

ENVIRONMENT


THE SCIENCE BEHIND THE STORIES
Jay Withgott • Scott Brennan

Ch 7

Environmental Systems and Ecosystem Ecology

Part 1: Foundations of Environmental Science

PowerPoint® Slides prepared by Jay Withgott and Heidi Marcum



Third Edition

Nutrients can limit productivity

- **Nutrients** = elements and compounds required for survival that are consumed by organisms
- **Macronutrients** = nutrients required in relative large amounts
 - Nitrogen, carbon, phosphorus, oxygen, sulfur, hydrogen
- **Micronutrients** = nutrients needed in smaller amounts
- Stimulate plant production
- Nitrogen and phosphorus are important for plant and algal growth



Dramatic growth of algae in water treated with phosphate

Ecosystems integrate spatially

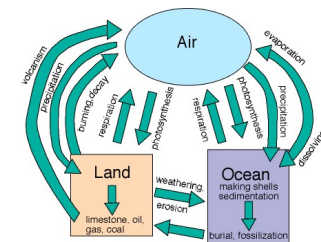
- Ecosystems vary greatly in size
- The term “ecosystem” is most often applied to self-contained systems of moderate geographic extent
- Adjacent ecosystems may share components and interact
- **Ecotones** = transitional zones between two ecosystems in which elements of different ecosystems mix



Marshes: Salt and freshwater mix

Nutrients circulate through ecosystems

- **Pools (reservoirs)** = where nutrients reside for varying amounts of time
- **Flux** = movement of nutrients among pools, which change over time and are influenced by human activities
- **Sinks** = accept more nutrients than they release
 - Fossilization, coal, oil



Matter cycles through the biosphere

- Biosphere- The combination of all ecosystems on Earth.
- Biogeochemical cycles- The movement of matter within and between ecosystems involving biological, geologic and chemical processes.

What is the source of energy for the majority of life on earth?

What 6 elements comprise the majority of all organisms?

CHNOPS

Law of Conservation of Matter. Matter cycles!
Earth is CLOSED system

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The Hydrologic Cycle CHNOPS

- Transpiration- The process where plants release water from their leaves into the atmosphere.
- Evapotranspiration- The combined amount of evaporation and transpiration.
- Runoff- When water moves across the land surface into streams and rivers, eventually reaching the ocean.
- Percolation/infiltration: water flow through porous soil.
- Surface runoff vs ground water
- Aquifer
- Condensation
- Precipitation
- The movement of water through the biosphere.

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Watershed Studies

- Watershed- All of the land in a given landscape that drains into a particular stream, river, lake or wetland



Figure 3.16
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Hydrologic Cycle

CHNOPS

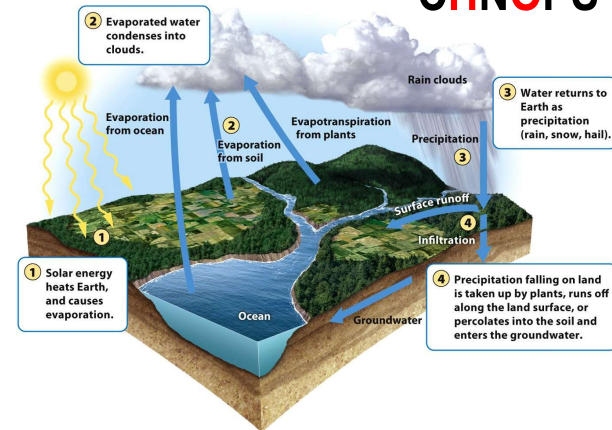


Figure 3.10
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Water's Special properties

- High Specific heat (long time to heat and cool)
- Solid form of water is less dense than liquid form (ICE floats)
- Cohesion, adhesion, and high surface tension

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The carbon cycle

CHNOPS

- Photosynthesis ↔ Cellular Respiration
- Anthropogenic carbon sources
- Greenhouse effect
- Carbon footprint
- Carbon sinks
 - **Largest reservoir of carbon:**
Ocean floor (Sedimentation)
- Sequestration = a natural or artificial process by which carbon dioxide is removed from the atmosphere and held in solid or liquid form.

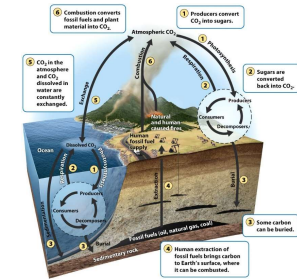


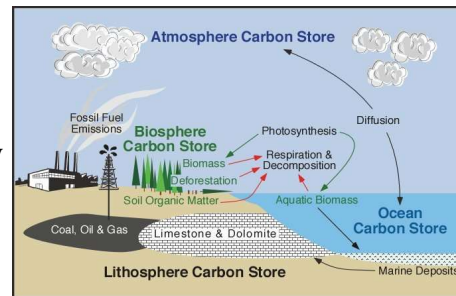
Figure 3.11
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Carbon Cycle

Term used

- Photosynthesis
- Plants
- Volcanic Activity
- Fossil Fuels
- Atmosphere
- Human activity
- Respiration
- CO₂



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Humans affect the carbon cycle

- Burning fossil fuels moves carbon from the ground to the air
- Cutting forests and burning fields moves carbon from organisms to the air
- Today's atmospheric carbon dioxide reservoir is the largest in the past 650,000 years
 - The driving force behind climate change
- The missing carbon sink: 1-2 billion metric tons of carbon are unaccounted for
 - It may be the plants or soils of northern temperate and boreal forests



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The Nitrogen cycle

- N_2 = Nitrogen as gas (78% of our atmosphere)
- **Nitrogen fixation** = N_2 is combined (fixed) with hydrogen by nitrogen-fixing bacteria to become ammonium NH_4^+



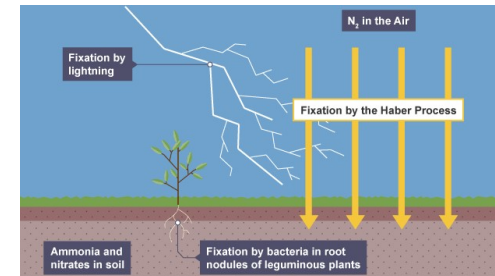
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- **Nitrification** = bacteria that convert ammonium ions first into nitrite ions (NO_2^-) then into nitrate ions (NO_3^-)

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The Nitrogen cycle

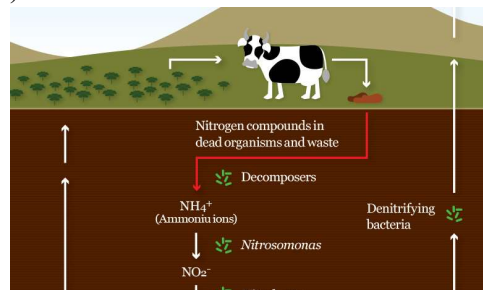
- **Atmospheric Fixation** -The enormous energy of lightning breaks nitrogen gases (N_2) and enables their atoms to combine with oxygen in the air forming nitrogen oxides. These dissolve in rain, forming nitrates (NO_3^-).



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The Nitrogen cycle

Ammonification/Mineralization -the process by which the organically bound nitrogen of microbial, plant, and animal biomass is recycled after their death by decomposers. They are converted by bacteria into ammonia (NH_4^+).



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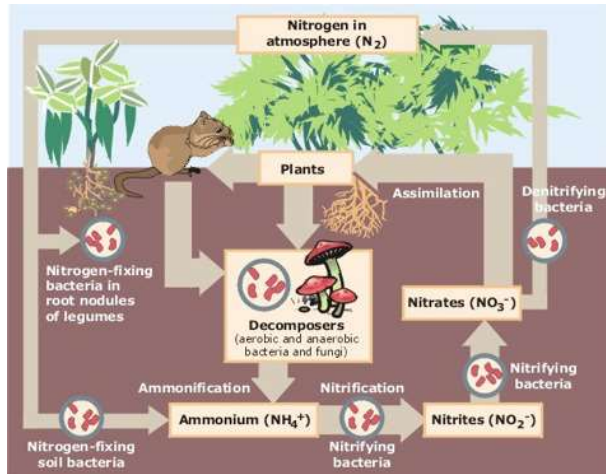
Nitrification and denitrification

- **Assimilation** is the process by which plants and animals incorporate the NO_3^- and ammonia formed through nitrogen fixation and nitrification.
 - Used by plant to form proteins and nucleic acids.
- **Denitrification** = **Denitrifying bacteria** convert nitrates (NO_3^-) in soil or water to gaseous nitrogen (N_2), releasing it back into the atmosphere.

	N_2	NO_3^-	NO_2^-	NH_4^+
Term used in cycle:	Nitrogen Fixation	Nitrification	Denitrification	Assimilation
	Atmospheric Fixation	Ammonification	Bacteria (What kind)	

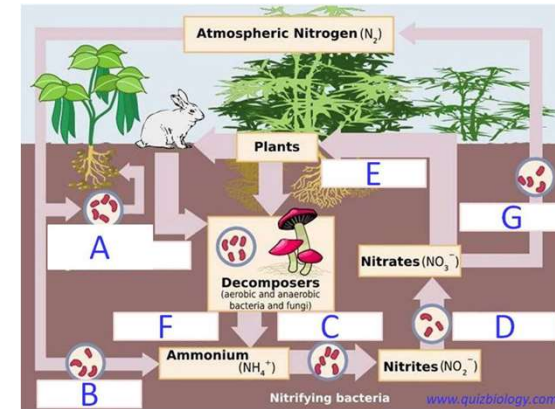
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Nitrogen Cycle



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Try this out

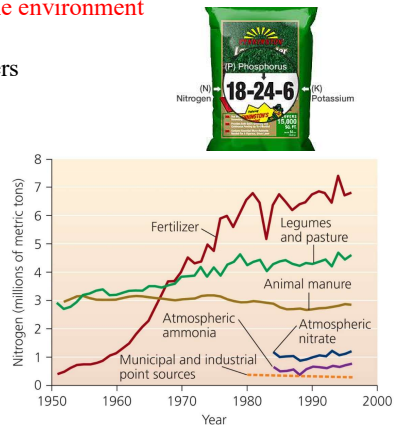


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Humans affect the nitrogen cycle

- Humans are fixing as much nitrogen as nature does
 - 1/2 of nitrogen entering the environment

- Eutrophication from fertilizers
- Acidified water and soils
- Reduced biodiversity of plants adapted to low-nitrogen soils
- Changed estuaries and coastal ecosystems and fisheries



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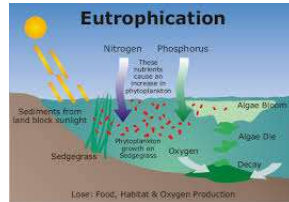
Draw the Nitrogen cycle

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The phosphorus cycle **CHNOPS**

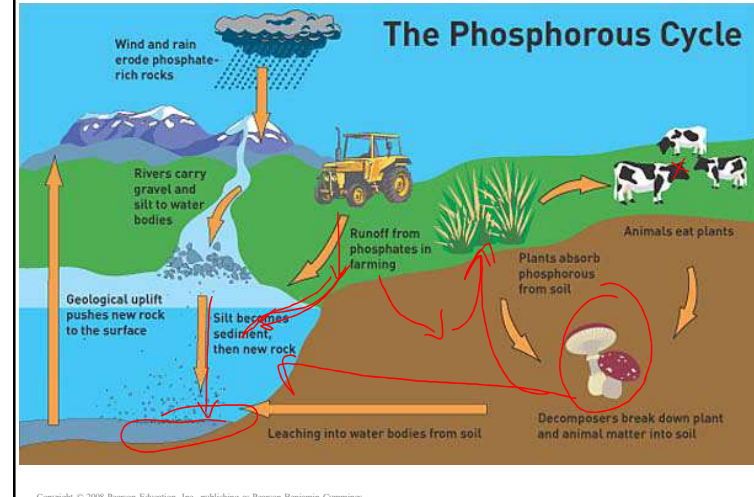


- Found in rocks and is released by weathering
- No atmospheric stage
- Essential for plant growth
- Phosphorus is a key component of cell membranes, DNA, RNA, ATP and ADP
- **Mining** rocks for fertilizer moves phosphorus from the soil to water systems
- **Runoff** containing phosphorus causes eutrophication of aquatic systems



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Phosphorus Cycle



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Sulfur Cycle

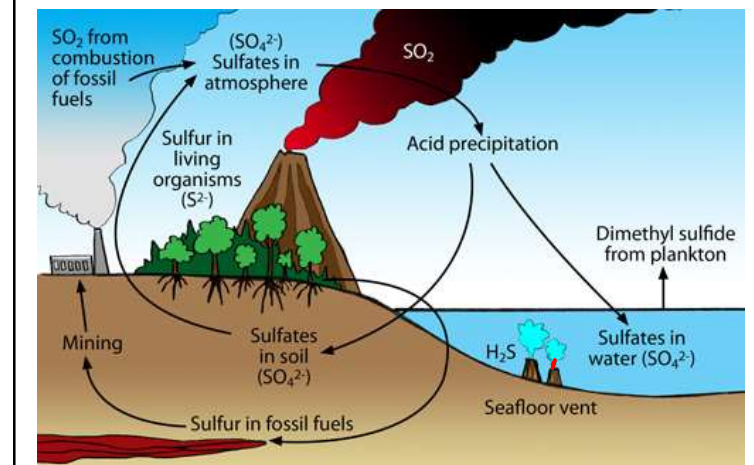
CHNOPS

- $SO_x + H_2O \Rightarrow H_2SO_4$
- Sulfur is found in rocks, or salt in earth, or as sediment at bottom of ocean
- **Causes**
 - H_2SO_4 (Sulfuric acid)
 - Acid Deposition= lowers pH level of soil
- **Main sources:**
 - Mined ores released to atmosphere in factories as H_2S and SO_2
 - Volcanoes and hot springs
 - Combustion of fossil fuels



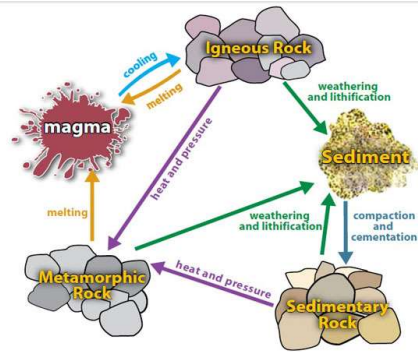
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Sulfur Cycle

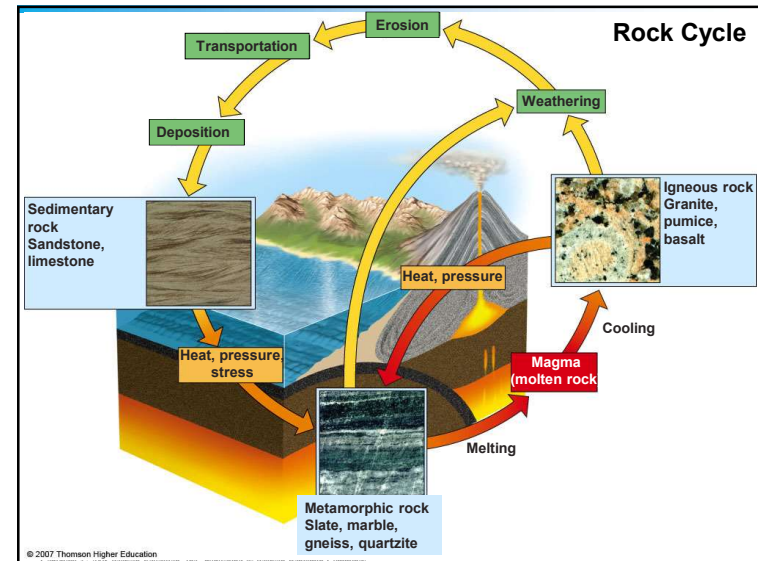


The rock cycle

- **Rock cycle** = The heating, melting, cooling, breaking and reassembling of rocks and minerals
- **Magma** = the molten, liquid state of rock
- **Lava** = magma released from the lithosphere



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Rock Cycle

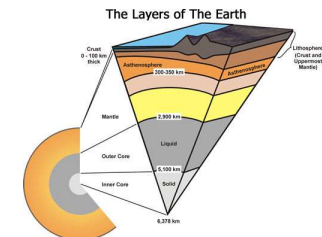
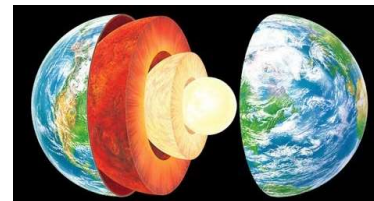
- **Igneous rock** = forms when magma cools
- **Sedimentary rock** = dissolved minerals seep through sediment layers and crystallize and bind sediment particles together
 - Limestone, rock salt, sandstone, shale
- **Metamorphic rock** = great heat or pressure on a rock changes its form
 - Marble, slate



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4 Major Layers of Earth

- **Crust** = thin component of Earth's surface (oxygen, silicon)
- **Mantle** = malleable layer on which the crust floats
 - Lithosphere includes crust & upper mantle
 - Asthenosphere-lower part that is semi-molten
- **Outer Core** = liquid forms of iron and nickel
- **Inner Core** = solid form of iron and nickel



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Plate Tectonics

2 Types of tectonic plates

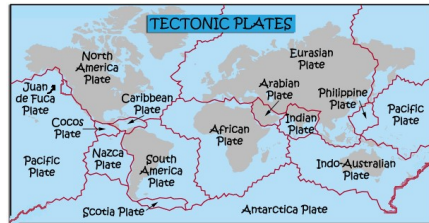
1. Oceanic

- Plates under the ocean
- Made of Basalt
- More active

2. Continental

- Plates that make the continents
- Made of rocks (Granite)

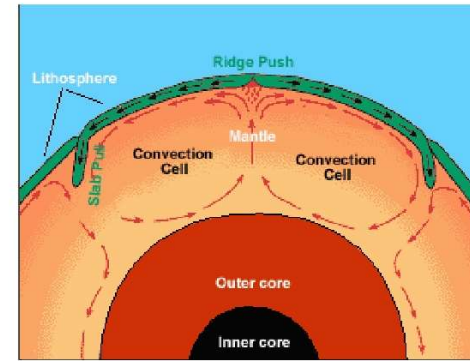
- Plate tectonics** = a theory explaining the movement of lithospheric plates over the underlying mantle.



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Cause of Plate Movement

Convection Cell

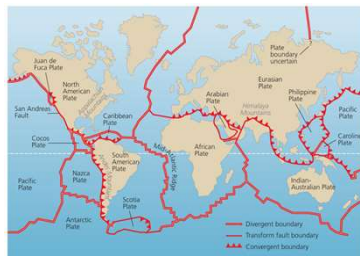


Plates at our planet's surface move because of the intense heat in the Earth's core that causes molten rock in the mantle to move. It moves in a pattern called a convection current that forms when warm material rises, cools, and eventually sinks down. As the cooled material sinks down, it is warmed and rises again.

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Pangaea: the supercontinent

The Earth has 15 major tectonic plates



(a) World map of tectonic plates
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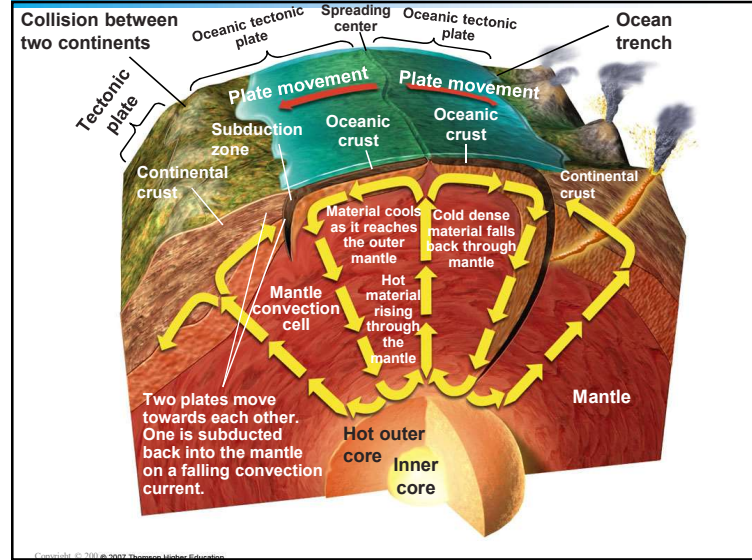
Pangaea = at least twice in Earth's history, all landmasses were joined in one supercontinent



(b) Pangaea, the "supercontinent," 225 million years ago
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3 types of Boundary Plates

1. Divergent plates

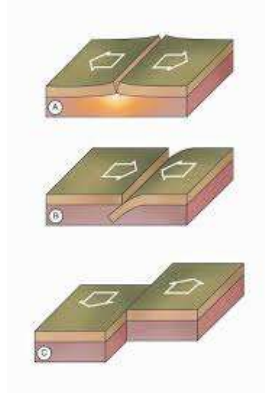
- Magma
- Oceanic ridge

2. Convergent plates

- Subduction
- Subduction zone
- Trench

3. Transform plates

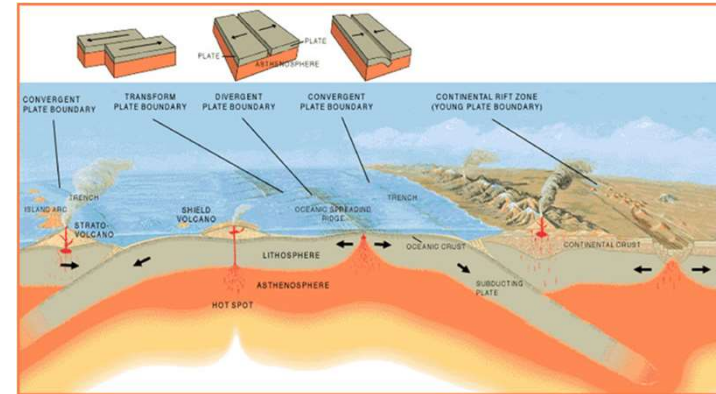
- Faults



Animation

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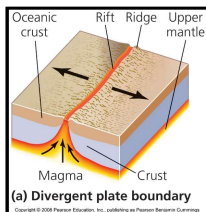
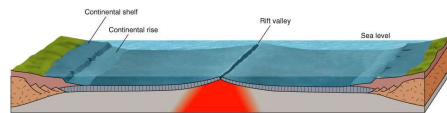
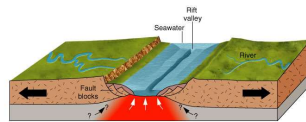
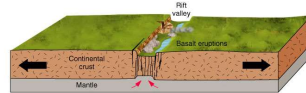
3 types of Boundary Plates



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Divergent plate boundaries

- Magma surging upward to the surface divides plates and pushes them apart, creating new crust as it cools and spreads
- Mid-Atlantic Ridge
- African Rift Valley



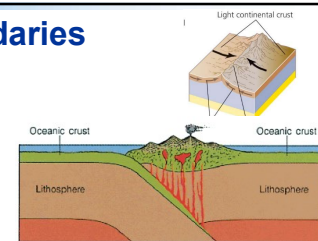
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Convergent plate boundaries

- Plates collide

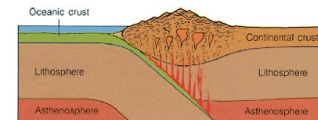
1. Ocean-Ocean

- Subduction= one plate slides beneath another (One is heavier)
- Island arc



2. Ocean-Continental

- Volcanoes
- Ring of Fire
- Trenches

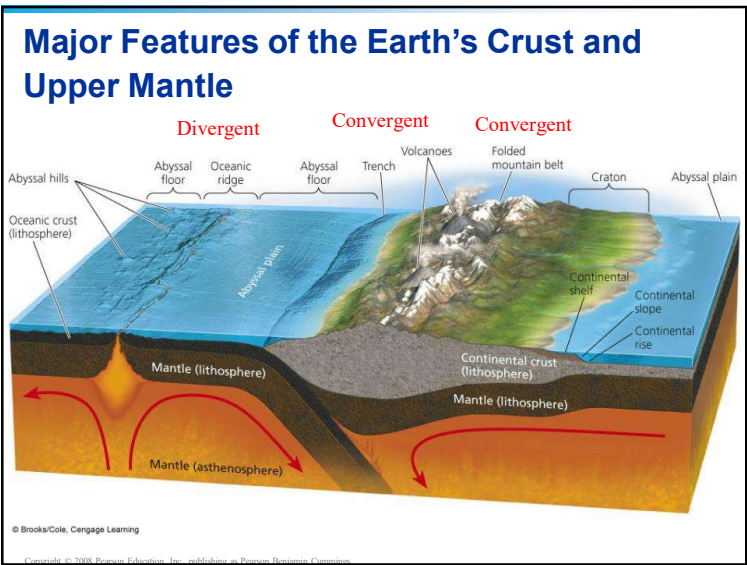
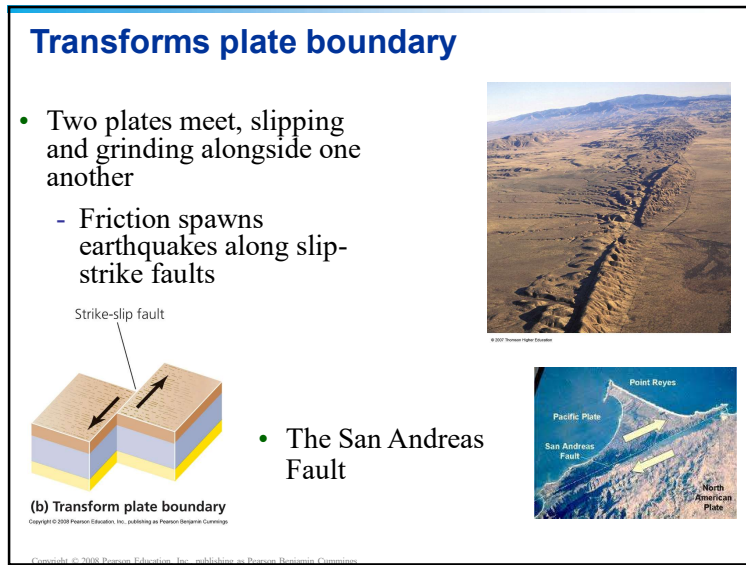
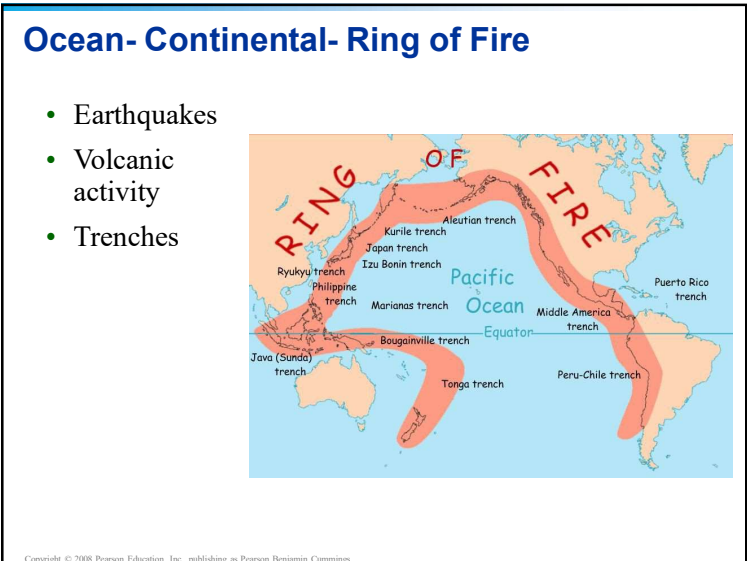
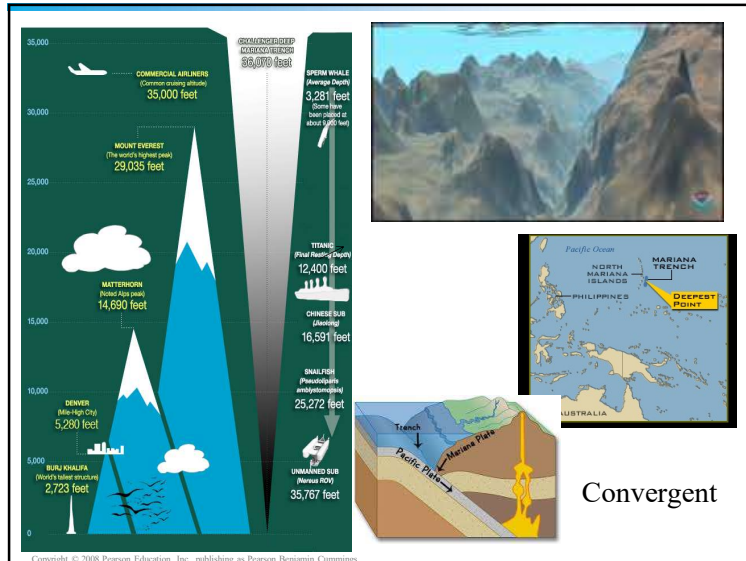


3. Continental-Continental

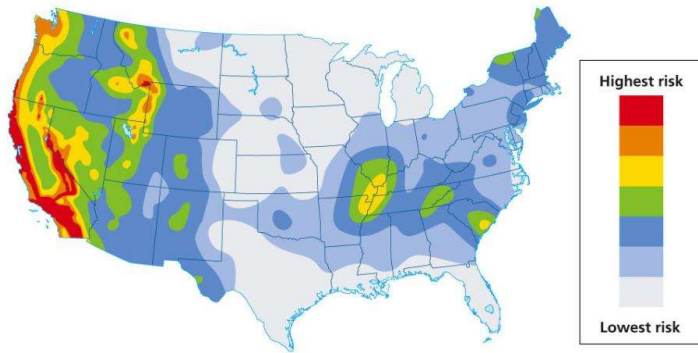
- Same density
- Mountains (Himalaya)



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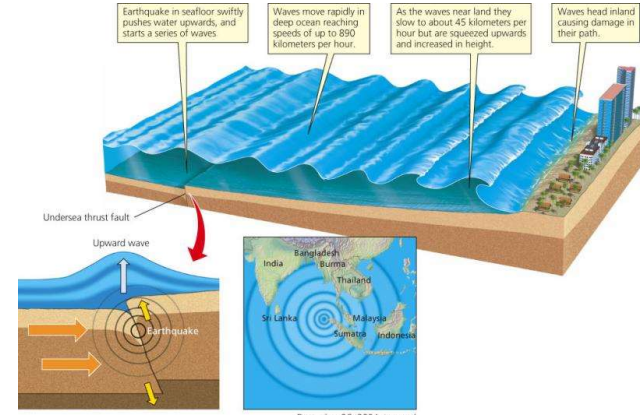


Areas of Greatest Earthquake Risk in the United States



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Formation of a Tsunami and Map of Affected Area of Dec 2004 Tsunami



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Chapter 17

Weather & Atmosphere

[Video](#)

4 Spheres of Life



- **1) Atmosphere**
- Troposphere is the bottom layer—where weather occurs (78% N, 21% O and 1% other gases—mainly Ar)
- Greenhouse gases are here...
- Next layer up—stratosphere contains ozone which O₃

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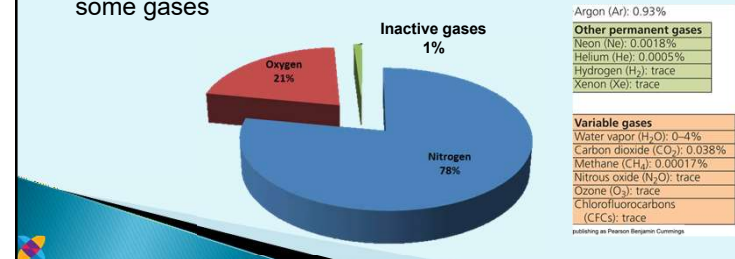
4 Spheres

- **2) Hydrosphere**
- **3) Geosphere:** Earth's crust, mantle and core—rock systems non renewable fuels...soil that contains nitrates, phosphates—support life
- **4) Biosphere**
- Includes all layers of the atmosphere, hydrosphere and geosphere where life exists
- Divided into Biomes—distinct climate regions, unique animal and plant life....

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Earth's Atmosphere

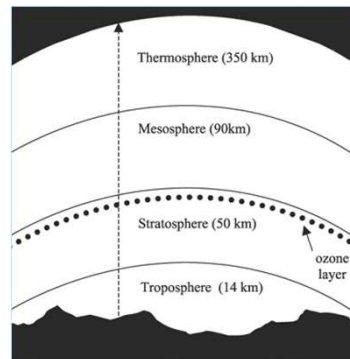
- Layer of gases surrounding the planet Earth and retained by the Earth's gravity.
- It contains roughly 78% nitrogen, 21% oxygen, and 1% other.
- Its four layers differ in temperature, density and composition
- Human activity is changing the amounts of some gases



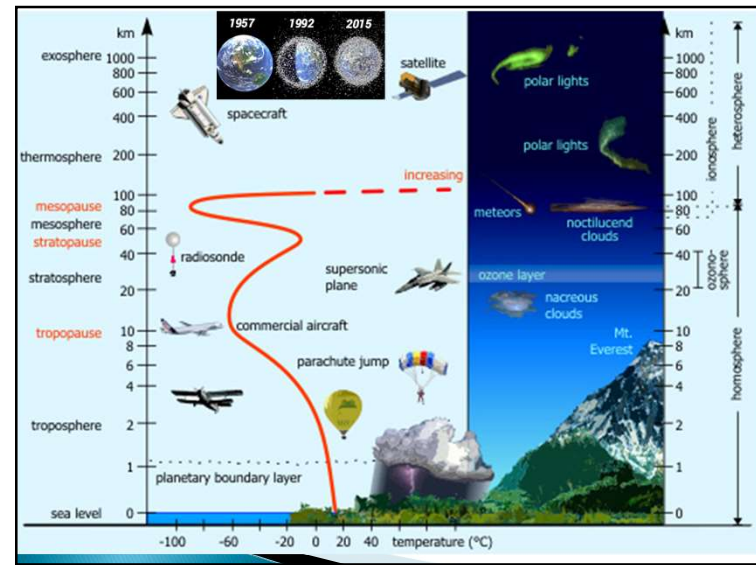
Layers of Atmosphere

Earth's atmosphere can be divided (called atmospheric stratification) into five main layers. From highest to lowest, these layers are:

1. **Exosphere:** atmosphere merges with outer space (>440 miles)
2. **Thermosphere:** International Space station orbits, aurora borealis (50 to 440 miles)
3. **Mesosphere:** coldest, meteors burn here (31 to 50 miles)
4. **Stratosphere:** ozone layer (7 to 31 miles)
5. **Troposphere:** weather (0 to 7 miles)



Space Junk



Weather and Climate

▶ Weather is a short-term atmospheric condition in an area. They include:

- Temperature
- Humidity
- Precipitation
- Cloud cover
- Happens in the Troposphere

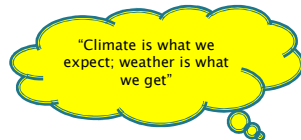
◦ What is the weather today here?



◦ What is the climate for here?

▶ Climate is a region's general pattern of atmospheric condition over a long period of time (**at least 30 years**). The two major factors contributing to a region's climate:

- ▶ average temperature
- ▶ average precipitation



Mark Twain

What Determines Climate

▶ Climate is determined by:

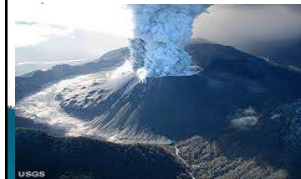
- Atmospheric Circulation Patterns
- Oceanic Circulation Patterns
- Local geography
- Solar activity
- Volcanic Activity



Which is most important?

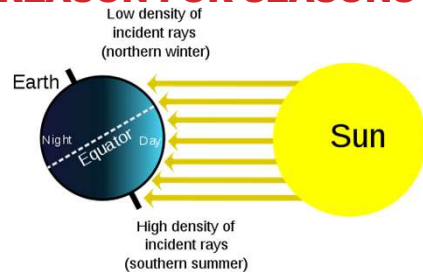
Latitude

(How far above/below you are from the equator)



Video

REASON FOR SEASONS



Latitude is the distance north or south of the equator. Measured in degrees.

- Equator is 0 degrees, the poles are 90 degrees
- Low Latitudes – get the strongest, most concentrated sunlight.
 - Night and Day are 12 hours, all year round
 - High temps all year round
- High Latitudes – sunlight is spread over a greater area, weaker, less energy
 - Daylight hours vary
 - At the poles the sun sets for only a few hours during the summer
 - Dark almost all day during winter
 - Average annual temperatures lower than at equator.

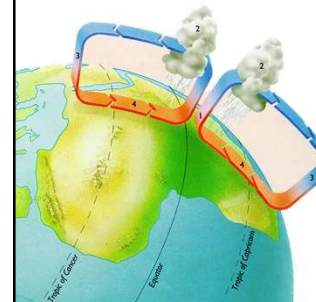
Convection cells

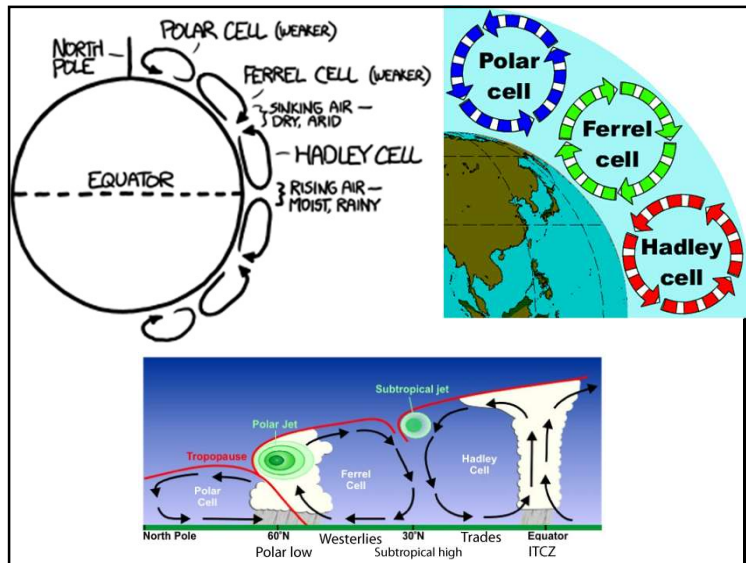
Three basic rules:

1. Cold air sinks – but pressure is stronger at lower levels so cold air gets compressed and thus warms.
2. Warm Air Rises – lower pressure lets it expand and it cools down
3. Warm Air holds more water vapor than cold air – so as it rises the water vapor cools and condenses

How do we get wind?

1. Sun heats the earth surface.
2. Hot Air Rises
3. Cold Air replaces it.....wind!

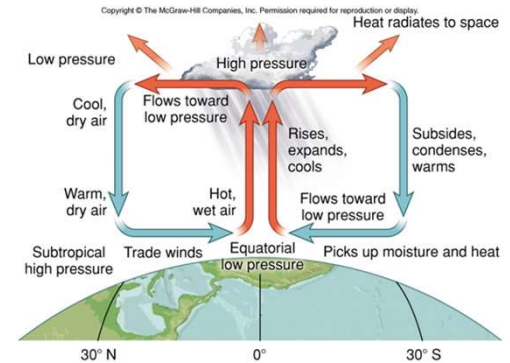




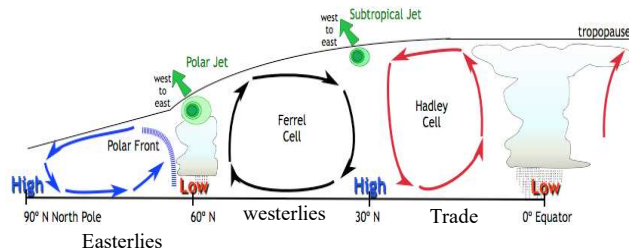
Convection cells: Hadley Cells

- **Hadley Cells** are the low-latitude overturning circulations that have air rising at the equator and air sinking at roughly 30° latitude.

- Causes trade winds.
- A lot of rain at equator.
- Dry warm air at 30°



Convection cells: Ferrel and Polar cells



- **Polar cell** - Air rises at 60° travels toward the poles and sinks at 90°. Causes easterly winds
- **Ferrel Cell** - sinking cool air near 30° and rising warm air farther poleward at 60°. Precipitation at 60°. Cause westerly winds

CORIOLIS EFFECT

Coriolis effect = the north-south air currents of the convective cells appear to be deflected from a straight path

- Results in curving global wind patterns

Because the Coriolis effect increases with an item's increasing speed, it significantly deflects airflows and as a result the wind.

In the Northern Hemisphere these winds spiral to the right and in the Southern Hemisphere they spiral to the left. This usually creates the westerly winds moving from the subtropical areas to the poles.

Planetary Winds

Global scale winds are winds that are created in the different Global circulation Cells.

- The polar easterlies blow from the Pole to 60
- The Prevailing Westerlies blow from 60 to 30
 - Near the equator
- The Trade Winds blow from 30 to 0

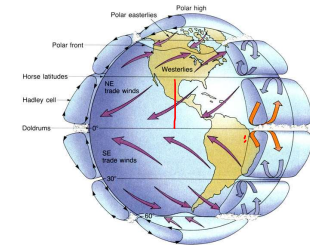
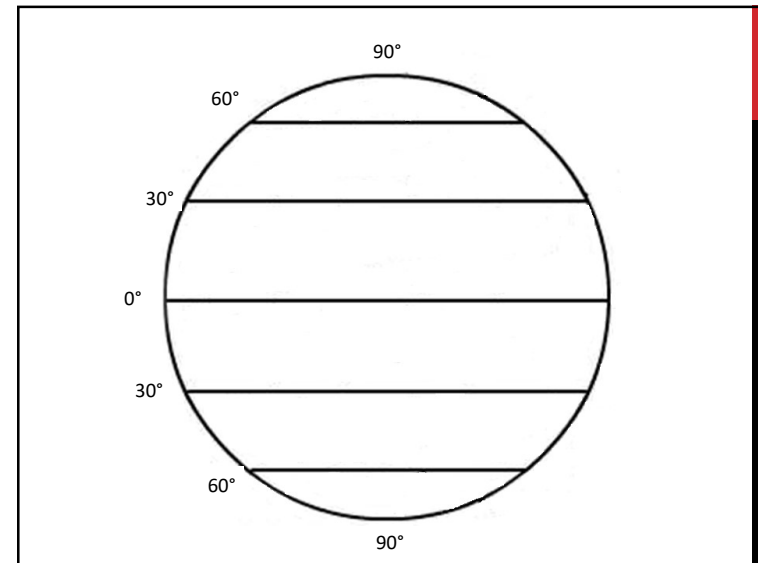
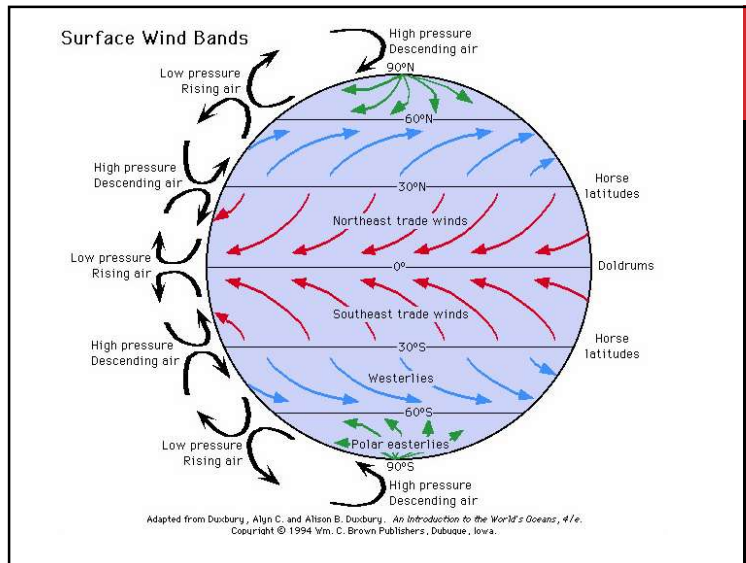


Figure 9-1 Idealized global circulation proposed for the three-cell circulation model.

[Video](#) [Current Animation](#) [GPS video](#)



OCEAN CIRCULATION PATTERNS

- An **ocean gyre** is a large system of circular **ocean** currents formed by global wind patterns and forces created by Earth's rotation.

GYRES
Whirlpools of water trapping huge collections of trash in their currents

- Home of 'The Great Pacific Garbage Patch'
 - Estimated 1.2 million tonnes of trash
 - About the size of Texas by some accounts
 - Located between Hawaii and California
- Research ships between Bermuda and Azores document floating garbage
 - Swag of micro-particles similar to the Great Pacific Garbage Patch
- 40% of all seabird species documented with plastic in or around their bodies
- Plastics have entangled birds and turned up in fish bellies
- Searchers for Malaysia Airlines Flight 370 have found ocean garbage instead of crash evidence

Video

Ocean currents

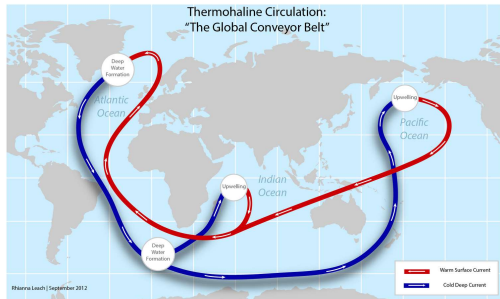
- Currents** = the upper waters of the ocean composed of vast riverlike flows
- Caused by winds and the movement of the earth
- The ocean currents move **heat** around the globe.
- Gulf Stream** currents are rapid and powerful
 - The warm water moderates Europe's climate

El Niño

Water temperatures in °C: 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

OCEAN CIRCULATION PATTERNS

Thermohaline circulation is a part of the large-scale ocean circulation that is driven by global density gradients created by surface heat and freshwater fluxes.

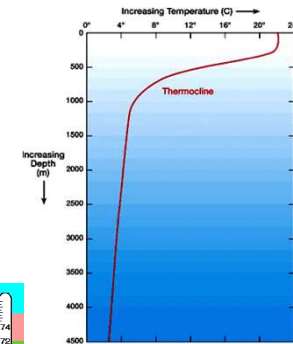
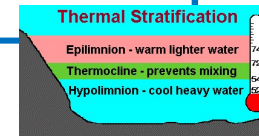


Ocean water is vertically structured

- Oceans regulate the earth's climate
 - They absorb and release heat
 - Ocean's surface circulation

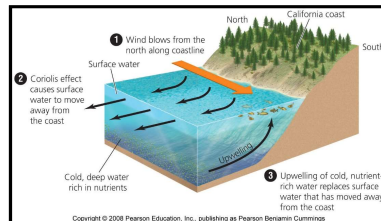
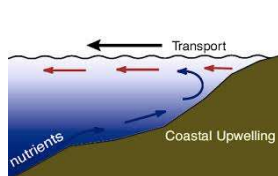
Thermal Stratification

- Epilimnion**- at the surface and warm water
- Thermocline**-transition layer between the mixed layer at the surface and the deep water layer.
- Hypolimnion**- deeper water and cold



Ocean currents

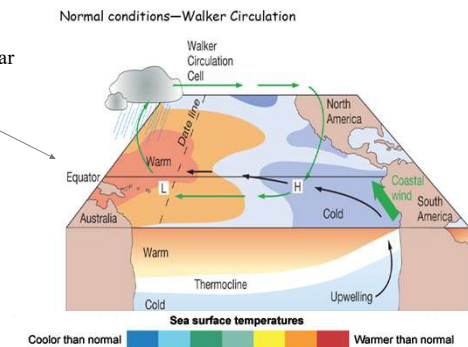
- Surface winds and heating create vertical currents**
- Upwelling** = the vertical flow of cold, deep water towards the surface
 - High primary productivity and lucrative fisheries
 - Also occurs where strong winds blow away from, or parallel to, coastlines



Simulation

Normal Ocean currents

- Strong trade winds** keep warm water near New Guinea and Australia
- Nutrient-rich water **upwells** along the west coast of the Americas
- Heavy rains** are concentrated in the western Pacific Ocean.

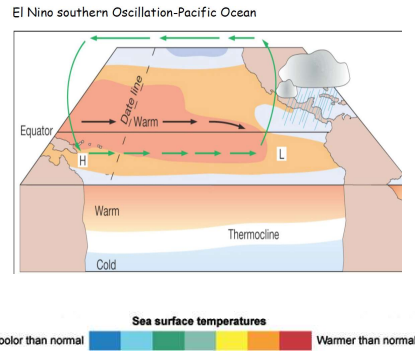


- These nutrients support large populations of phytoplankton, zooplankton, fish, and fish-eating sea birds.
- El Niño and La Niña are changes in climate patterns that can trigger mild to extreme weather changes over at least 1/3 of the globe.

ENSO

El Niño/Southern Oscillation

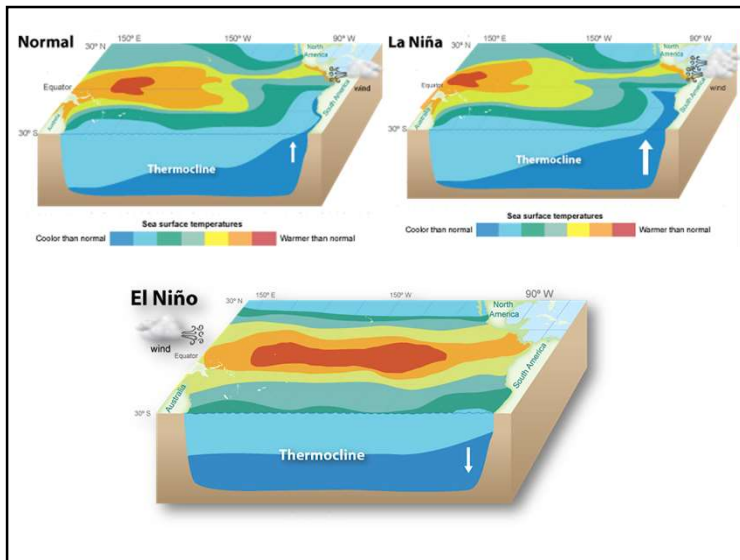
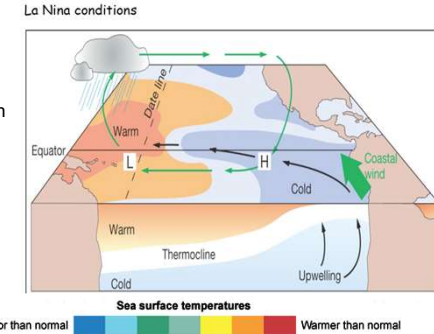
- Warm pool migrates eastwards
- High pressure in eastern Pacific weakens
- Weaker trade winds
- Thermocline deeper in eastern Pacific
- Downwelling
- Lower biological productivity
 - Corals particularly sensitive to warmer seawater
- Occur every two to seven years



[Simulation](#)
[El Niño Animation](#)

La Nina

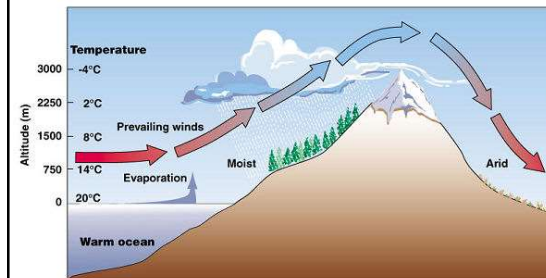
- Trade winds increase, blowing stronger from east to west
 - Western Pacific Ocean becomes warmer
 - Eastern Pacific Ocean near coast of South America becomes colder
 - Warm ocean waters, clouds and moisture are pushed away from North America. Causes hurricanes and tornadoes in US.
- Causes
 - Hot, dry weather with droughts in southern US
 - Cold weather and excess rainfall in the northeastern US.
 - Enhanced upwelling
 - Enhanced trade winds
- **Similar to normal conditions, just enhanced.**
- Occur every few years and can persist for as long as two years



RAIN SHADOW

•Rain Shadow

- Dry area on the eastern side of mountains
- The smaller the mountains, the weaker the rain shadow effect, and vice versa.



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Temperature Inversion

- Air circulation usually stops pollution from accumulating to dangerous levels.
- Inversions trap pollution near the Earth's Surface
- Temperature usually decreases with altitude
- But a warm layer above a cold layer will trap pollution
- (Hot air rises, right? Hot smoke rises, but if atmosphere is just as warm, the smoke stays put)

Video

