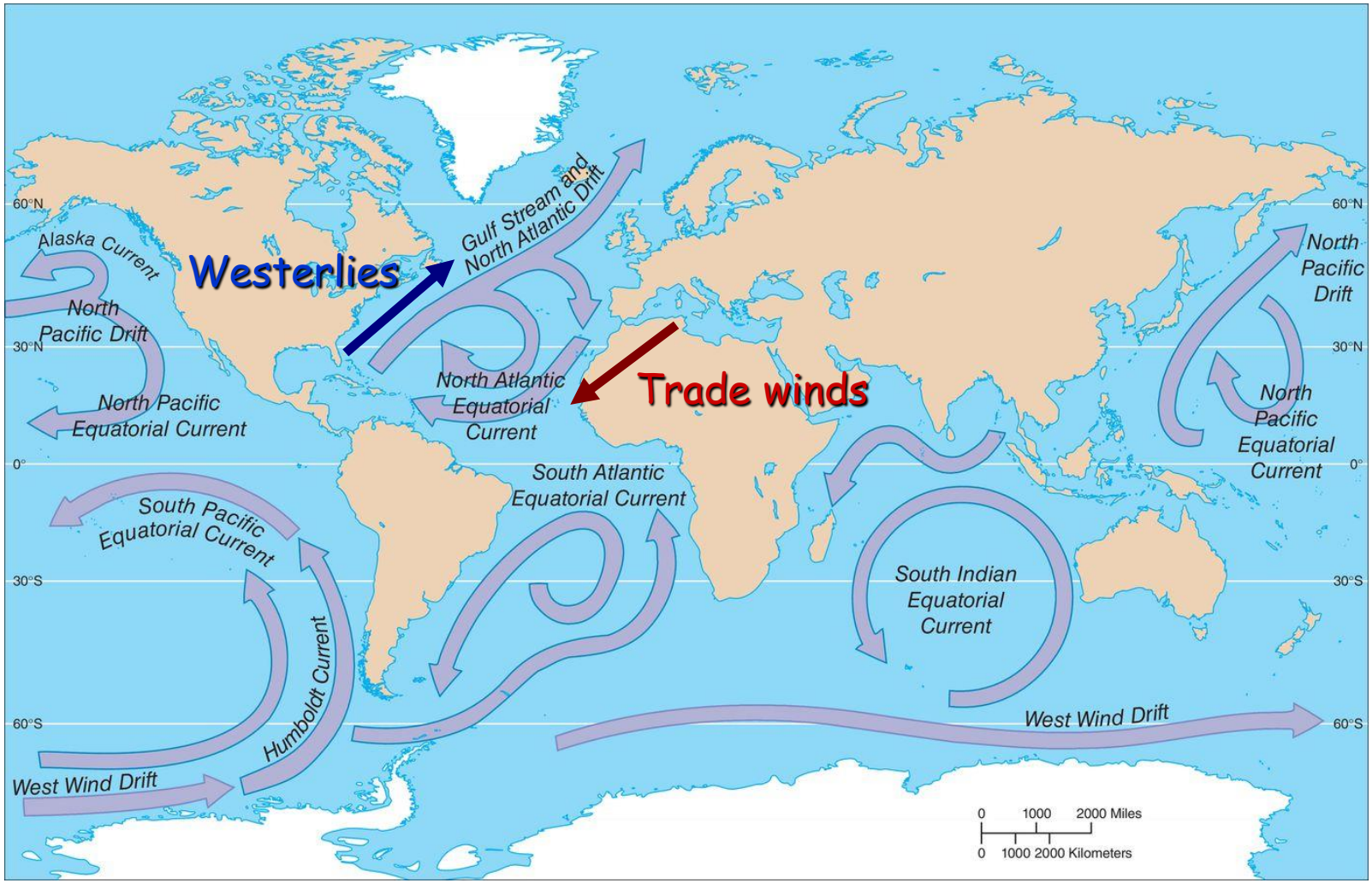
Coriolis Effect



Patterns of Ocean Circulation

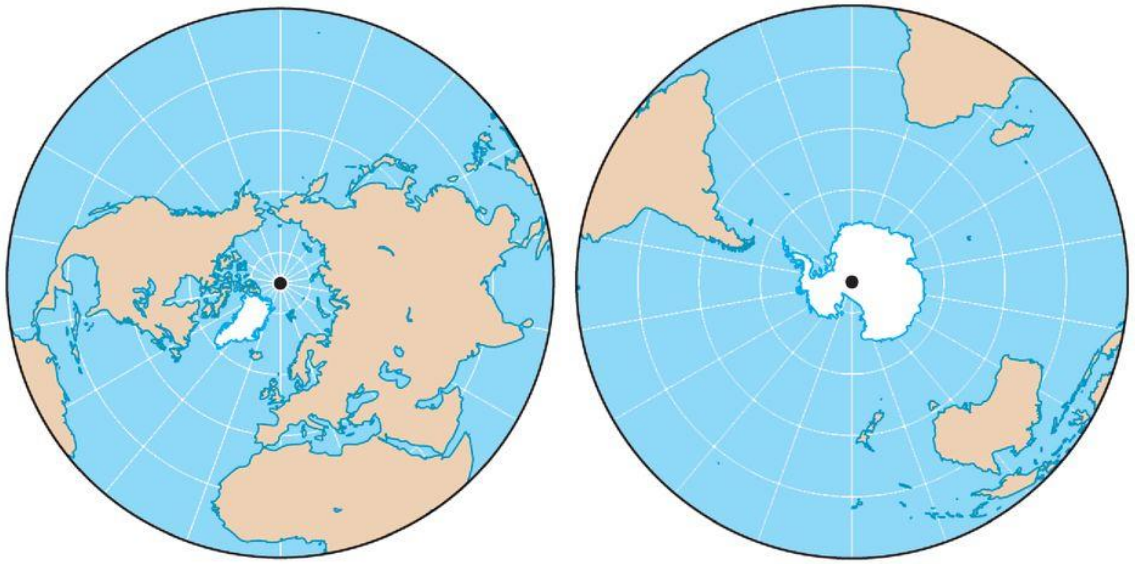
- Prevailing winds produce ocean currents and generate gyres
- Example: the North Atlantic Ocean
  - Trade winds blow west
  - Westerlies blow east
  - Creates a clockwise gyre in the North Atlantic
- Circular pattern influenced by Coriolis Effect

Patterns of Ocean Circulation



Position of Landmasses

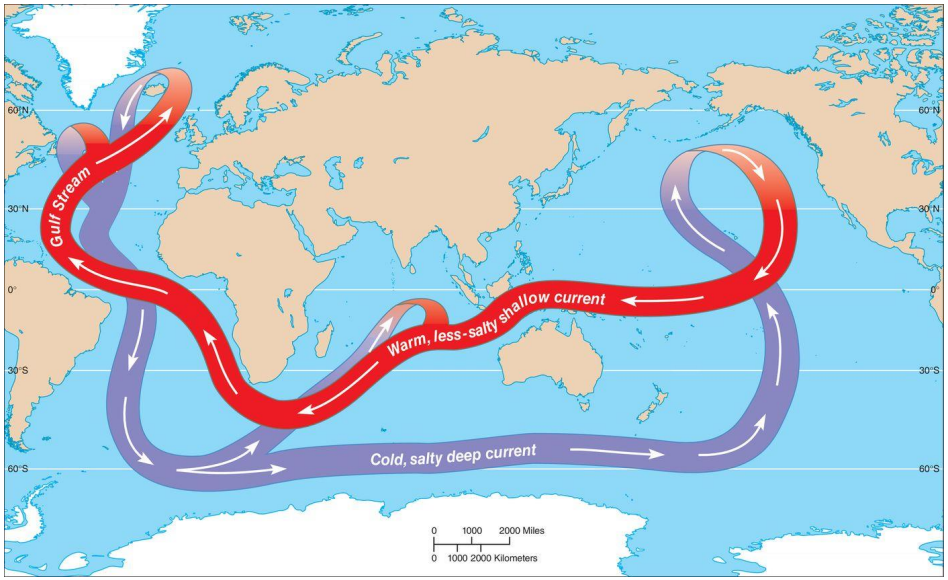
Large landmasses in the Northern Hemisphere help to dictate ocean currents and flow



Very little land in the Southern Hemisphere

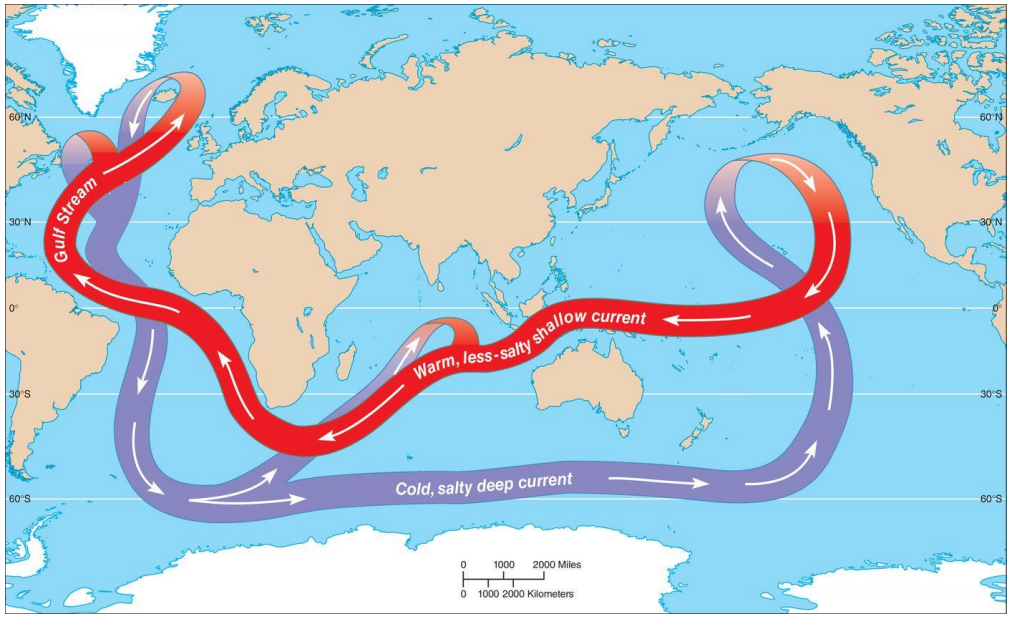
Vertical Mixing of Ocean

- Ocean water varies in density
- Gulf Stream and N. Atlantic Drift deliver heat from tropics to Europe
  - Heat transferred to atmosphere, becomes denser, sinks
  - ~8ºC cooler than surface current



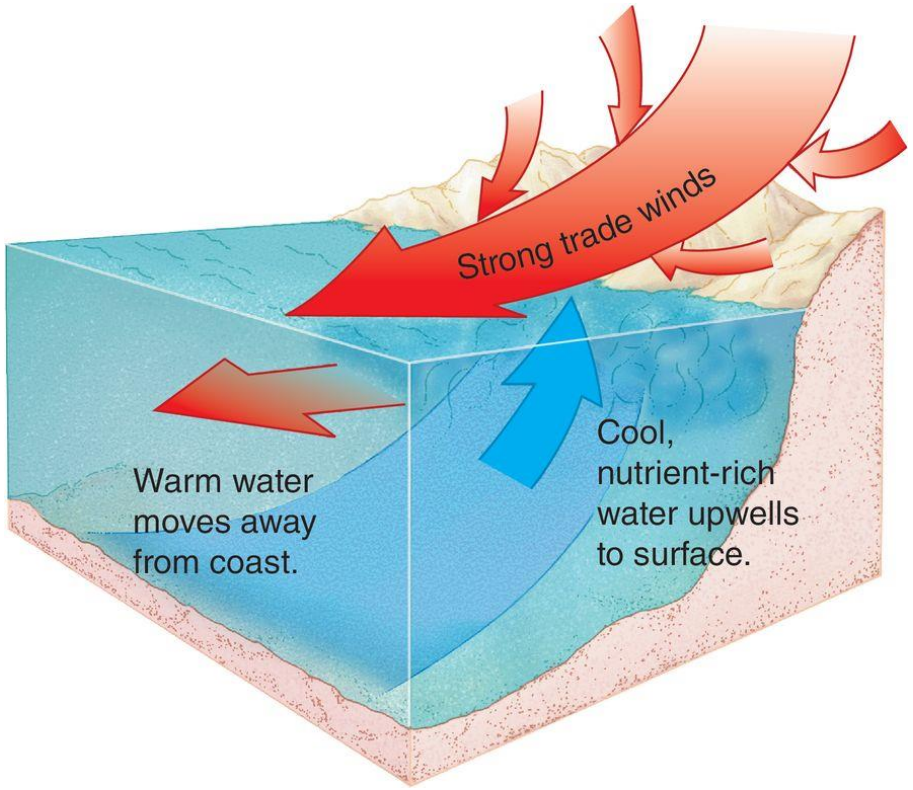
Vertical Mixing of Ocean

- Ocean Conveyor Belt
  - Affects regional and possibly global climate
  - Has shifted 11-12 kya
  - Climate change could result in mini ice age?



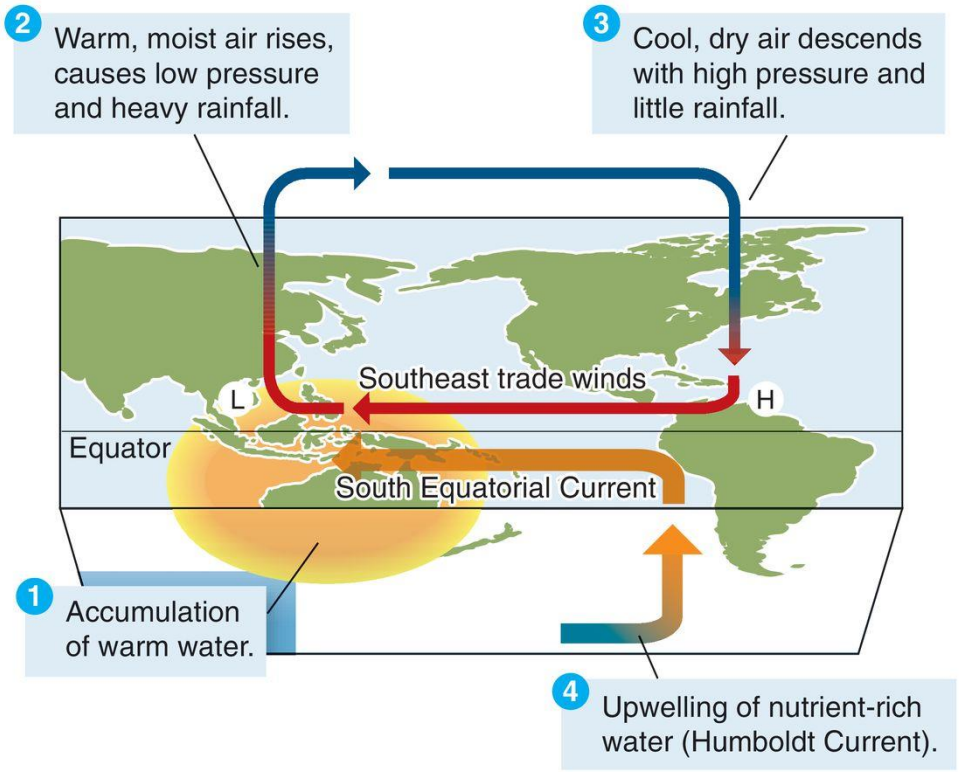
Ocean Interaction with Atmosphere-ENSO

- El Niño-Southern Oscillation (ENSO)
  - Periodic large scale warming of surface waters of tropical E. Pacific Ocean
  - Every ~2-7 years
  - Prevents upwelling (pictured right) of nutrient-rich waters off South America



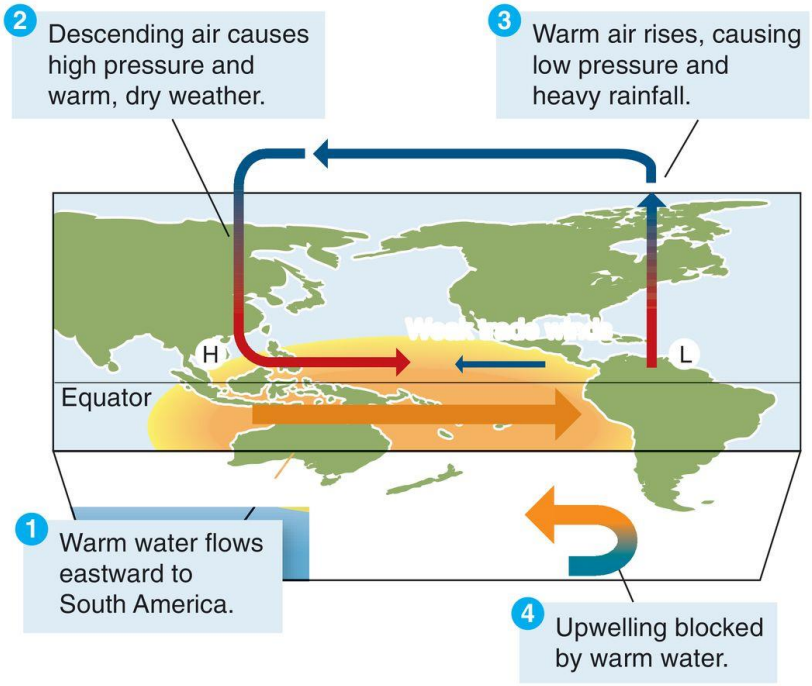
Normal Conditions

- Westward blowing tradewinds keep warmest water in western Pacific



ENSO Conditions

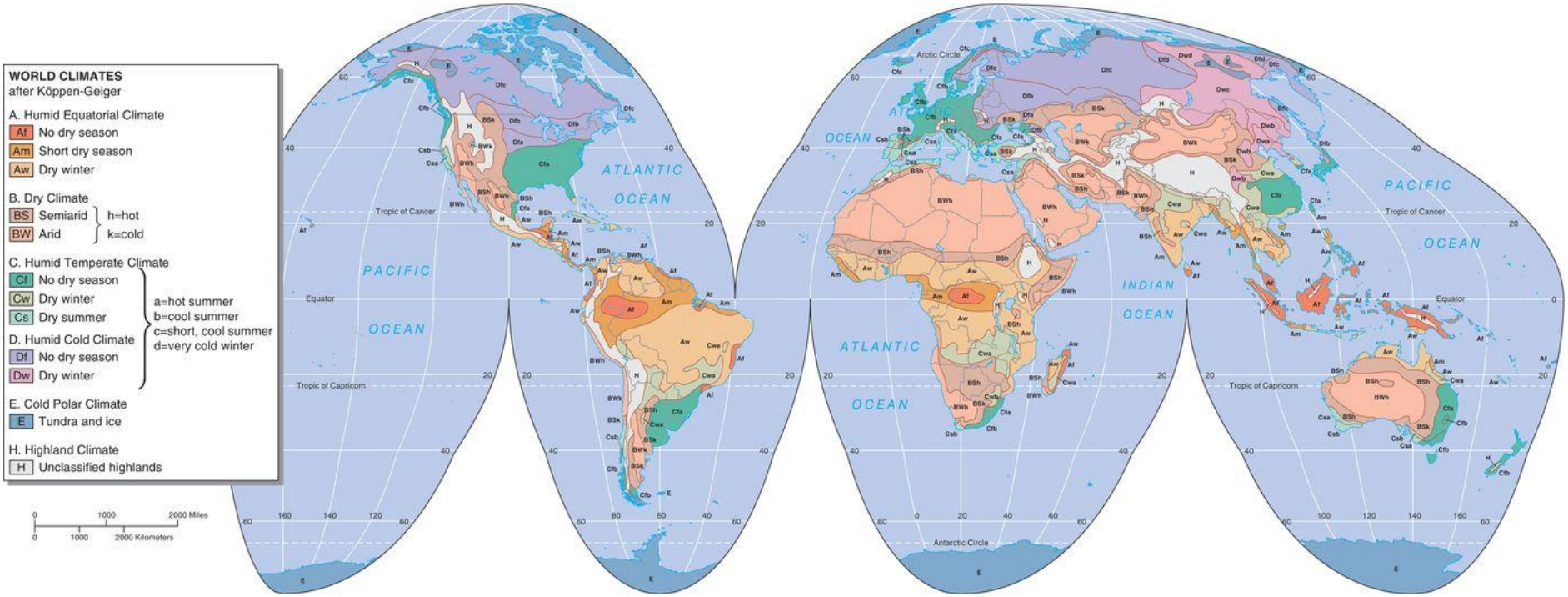
- Trade winds weaken and warm water expands eastward to South America
  - Big effect on fishing industry off South America
  - Floods in Peru
    - May flood west coast of U.S.
  - Australia and Indonesia have droughts
- La Nina
  - Water in E. Pacific cools, west trade winds strengthen



Weather and Climate

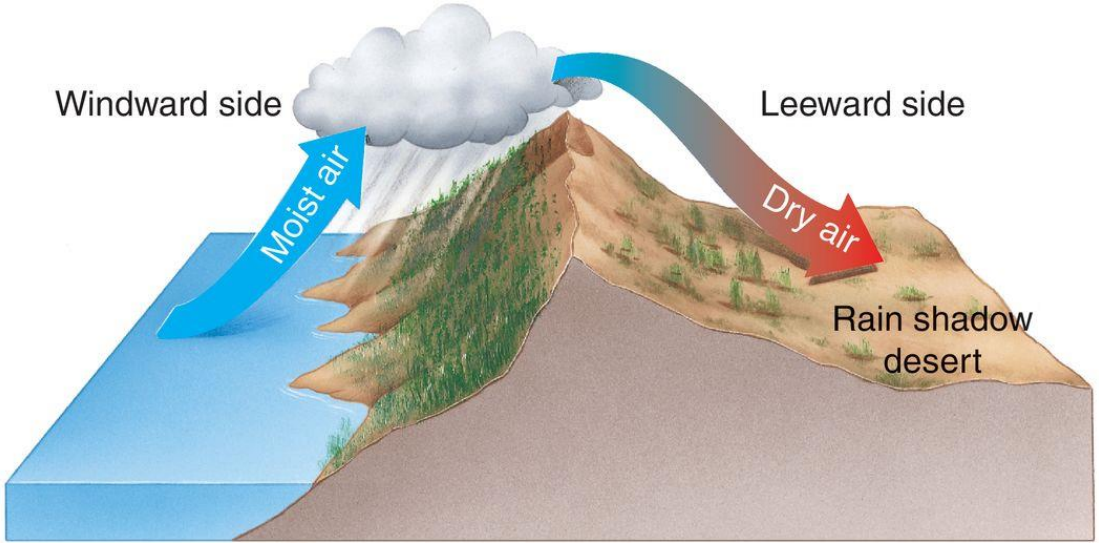
- Weather
  - The conditions in the atmosphere at a given place and time
  - Temperature, precipitation, cloudiness, etc.
- Climate
  - The average weather conditions that occur in a place over a period of years
  - Two most important factors: temperature and precipitation

Climate zones (revise in 50yrs?)



Rain Shadows

- Mountains force humid air to rise
- Air cools with altitude, clouds form, and precipitation occurs (windward side)
- Dry air mass moves leeward side of mountain



Rain Shadows

- True-color satellite image of Oregon shows the rain shadow effect

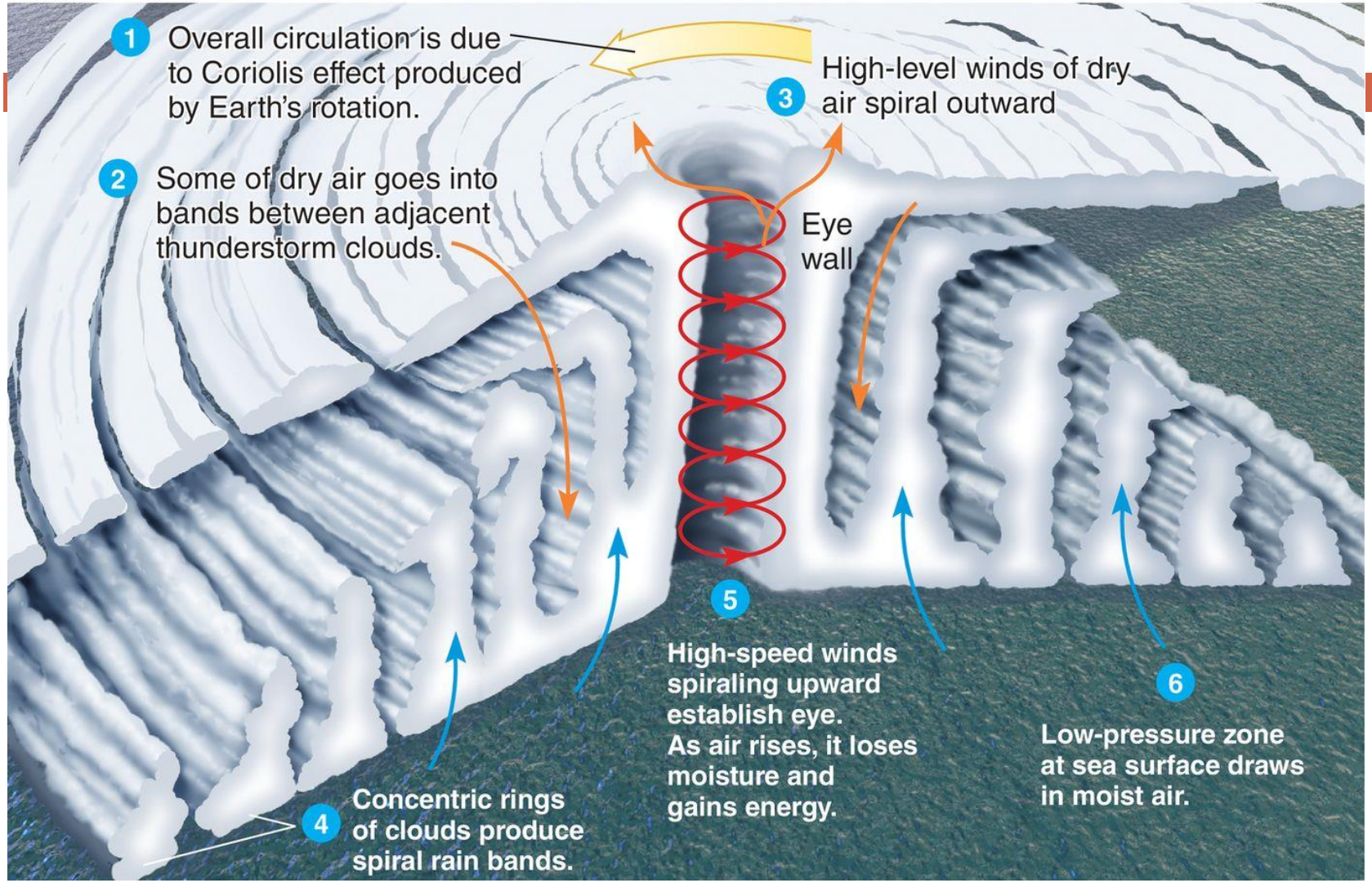
Earth Satellite Corporation / Science Source

Tornadoes

- Powerful funnel of air associated with a severe thunderstorm
- Formation
  - Strong updraft of spinning air forms as mass of cool dry air collides with warm humid air
  - Spinning funnel becomes tornado when it descends from cloud
- Wind velocity = up to 300mph
- Width as large as 2miles
- U.S. has more tornadoes than anywhere else

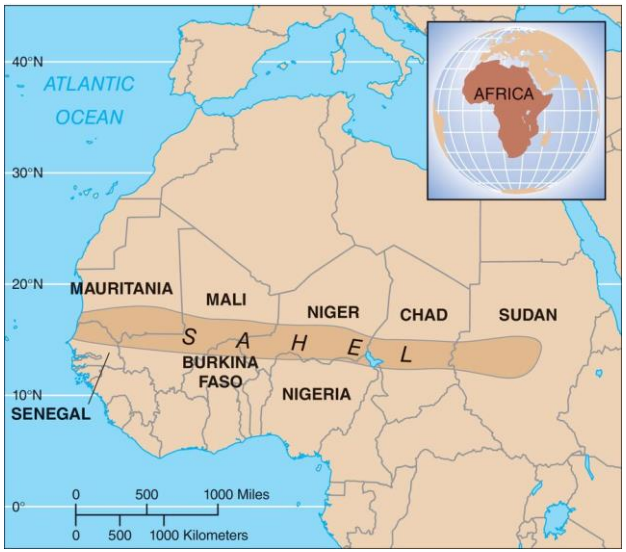
Tropical Cyclones

- Giant rotating tropical storms
- Wind >73mph, many >155mph
- Formation
  - Strong winds pick up moisture over warm surface waters and starts to spin due to Earth's rotation
  - Spin causes upward spiral of clouds
- Many names:
  - Hurricane (Atlantic), typhoon (Pacific), cyclone (Indian Ocean)



Tropical Cyclones

- Frequency of hurricanes varies annually
  - 2005 most active on record (Katrina)
- Factors that influence formation include
  - Precipitation in Africa
  - Water temperatures in eastern Pacific
  - Wetter rainy season in Sahel
  - Dissipation of ENSO

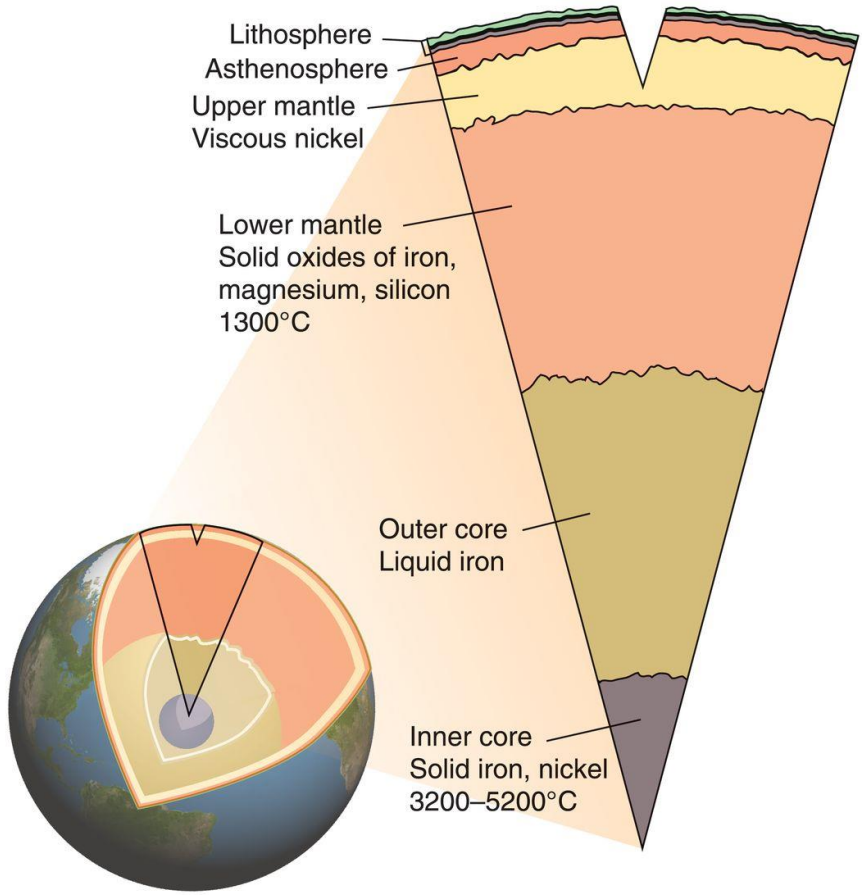


Hurricane Katrina

- North central Gulf coast in August 2005
- Storm surge that severely damaged New Orleans and flooding in ~80% of the city
- Erosion of Mississippi River delta region contributed to damage
  - With area's development, engineers built canals and levees
  - River normally resupplies sediment building up delta
- New Orleans is sinking (has no bedrock)

Internal Planetary Processes

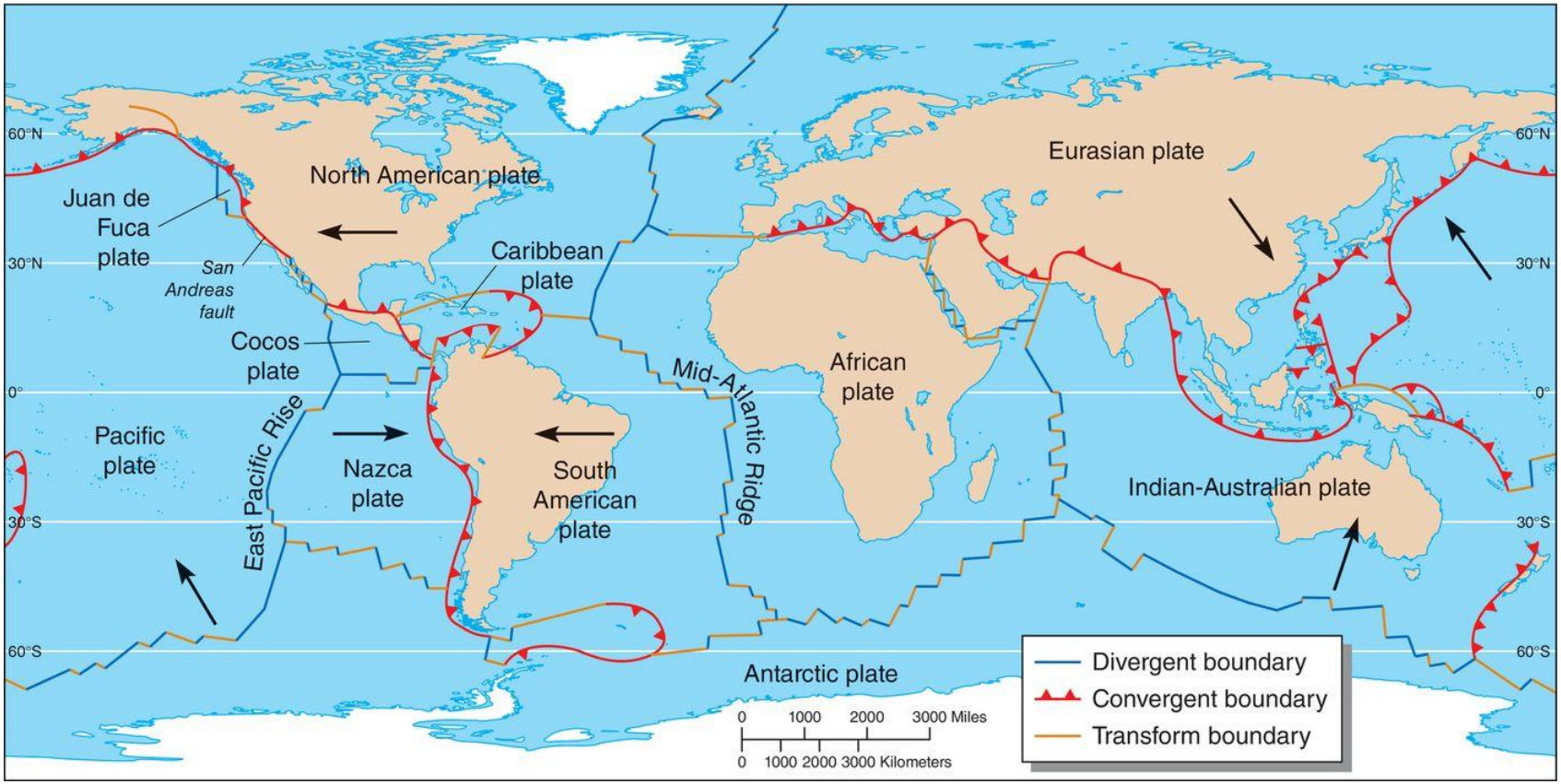
- Layers of the earth
  - Lithosphere
    - Outermost rigid rock layer composed of plates
  - Asthenosphere
    - Lower mantle comprised of hot soft rock



Internal Planetary Processes

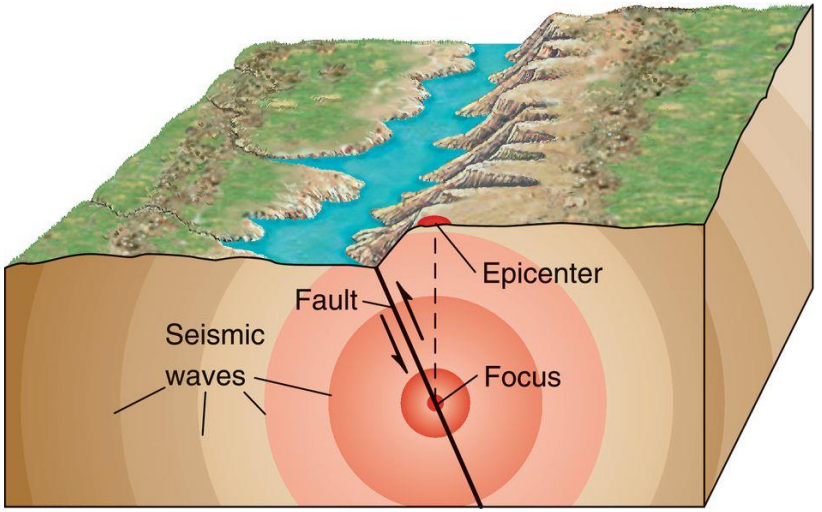
- Plate Tectonics- study of the processes by which the lithospheric plates move over the asthenosphere
- Plate Boundary - where 2 plates meet
  - Divergent
    - Two plates move apart
  - Convergent
    - Two plates collide
  - Transform
    - Plates move horizontally, opposite but in parallel

Plates and Plate Boundaries



Earthquakes

- Caused by the release of accumulated energy as rocks in the lithosphere suddenly shift or break
  - Occur along faults
  - Energy released as seismic wave
- Richter scale measures magnitude
  - Each unit 30x larger
  - Cannot feel magnitude 2
- Landslides and tsunamis are side effects



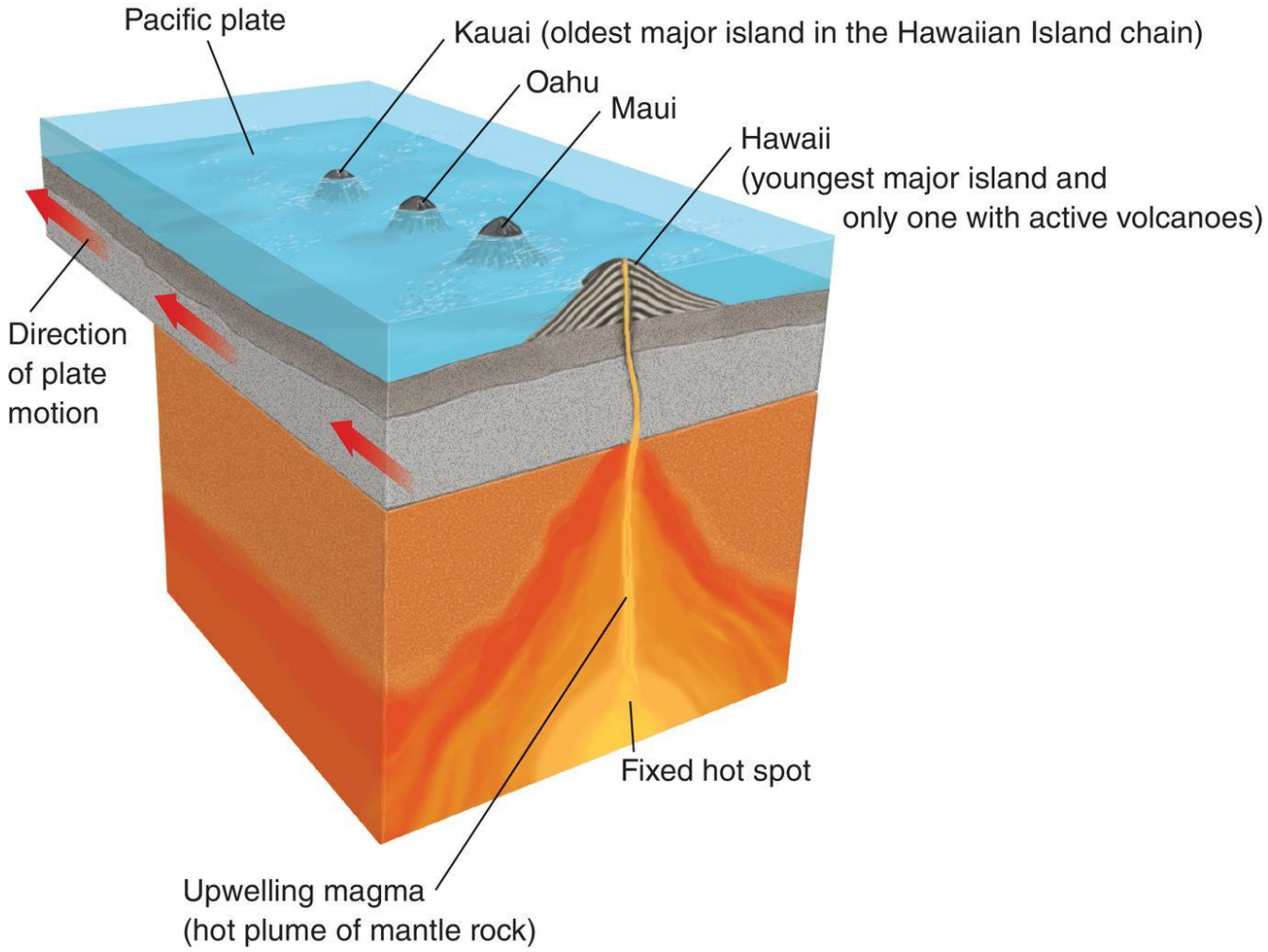
Tsunami

- Giant undersea wave caused by an earthquake, volcanic eruption or landslide
  - Travel > 450mph
- Tsunami wave may be 1m deep in ocean
  - Becomes 30m high on shore
- Magnitude 9.3 earthquake in Indian Ocean
  - Triggered tsunami that killed over 230,000 people in South Asia and Africa

Volcanoes

- Magma pushes through plate reaching surface becoming lava
- Volcanoes occur at
  - Subduction zones
  - Spreading plates
  - Above hot spots
    - Rising plume of magma that flowed from rocky mantle to opening in crust
- “Ring of Fire” in Pacific Basin
- Mt. Pinatubo (1991) ash cloud 30mi upward

Volcanoes



ENVIRONEWS

- Two coastal Sri Lankan villages
  - One with extensive mangrove forest
  - Other deforested
    - Often to build tourist resorts or for aquaculture
- Village with intact mangrove forest recorded 3 deaths
- Village which as cut down mangroves had ~6,000 deaths
- Mangroves can buffer storm surges