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AP Environmental Science

"Cheat" Sheet

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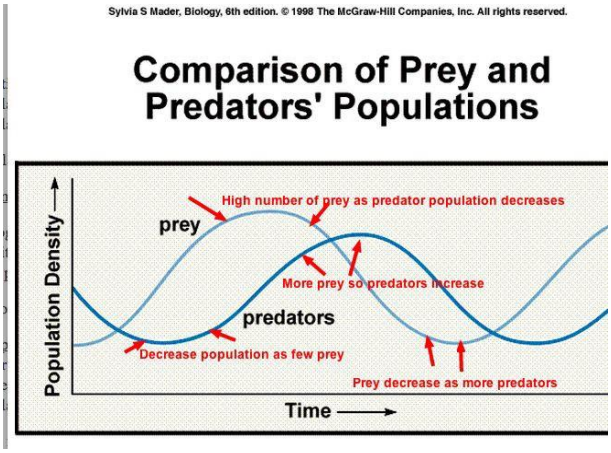
Unit 1 Ecosystems Big Ideas

1.1 Introduction to Ecosystems

1. Predator-prey relationship

Predator: organism that eats another organism

Prey: organism eaten by prey



2. Symbiotic Relationships

Symbiosis: relationship between two species in an ecosystem

Types

(1) Mutualism - both benefit

(2) Commensalism - one benefits/other isn't affected

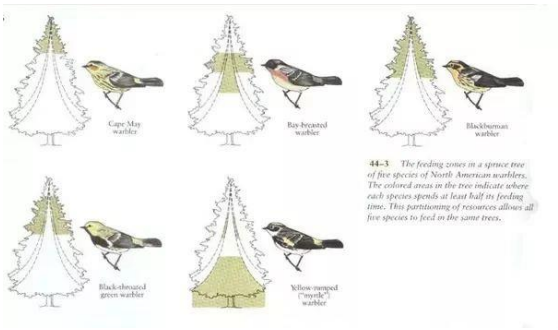
(3) Parasitism - one benefits (parasite)/other is harmed (host)

	Organism 1	Organism 2	Example
Mutualism	Benefits	Benefits	Bacteria in human colon
Commensalism	Benefits	Neither benefits nor is harmed	*Staphylococcus* on skin
Parasitism	Benefits	Is harmed	Tuberculosis bacteria in human lung

3. Competition

-occurs when resources are limited

-reduced by Resource Partitioning



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1.2 Terrestrial Biomes

1. Biome

-area with characteristic plants & animals
-defined by climate (temperature & precipitation)

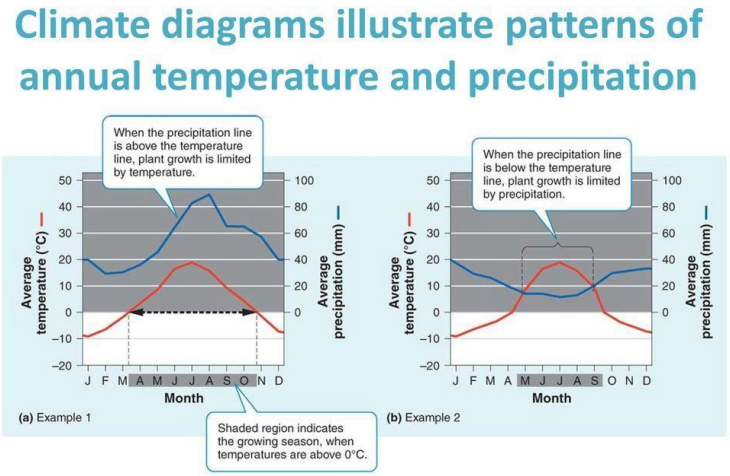

Figure 12.4
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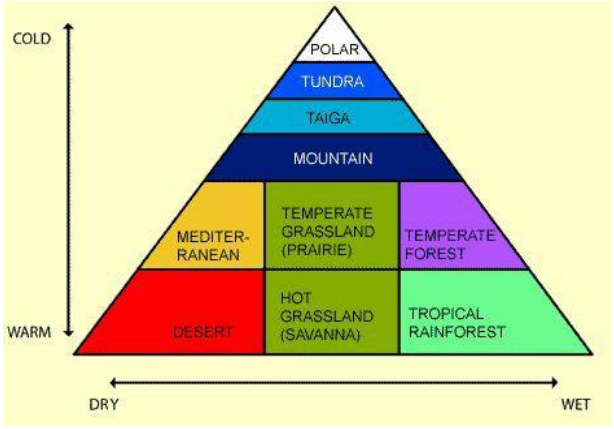
Climate diagrams. Climate diagrams display monthly temperature and precipitation values, which help determine the productivity of a biome.



2. Types
   (1) Taiga (Boreal, Northern coniferous forest)
   (2) Temperate rainforests
   (3) Temperate seasonal forests (deciduous)
   (4) Tropical rainforests
   (5) Shrubland
   (6) Temperate grasslands
   (7) Savanna
   (8) Desert
   (9) Tundra
3. Factors Influencing Global Distribution of Resources
   Climate, Geography, Latitude, Altitude, Nutrient availability, Soil

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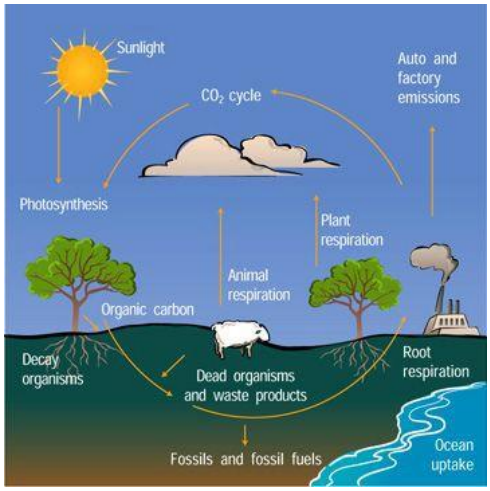
4. Worldwide Distribution of Biomes
   -is dynamic (changes) and affected by global climate change

1.3 Aquatic Biomes

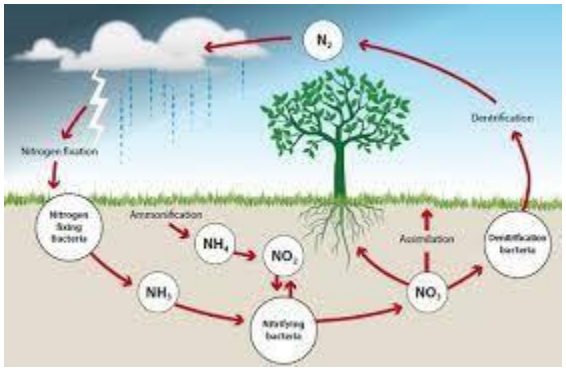
1. Freshwater Biomes
   Streams, Rivers, Ponds, Lakes
   -vital resource for drinking water
2. Marine Biomes
   oceans, coral reefs, marshland, estuaries
   -Algae supplies large amount of O2 AND removes CO2 from atmosphere (through photosynthesis)
3. Factors Influencing Global Distribution of Resources
   salinity, depth, turbidity, nutrient availability, temperature

1.4 Carbon Cycle



Reservoirs: plants, animals, fossil fuels, atmosphere

1.5 Nitrogen Cycle



Reservoirs: atmosphere, plants, animals
Nitrogen fixation: N2 converted to NH3, NO2-, NO3-

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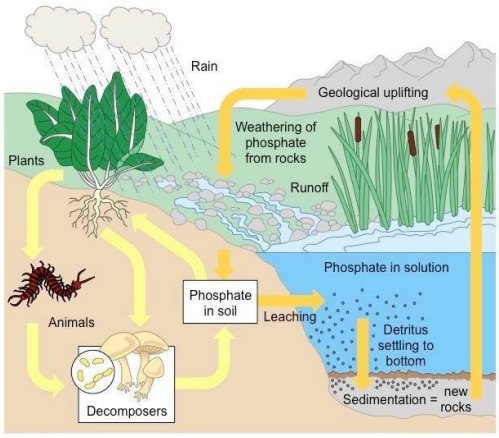
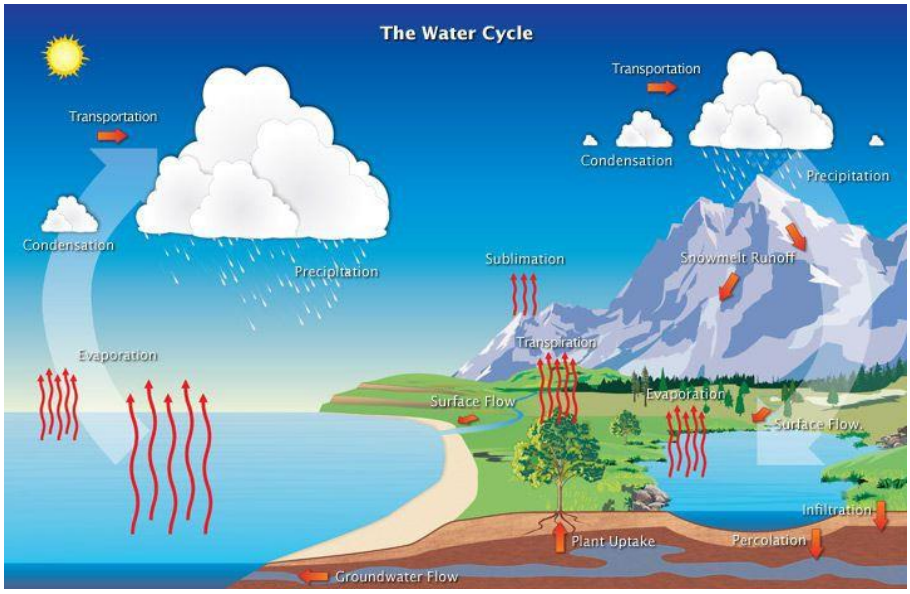
1.6 Phosphorus Cycle



Reservoirs: rocks, soil, water, plants
NO ATMOSPHERIC COMPONENT (No gaseous form)
-is a Limiting Factor in ecosystems (because it is scarce)

1.7 Hydrologic (Water) Cycle



Reservoirs: oceans, ice caps, groundwater

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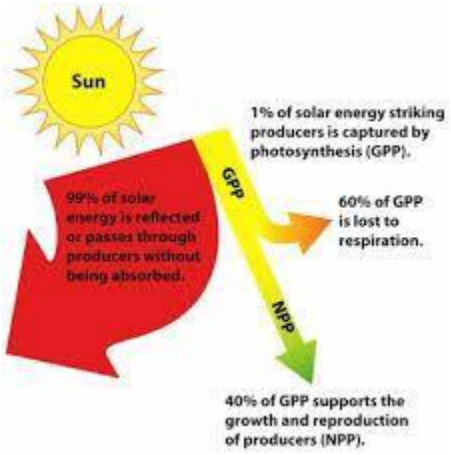
1.8 Primary Productivity

-rate at which solar energy (sunlight) is converted into organic compounds through

Photosynthesis



GPP (Gross Primary Productivity)

-TOTAL rate of photosynthesis in an area

NPP (Net Primary Productivity)

NPP = GPP - Respiration

1.9 Trophic Levels

1.10 Energy Flow & 10% Rule

1st Law of Thermodynamics - total amount of energy stays the same

2nd Law of Thermodynamics - as energy changes from one form to another, some is lost as heat

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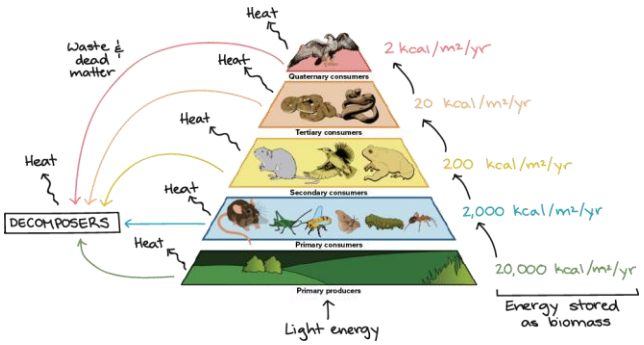
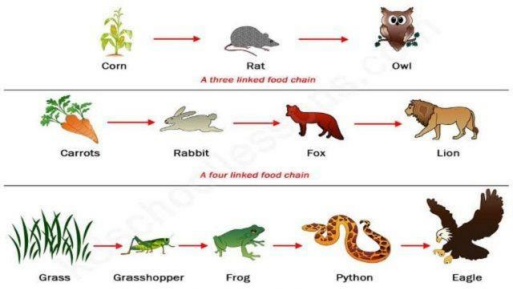
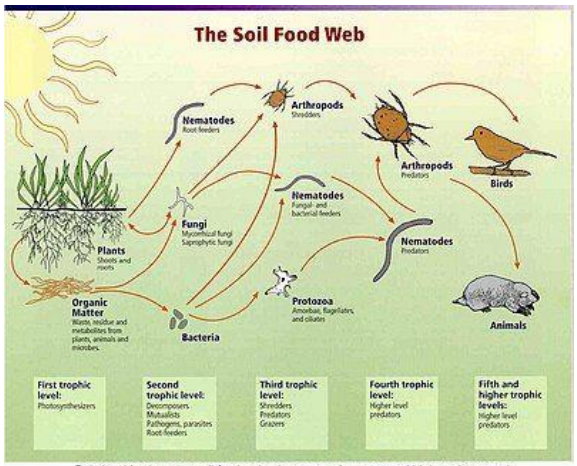


1.11 Food Chains & Food Webs

Food Chain

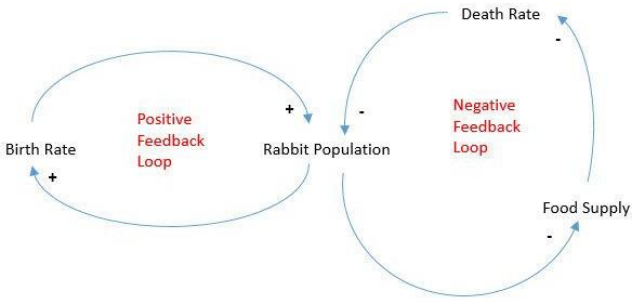


Food Web



Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html

Feedback loops compared



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Unit (# 2)--The Living World: Biodiversity

Biodiversity Outline

I. Levels of Diversity
   A. species diversity (**biodiversity**)
   B. Ecosystem diversity
   C. Genetic diversity

II. Benefits of Biodiversity
   A. species are connected to ecosystems
   B. for species and population survival
   C. medical, industrial, and agricultural uses
   D. ethics, aesthetics, and recreation

III. Species at risk
   A. small populations in limited areas
   B. those that migrate
   C. those that need large or special habitats
   D. exploited by humans

IV. How humans affect biodiversity
   A. **H** – Habitat Destruction/Alteration/Fragmentation
   B. **I** – Invasive/exotic/alien species
   C. **P** – Pollution
   D. **P** – Human population growth
   E. **C** – Climate Change
   F. **O** – Overexploitation – harvesting, hunting, poaching
   G. Disease - can sometimes be caused/spread by us

V. Areas of critical biodiversity
   A. Tropical Rain Forests
   B. Coral Reefs & Coastal Ecosystems
   C. Islands

VI. Ways to protect biodiversity
   A. Captive-breeding programs
   B. Preserving genetic material (germ-plasm banks)
   C. Zoos, Aquariums, Parks, Botanical Gardens
   D. Education
   E. Preserving habitats and ecosystems (BEST METHOD)

VII. Endangered Species Act
   A. Established by US Congress in 1973
   B. USFWS must compile a list of endangered & threatened species
   C. Species on the list may not be caught or killed, uprooted from federal lands, sold or traded
   D. The federal govt may not carry out any project that jeopardizes species on the list
   E. USFWS must prepare a recovery plan for species on the list

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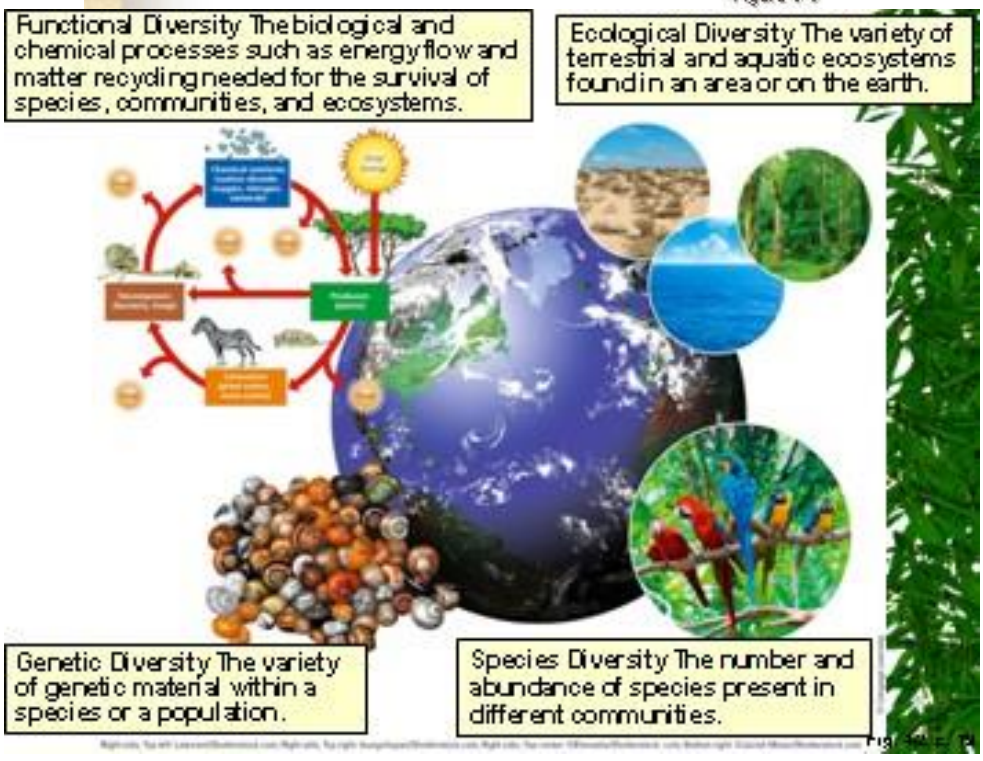
2.1 Introduction to Biodiversity

Biodiversity in an ecosystem includes genetic, species, and habitat diversity.

- Biodiversity – variety of different species
- Species – set of individuals who can mate and produce fertile offspring
  - 8 million to 100 million species
  - About 2 million identified
  - Unidentified species are mostly in rain forests and oceans

Figure 3-3

- 

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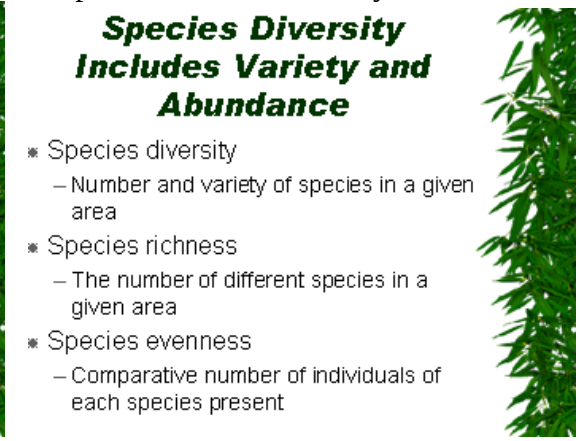
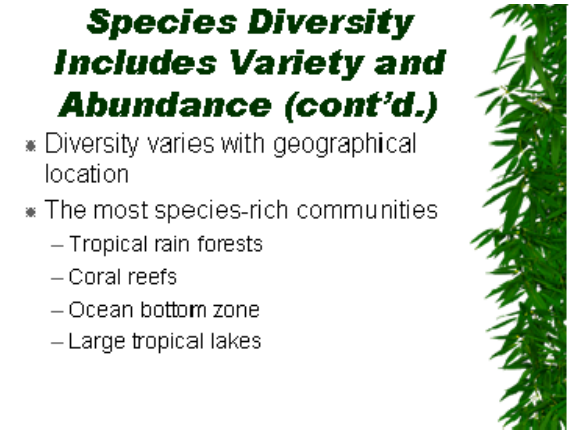
- The more genetically diverse a population is, the better it can respond to environmental stressors. Additionally, a population bottleneck can lead to a loss of genetic diversity.
- Ecosystems that have a larger number of species are more likely to recover from disruptions.
- Loss of habitat leads to a loss of specialist species, followed by a loss of generalist species. It also leads to reduced numbers of species that have large territorial requirements.
- Species richness refers to the number of different species found in an ecosystem.





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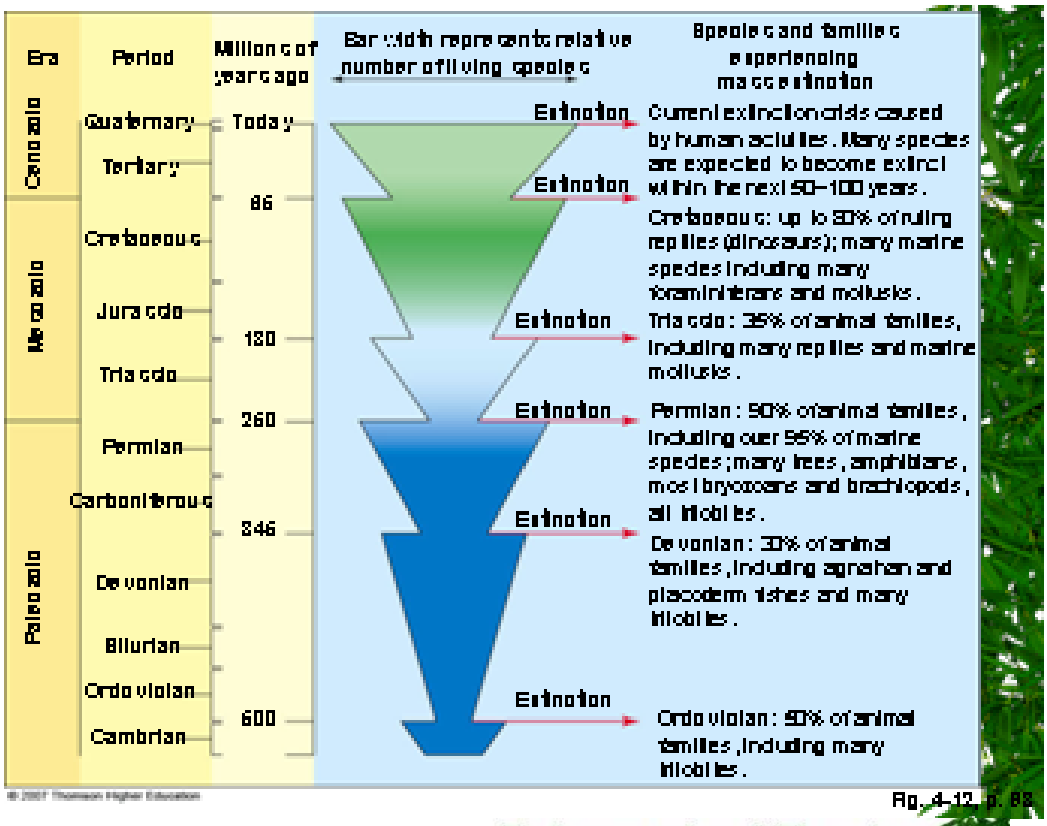
- 

Fig. 4-12, p. 88

- 

Regionally extinct - In areas a species is normally found
Functionally extinct - To the point at which species can no longer play a functional role in the ecosystem

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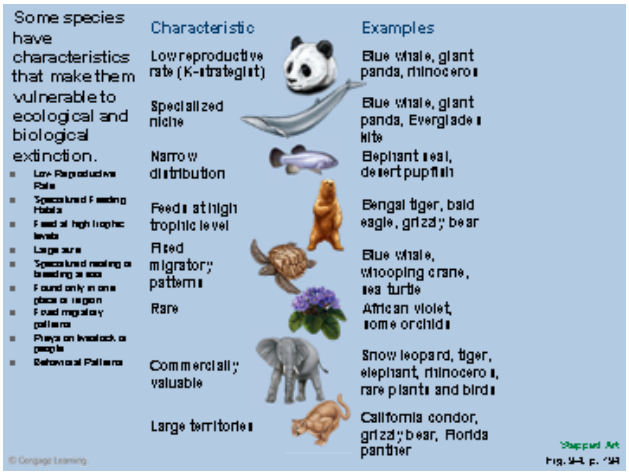

2.2 Ecosystem Services

- There are four categories of ecosystem services: provisioning, regulating, cultural, and supporting.
- Anthropogenic activities can disrupt ecosystem services, potentially resulting in economic and ecological consequences.
- Print FRQ 11-1d for list of ecosystem services:
  - https://secure-media.collegeboard.org/apc/ap11_env_sci_scoring_guidelines.pdf

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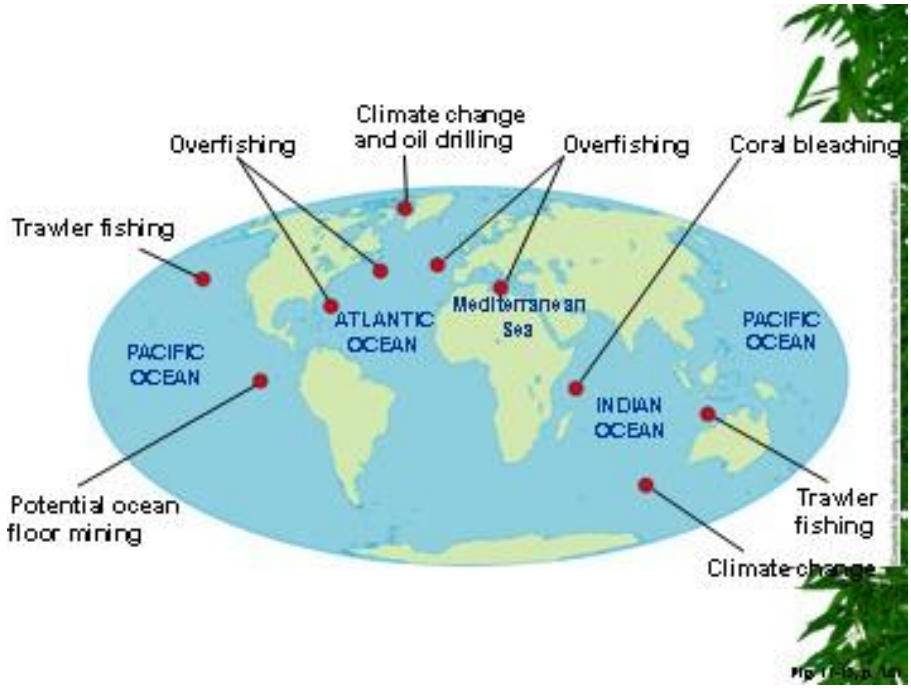

2.3 Island Biogeography

- Island biogeography is the study of the ecological relationships and distribution of organisms on islands, and of these organisms' community structures.
- Islands have been colonized in the past by new species arriving from elsewhere.

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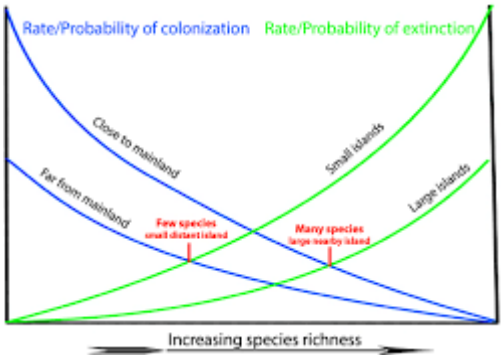
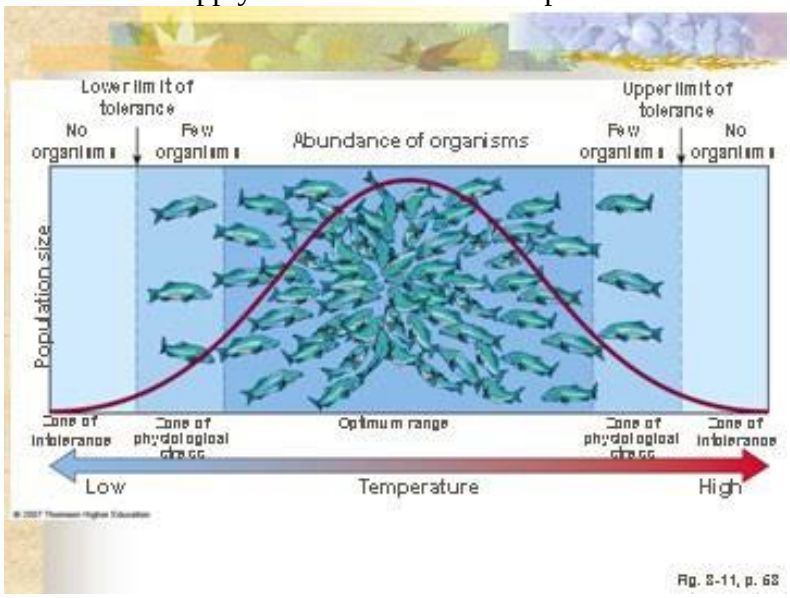


FIG. 8. *Upper:* The scaffolding constructed around E7, complete except for the top walkway. *Lower:* the fumigation tent over E7.

- Many island species have evolved to be specialists versus generalists because of the limited resources, such as food and territory, on most islands. The long-term survival of specialists may be jeopardized if and when invasive species, typically generalists, are introduced and outcompete the specialists.

2.4 Ecological Tolerance

- Ecological tolerance refers to the range of conditions, such as temperature, salinity, flow rate, and sunlight that an organism can endure before injury or death results. Ecological tolerance can apply to individuals and to species.



2.5 Natural Disruptions to Ecosystems

- Natural disruptions to ecosystems have environmental consequences that may, for a given occurrence, be as great as, or greater than, many human-made disruptions.

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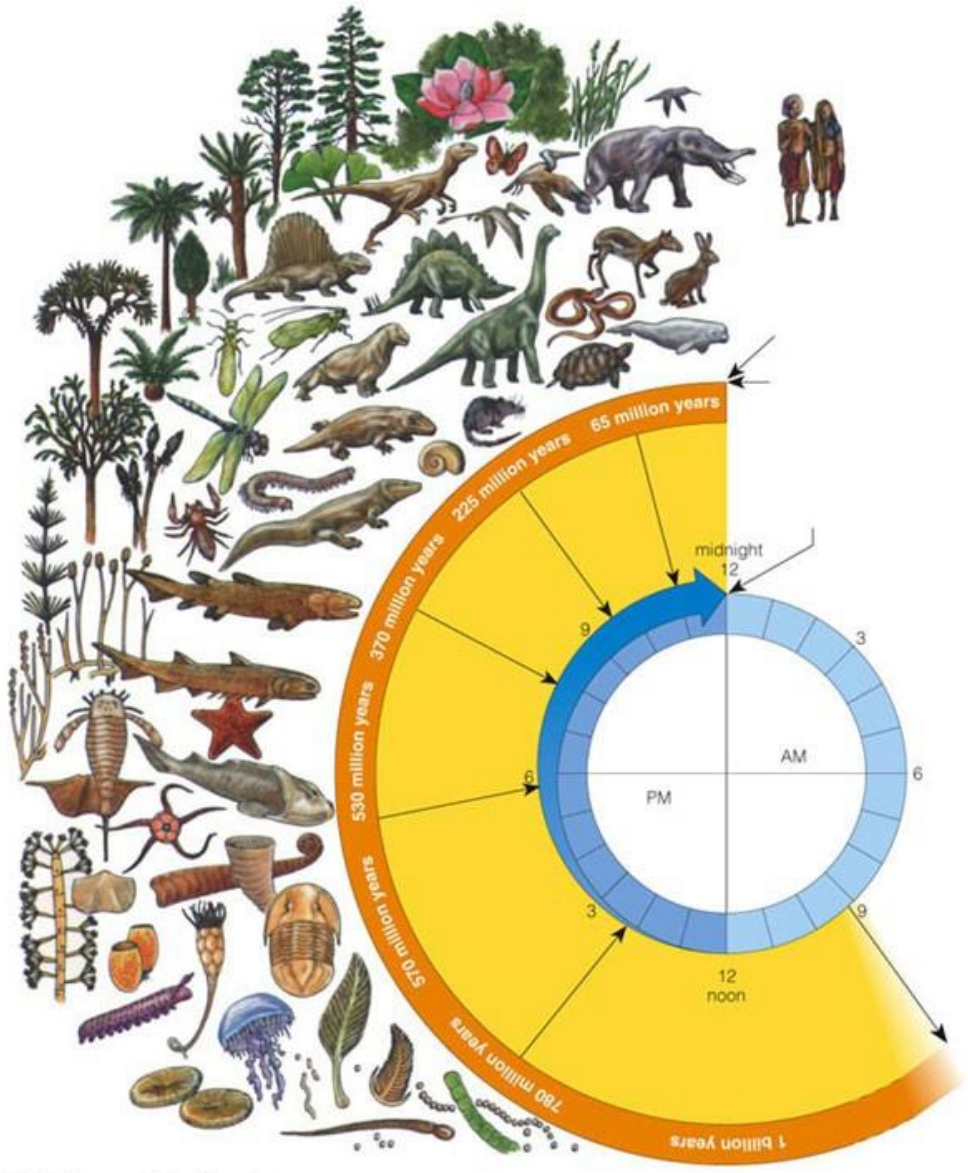
- Earth system processes operate on a range of scales in terms of time. Processes can be periodic, episodic, or random.



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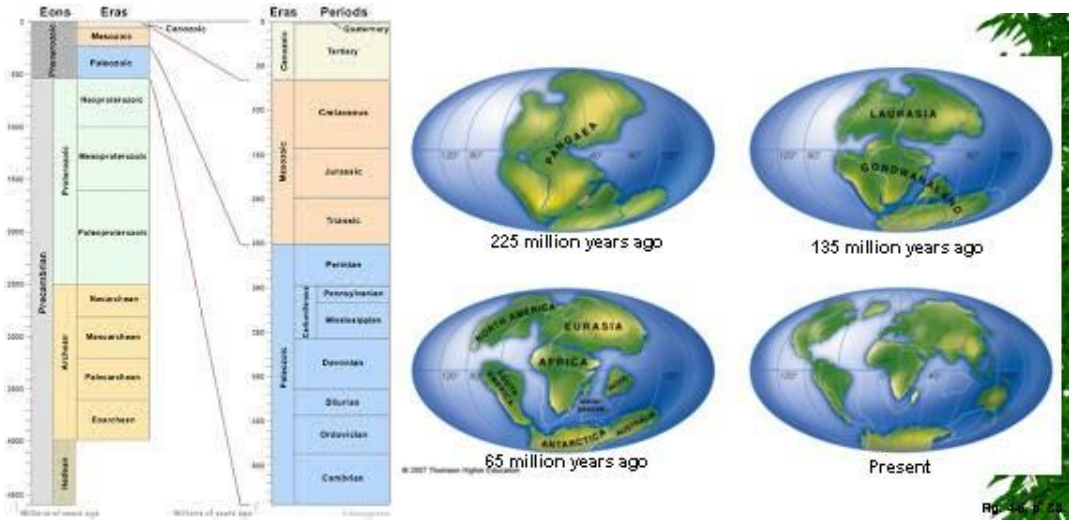
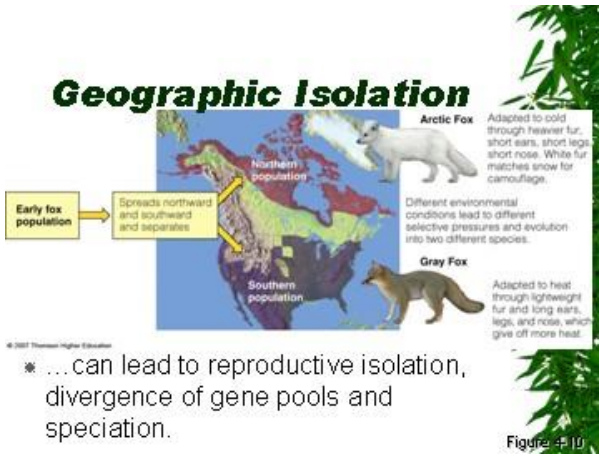
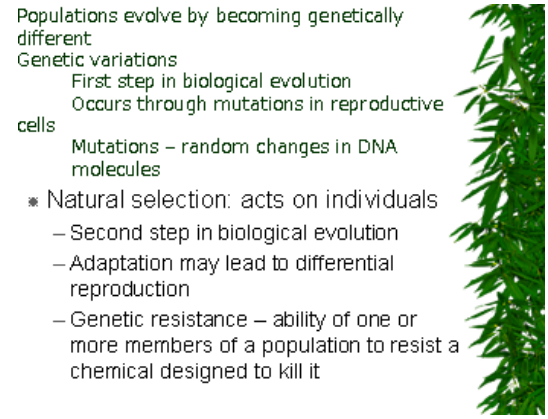


- Earth's climate has changed over geological time for many reasons.
- Sea level has varied significantly as a result of changes in the amount of glacial ice on Earth over geological time.
- Major environmental change or upheaval commonly results in large swathes of habitat changes.
- Wildlife engages in both short- and long-term migration for a variety of reasons, including natural disruptions.





2.6 Adaptations

- Organisms adapt to their environment over time, both in short- and long-term scales, via incremental changes at the genetic level.
- Environmental changes, either sudden or gradual, may threaten a species' survival, requiring individuals to alter behaviors, move, or perish.

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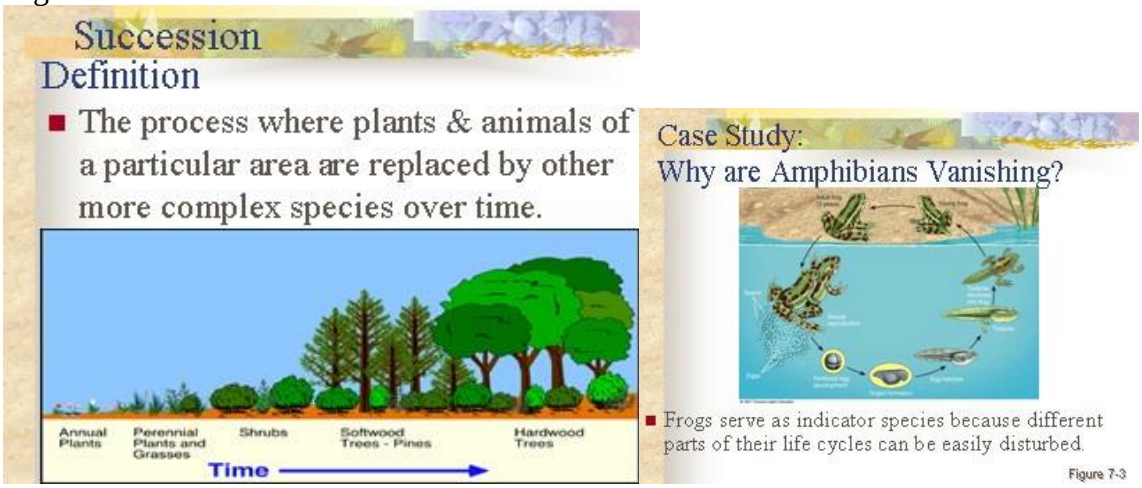
2.7 Ecological Succession

- There are two main types of ecological succession: primary and secondary succession.
- Primary begins with a lifeless area where there is no soil (ex. bare rock). Soil formation begins with lichens or moss.
- 

- A keystone species in an ecosystem is a species whose activities have a particularly significant role in determining community structure.
- An indicator species is a plant or animal that, by its presence, abundance, scarcity, or chemical composition, demonstrates that some distinctive aspect of the character or quality of an ecosystem is present.
- Pioneer members of an early successional species commonly move into unoccupied habitat and over time adapt to its particular conditions, which may result in the origin of new species.
- Lichens – pioneer species
- Foundation species can create and enhance habitats that can benefit other species in a community.Elephants push over, break, or uproot trees, creating forest openings promoting grass growth for other species to utilize.
- Succession in a disturbed ecosystem will affect the total biomass, species richness, and net productivity over time.

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Unit 3: Populations

3.1 Generalist and Specialist Species

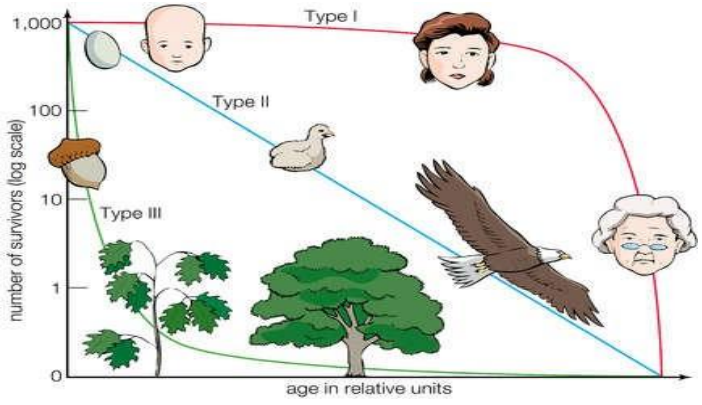
- Generalists can live in a variety of habitats or feed on a variety of species
- Specialists are specialized to live in a specific habitat or feed on a small group of species
  - Niche specialists are vulnerable to extinction if conditions change because the loss of a favored habitat or food source leaves them with few alternatives for survival
  - Niche generalists fare better under changing conditions because they have a number of alternative habitats and food sources available

3.2 K-selected and r-selected Species

- ***K*-Selected Species** have a low intrinsic growth rate and their abundance is determined by the carrying capacity of the environment.
  - Traits of *K*-selected species: large organisms, reach reproductive maturity relatively late in life, have few, large offspring, provide substantial parental care (ex. elephants)
- ***r*-Selected Species** have a high intrinsic growth rate and do not remain near their carrying capacity, but exhibit cycles of overshoots and die-offs.
  - Traits of *r*-selected species: small organisms, reach reproductive maturity relatively early in life, reproduce frequently and have many, small offspring, provide little or no parental care (ex. insects)

3.3 Survivorship Curves

- Survivorship curves are species' distinct patterns of survival over time.
  - *Type I survivorship curves:* high survival rates throughout most of the species' life spans with large numbers of die-offs as they approach old age (*K*-selected)
  - *Type II survivorship curves:* relatively constant decline in survivorship throughout the species' life spans (ex. small birds and mammals)



  - *Type III survivorship curves:* low survivorship early in life with few individuals reaching adulthood (*r*-selected)

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3.4 Carrying Capacity

- The exponential growth model describes a continuously increasing population that grows at a fixed rate; produces a J-shaped curve when it is graphed
- The logistic growth model describes a population whose growth is initially exponential, but slows as the population approaches the carrying capacity of the environment; produces a S-shaped curve when it is graphed.
- If a population overshoots the environment's carrying capacity there is less food available than needed to feed the offspring; this can produce a die-off, or population crash

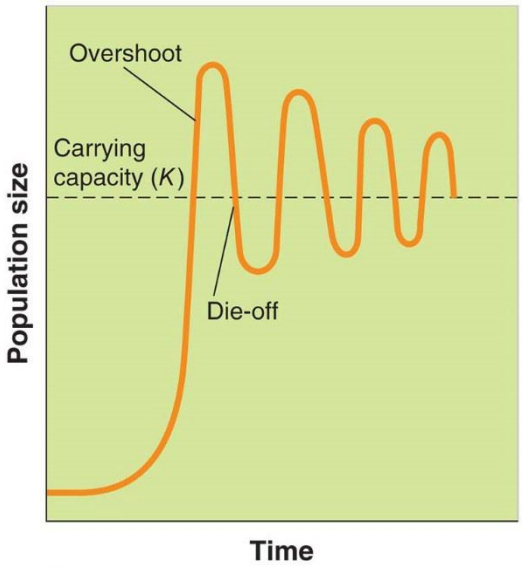

Figure 6.9
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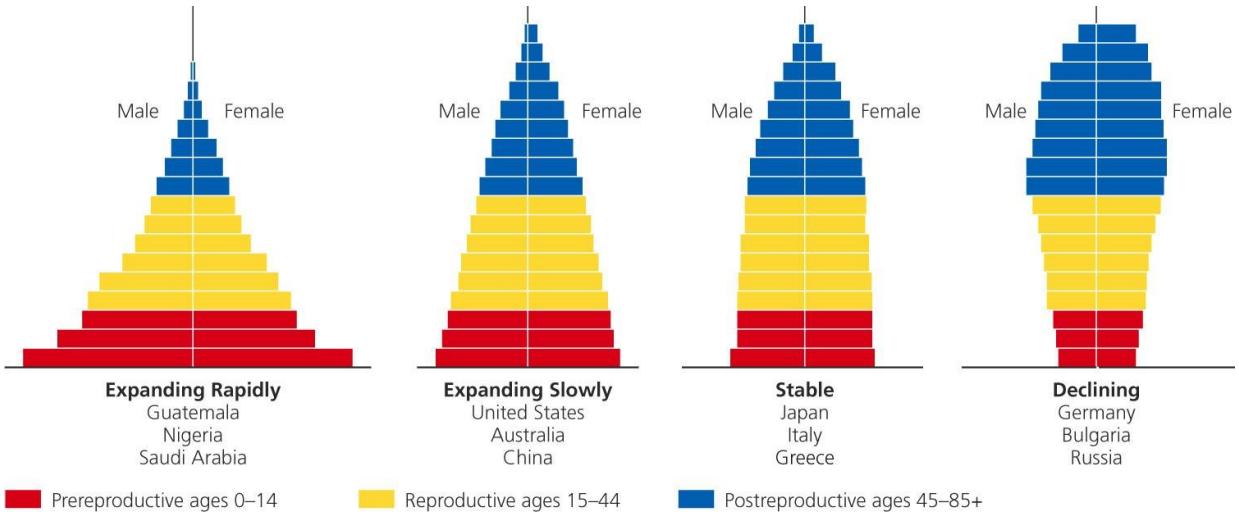
3.5 Population Growth and Resource Availability

- Density-dependent factors have a greater effect on the population as its density increases. (ex. food availability, parasites, diseases)
- A limiting resource is a resource that a population cannot live without and which occurs in quantities lower than the population would require to increase in size.
- Density-independent factors affect a population's size regardless of its density. (ex. natural disasters)

3.6 Age Structure Diagrams

- Age structure diagrams are visual aids that show the distribution of males and females in each age group.
  - If a country has more young people than old people, its age structure diagram will be wider at the bottom, this is called a population pyramid.
  - Countries with little difference between the numbers of individuals in different age groups looks more like a column.
  - A country with more older than younger people has a diagram that resembles an inverted pyramid.



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3.7 Total Fertility Rate

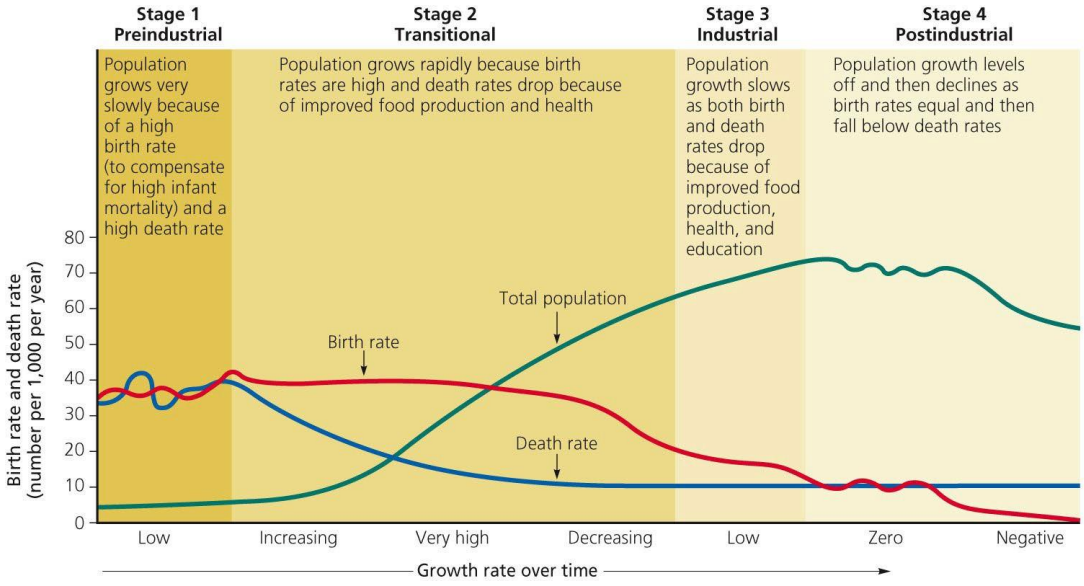
- Total fertility rate (TFR) is an estimated of the average number of children that each woman in a population will bear throughout her reproductive years. (2.1 in the US)
- Replacement-level fertility is the TFR required to offset the average number of deaths in a population so that the current population size remains stable.
- Infant mortality rate is the number of babies out of every 1,000 born who die before their first birthday; availability of prenatal care is an important predictor of infant mortality.

3.8 Human Population Dynamics

- In 1798 Thomas Malthus noticed that the human population was growing exponentially while the food supply was only growing linearly; he concluded that the human population would eventually exceed its food supply.
- Doubling time is the number of years it takes for a population to double, assuming the growth rate is constant.; doubling time (in years) = 70/growth rate

3.9 Demographic Transition

- The theory of demographic transition states that as a country moves from a subsistence economy to industrialization and increased affluence, it undergoes a predictable shift in population.
  - **Phase One**: preindustrial; early steady state (high birth & death rates); short life expectancy, high infant mortality rate; subsistence economy
  - **Phase Two**: transitional; death rates decline while birth rates remain high (large TFR); better sanitation, clean drinking water, increased access to food, goods & health care (vaccines)
  - **Phase Three**: industrial; birth rate & death rates decrease (return to steady state); economy & educational system improve, income increases
  - **Phase Four:** postindustrial; declining population, higher proportion of elderly people; pension programs and social security strained; people need to immigrate in to care for elderly



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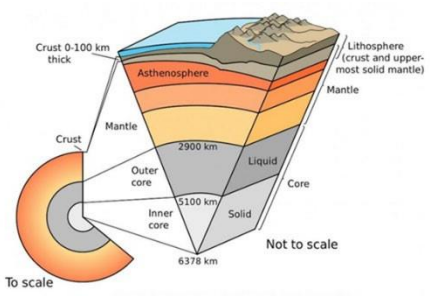
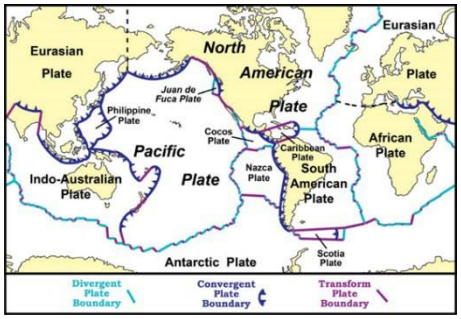
Unit 4: Earth Systems and Resources

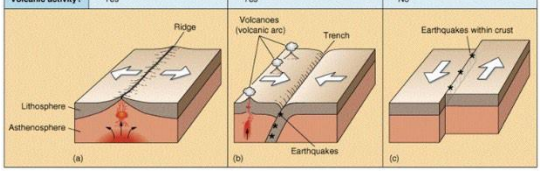
4.1 Plate Tectonics

- Earth's structure
  - Lithosphere
  - Mantle
  - Core
- 3 Plate Boundary Types
  - Convergent
  - Divergent
  - Transform
- Subduction Zones
- Earthquakes (Richter scale)
- Volcanoes



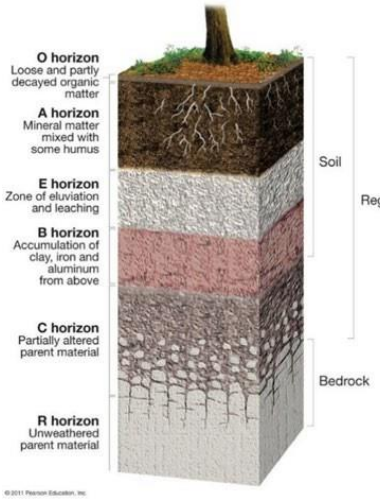


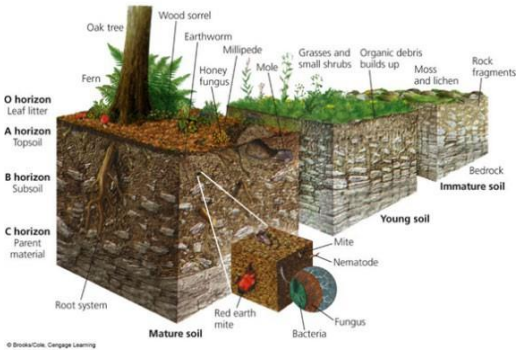
Type of Margin	Divergent	Convergent	Transform
Motion	Spreading	Subduction	Lateral sliding
Effect	Constructive (oceanic lithosphere created)	Destructive (oceanic lithosphere destroyed)	Conservative (lithosphere neither created or destroyed)
Topography	Ridge/Rift	Trench	No major effect
Volcanic activity?	Yes	Yes	No



4.2 Soil Formation & Erosion

- Weathering (biological, chemical, physical)
- Transportation
- Erosion
- Deposition
- Soil Horizons
  - O
  - A
  - E
  - B
  - C
  - R





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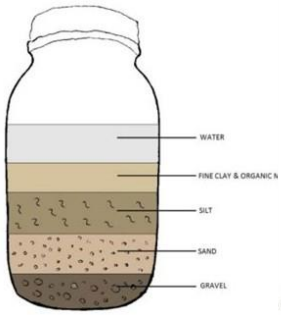
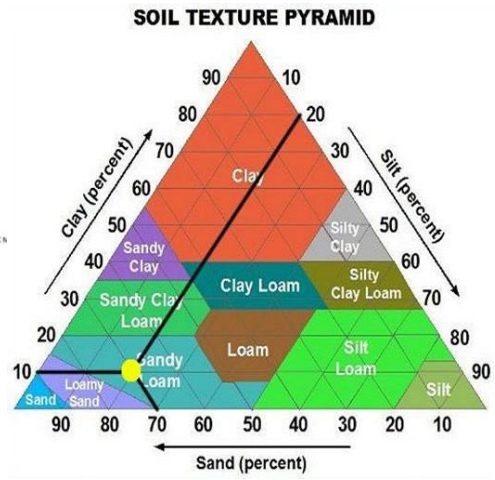
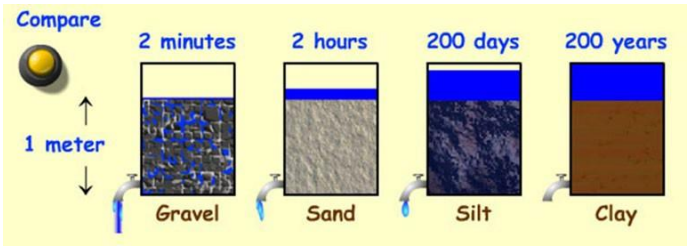
4.3 Soil Composition & Properties

- Water Holding Capacity
- Porosity (pore space)
- Permeability (rate of water flow)
- Soil Testing
  - Nutrients (N, P, K)
  - pH
  - Texture
- Soil Triangle
  - Sand
  - Silt
  - Clay

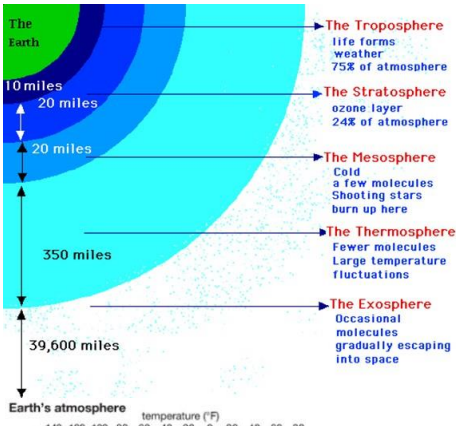


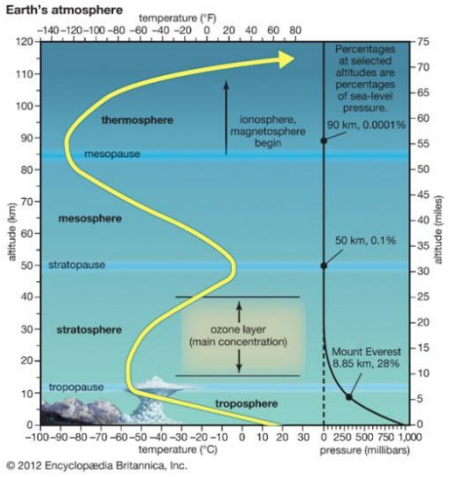




4.4 Earth's Atmosphere

- Current Composition
  - 78% Nitrogen
  - 21% Oxygen
  - 0.9% Argon
  - 0.03% CO_2
- Layers & Characteristics
  - Troposphere
    - Weather
    - Greenhouse Gases
  - Stratosphere
    - Ozone (UV filter)
  - Mesosphere
    - Meteors burn up
  - Thermosphere
    - Aurora Borealis
  - Exosphere
- Temperature Changes





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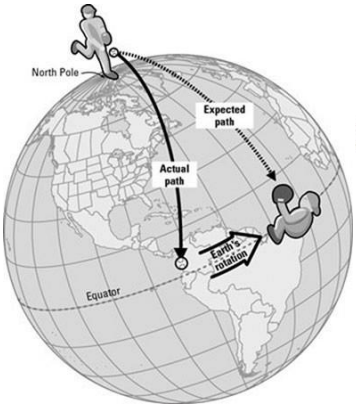
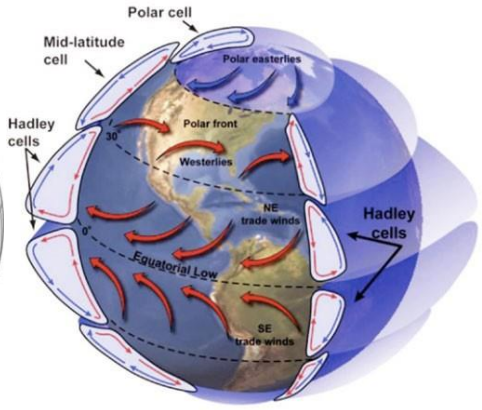
4.5 Global Wind Patterns

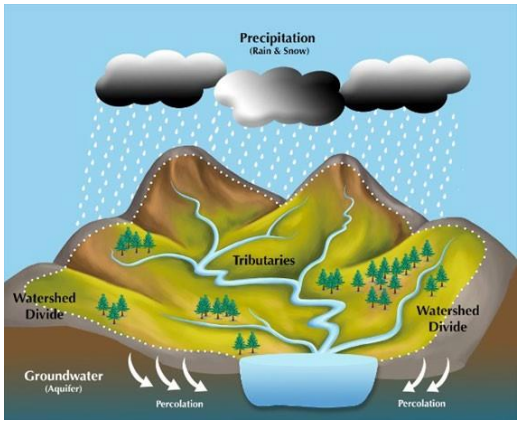
- Winds blow from high to low pressure (from sinking cool air to rising warm air)
- Convection Cells
  - Hadley
  - Ferrel
  - Polar
- Coriolis Effect





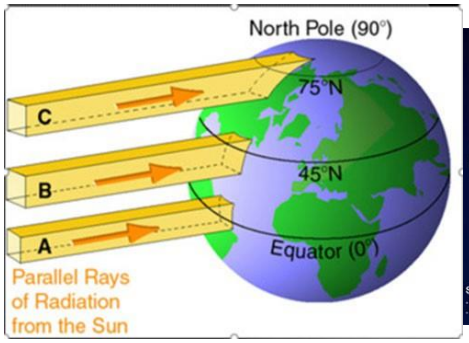
4.6 Watersheds

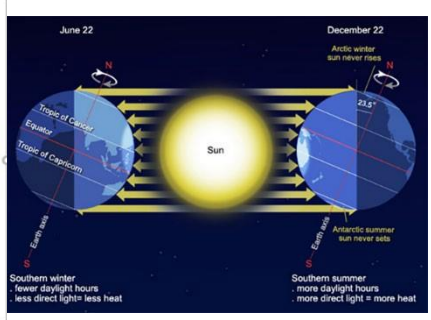
- Topography
- Precipitation
- Percolation
- Tributaries
- Rivers
- Groundwater
- Divide



4.7 Solar Radiation & Earth's Seasons

- Earth's Axis has 23° Tilt
- Rotation
- Insolation
- Angle of Incidence (zero at the equator, 90° at the poles)
- Latitude
- Hemispheres
- Hours of sunlight





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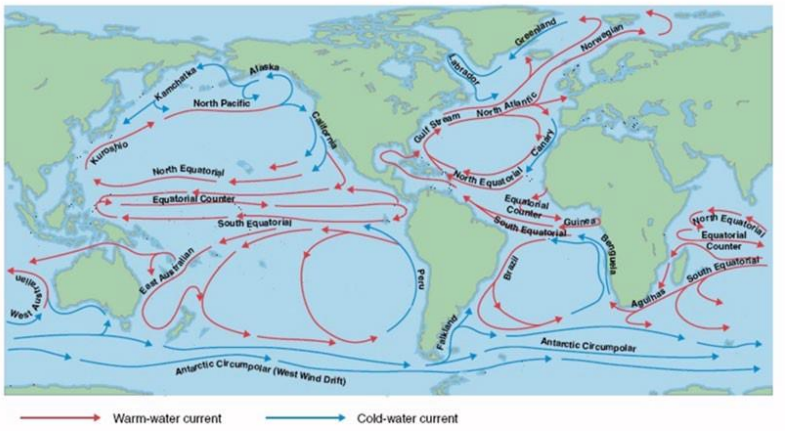
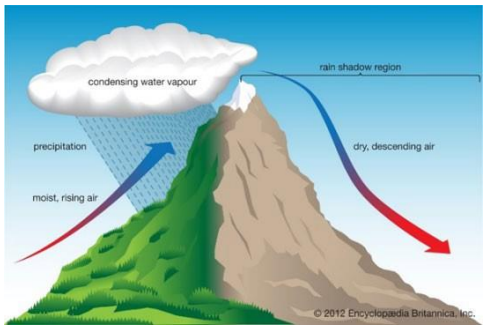
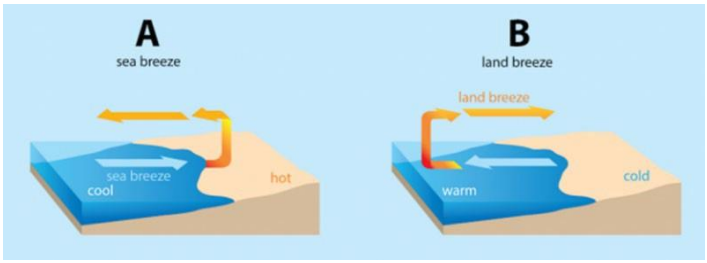
4.8 Earth's Geography & Climate

- Ocean Currents move heat from equator
- Temperature moderating effect of large bodies of water
- Land heats/cools faster than oceans
- Rainshadow Effect

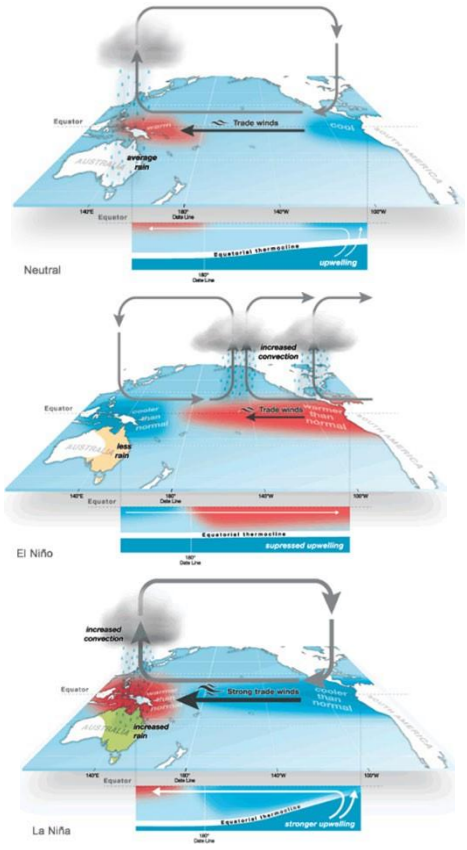






4.9 El Nino & La Nina

- Pacific Ocean
- Normal/Neutral
  - Winds blow E-W
  - Upwelling in S. America
  - Warm & wet in Asia
- El Nino
  - Winds weaken or stop
  - Upwelling stops
  - Warm & wet in S. America
- La Nina
  - "extreme" normal



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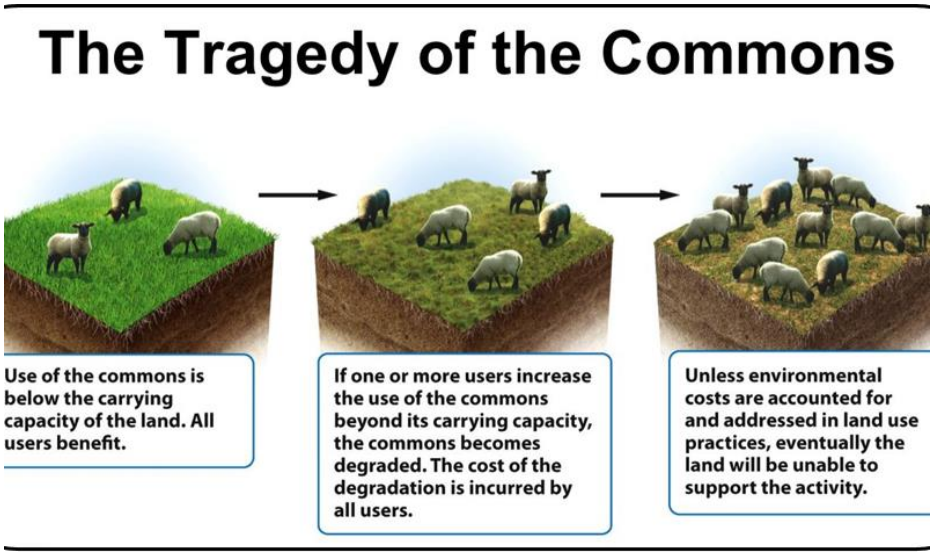
Unit 5--Land & Water Use

5.1 The Tragedy of the Commons

-individuals use shared resources selfishly resulting in depleted resources



5.2 Clearcutting

-removal of all trees from an area

Advantage: more land for crops/animals leading to economic benefit

Disadvantages: increases soil erosion, soil & stream temps., flooding, atmospheric CO2

5.3 The Green Revolution

-use of mechanization, GMOs, fertilization, irrigation, pesticides to INCREASE food production

Advantage: increases profits & efficiency

Disadvantage: increased use of fossil fuels

5.4 Impact of Agricultural Practices

-practices include tilling, slash-and-burn farming, use of fertilizers

-causes eutrophication, soil degradation, habitat destruction, erosion

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5.5 Irrigation Methods

-70% of freshwater used for irrigation

-excess irrigation leads to *Waterlogging* - excess water in soil, raises water table, inhibits plant root absorption of O2

Types

1) Furrow irrigation: furrows flooded between crop rows
   -inexpensive
   -low efficiency (approx. 50% water loss)
2) Flood irrigation: flooding field
   -low efficiency (approx. 20% water loss)
   -leads to waterlogging
3) Spray irrigation: spray water across field from sprinkler system
   -low efficiency (approx. 25% water loss)
   -expensive
   -requires energy to run (fossil fuels)
4) Drip irrigation: water released through perforated hoses at plant roots
   -higher efficiency (approx. 5% water loss)
   -expensive

Salinization: salts in groundwater remain in soil after water evaporates causing soil to become toxic to plants

Aquifers: underground freshwater reservoirs
-depleted due to overuse for agricultural irrigation
EX: Ogallala Aquifer

5.6 Pest Control Methods

Common methods include: pesticides, herbicides, fungicides, rodenticides, insecticides

-leads to Resistance

-decreases crop damage

-increases crop yields

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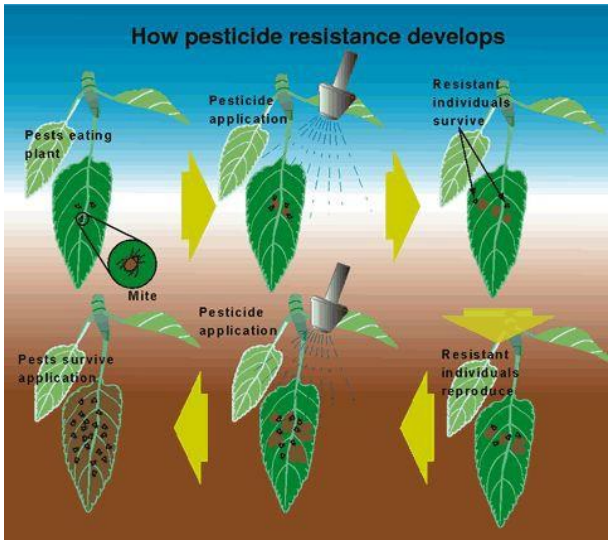
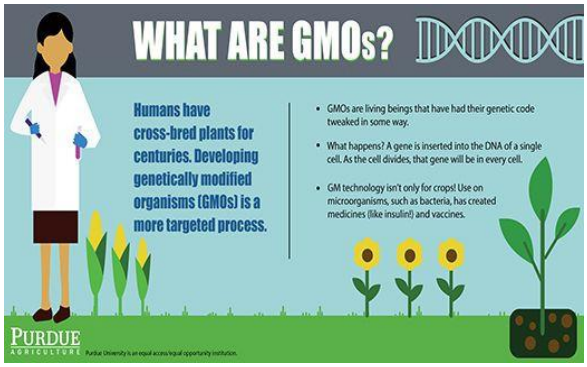


GMOs (Genetically Engineered Crops)

-increase resistance to pests, crops

-leads to loss of genetic diversity



5 .7 Meat Production

1. CAFOs (Confined Animal Feeding Operation)
   -produces large amounts of food fast
   -crowded - so use antibiotics more
   -feed is grains, not grass
   -produce large amounts of waste
   -less expensive & consumer costs are decreased
2. Free range grazing
   -feed on grass
   -less crowded - use less antibiotics
   -requires lots of land
   -more expensive product for consumer
3. Meat production is less productive than agriculture
   -takes approx. 20 times more land to produce same amount of calories

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from meat as from plants

4. Overgrazing - causes decreased vegetation, soil erosion, desertification
5. Advantages of Reduced Meat Consumption
   -reduces CO2, CH4, N2O gas emissions
   -conserves water
   -reduces use of antibiotics, growth hormones
   -improves topsoil

5.8 Impacts of Overfishing

-decreased fish populations and biodiversity
-reduced income and food sources

5.9 Impacts of Mining

-habitat destruction, soil degradation, increased turbidity due to erosion/sedimentation, increased fossil fuel use, increases waste & pollution
-acid mine drainage

Surface mining: removal of soil/rock (overburden)
-increases erosion
Slag/tailings: waste remaining when mineral is extracted from ore

Subsurface mining: deeper, underground removal of ores
-more expensive

6 Urbanization

Urban sprawl: change in population distribution from cities to suburbs

Results in:

1) increased impervious surfaces (roads, buildings, sidewalks, parking lots) which decreases water infiltration and increases flooding
2) decreases vegetation(less infiltration - more erosion)
3) increased CO2
4) habitat destruction
5) increased temperatures
6) depletion of groundwater sources (aquifer depletion, saltwater intrusion)

5 Ecological Footprints

-shows resource use and waste production required for individual or group

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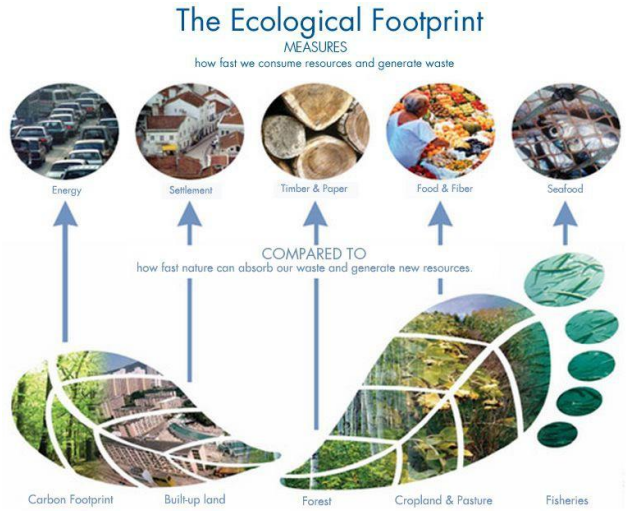

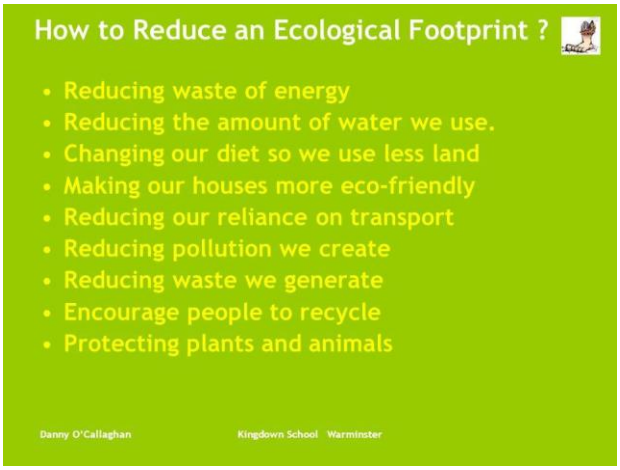

5.12 Introduction to Sustainability

Sustainability: using resources in ways that don't deplete amounts available for future use

Sustainable yield: amount of a renewable resource that can be taken without reducing available supply

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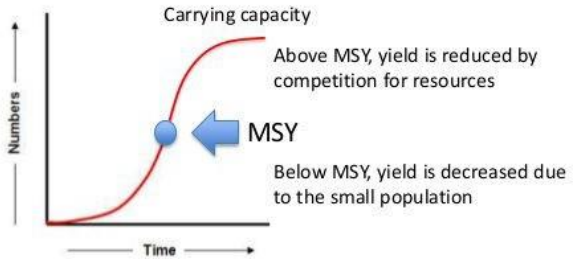
Calculations

- MSY occurs at the point where population is increasing at its maximum rate



5.13 Methods to Reduce Urban Runoff

Increase water infiltration by:

1) use permeable pavement
2) plant trees
3) use public transportation
4) build vertically

5.14 Integrated Pest Management

-pest control methods that minimize environmental damage
-reduces pesticide use
-complex and expensive
Include:

1) biocontrol
2) intercropping
3) crop rotation
4) natural predators

5 Sustainable Agriculture

Soil conservation methods

1) contour plowing
2) windbreaks
3) perennial crops
4) terracing
5) no-till
6) strip cropping
7) crop rotation

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8) rotational grazing

6 Aquaculture

-fish and aquatic plants farming

Advantages: efficient, uses small areas of water & amounts of fuel

Disadvantages: contamination from wastes, escapees competing/breeding with wild fish (decreases biodiversity, introduces diseases into wild population

5 Sustainable Forestry

Ways to decrease Deforestation

1) reforestation
2) use ecologically sustainable wood
3) reuse wood

Reduction of Pests

1) Integrated Pest Management
2) removal of infected trees

Prescribed burns: controlled fires in forests to reduce occurrence of natural fires

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Unit 6--Energy Resources & Consumption

- **Important Concepts to Know:** Fossil Fuels, Nuclear Fuel, Nonrenewable vs. Renewable Resources, Turbine, Electrical Grid, Energy Carrier, Cogeneration, Capacity, Combined Cycle, Commercial vs. Subsistence Energy Source, Energy Efficiency

6.1 Renewable and Nonrenewable Energy Sources

- Nonrenewable energy sources are those that exist in a fixed amount and involve energy transformation that cannot be easily replaced.
- Renewable energy sources are those that can be replenished naturally, at or near the rate of consumption, and reused.

6.2 Global Energy Consumption

- The use of energy resources is not evenly distributed between developed and developing countries.
- The most widely used sources of energy globally are fossil fuels.
- As developing countries become more developed, their reliance on fossil fuels for energy increases.
- As the world becomes more industrialized, the demand for energy increases.
- Availability, price, and governmental regulations influence which energy sources people use and how they use them.

6.3 Fuel Types and Uses

- Wood is commonly used as fuel in the forms of firewood and charcoal. It is often used in developing countries because it is easily accessible.
- Peat is partially decomposed organic material that can be burned for fuel.
- Three types of coal used for fuel are lignite, bituminous, and anthracite. Heat, pressure, and depth of burial contribute to the development of various coal types and their qualities.
- Natural gas, the cleanest of the fossil fuels, is mostly methane.
- Crude oil can be recovered from tar sands, which are a combination of clay, sand, water, and bitumen.
- Fossil fuels can be made into specific fuel types for specialized uses (e.g., in motor vehicles).
- Cogeneration occurs when a fuel source is used to generate both useful heat and electricity.

6.4 Distribution of Natural Energy Resources

- The global distribution of natural energy resources, such as ores, coal, crude oil, and gas, is not uniform and depends on regions' geologic history.

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6.13 Energy Conservation

- Some of the methods for conserving energy around a home include adjusting the thermostat to reduce the use of heat and air conditioning, conserving water, use of energy-efficient appliances, and conservation landscaping.
- Methods for conserving energy on a large scale include improving fuel economy for vehicles, using BEVs (battery electric vehicles) and hybrid vehicles, using public transportation, and implementing green building design features

  All Energy Has Its Consequences (Santa Barbara Blowout, Exxon Valdez oil spill, BP oil refinery explosion, BP Deepwater Horizon explosion, West Virginia coal mining accident, Fukushima, Lac-Megantic Train Explosion, Chernobyl, Benxi Coal Mining Explosion, India Power Blackout, Hurricane Katrina (Oil affect), Burning Kuwait Oil Fields, Sandy Creek Power Plant Accident, San Bruno Pipeline Explosion, Yellowstone River Oil Spill, Enbridge Oil Spill, Connecticut Power Plant Explosion, Three Mile Island (PA)

- Ecological Disasters

Occurred with fossil fuels and nuclear energy
Oil spills kill wildlife and are difficult to contain/clean up
Nuclear meltdowns cause cancer and make the land unsafe for decades
Coal mining is dangerous

Energy Units Joule = basic unit of energy
Gigajoule (GJ) = 1 billion joules
Exajoule (EJ) = 1 billion gigajoules
1 quad = 1 quadrillion BTU = 1.5 EJ

- World Energy Consumption

Development → increased energy use
Subsistence energy use is higher in rural areas; commercial energy sources are more important in urban centers/developed nations

- US energy usage

1973 OPEC Oil Embargo
Oil was used as a political weapon
So much is tied to oil production, if oil prices rise other areas suffer
Today oil > natural gas > coal > renewable > nuclear

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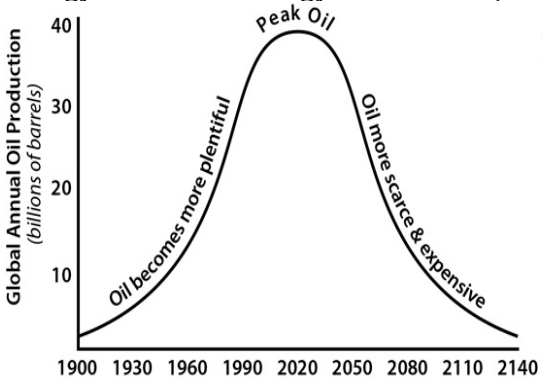
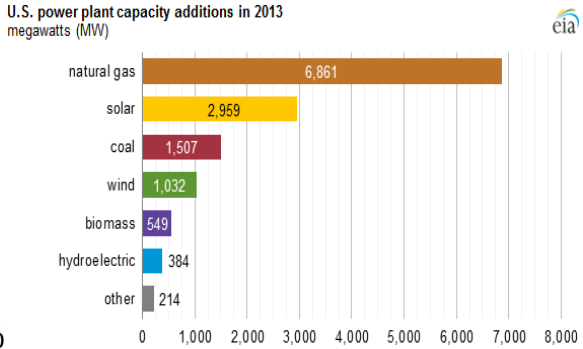
- Energy Return on Energy Investment (EROEI)





How does EROEI exacerbate the concept of peak oil?

- Powerplants

Most US power plants have a capacity of 500 MW.

Why should a power plant's capacity always be greater than the town's average or even maximum electrical use?

Half of power plant capacity additions in 2013 came from natural gas

Natural gas-fired power plants accounted for just over 50% of new utility-scale generating capacity added in 2013. Solar provided nearly 22%, a jump up from less than 6% in 2012. Coal provided 11% and wind nearly 8%. Almost half of all capacity added in 2013 was located in California. In total, a little over 13,500 megawatts (MW) of new capacity was added in 2013, less than half the capacity added in 2012

Fossil Fuel Resources

- **Important Concepts to Know:** Coal, Petroleum, Crude Oil, Oil Sands, Bitumen, Coal to Liquid, Energy Intensity, Hubbert Curve and Peak Oil

6.2 Global Energy Consumption

- The use of energy resources is not evenly distributed between developed and developing countries.
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- Fossil fuels can be made into specific fuel types for specialized uses (e.g., in motor vehicles).
- Cogeneration occurs when a fuel source is used to generate both useful heat and electricity.

6.5 Fossil Fuels

- The combustion of fossil fuels is a chemical reaction between the fuel and oxygen that yields carbon dioxide and water and releases energy.
- Energy from fossil fuels is produced by burning those fuels to generate heat, which then turns water into steam. That steam turns a turbine, which generates electricity.
- Humans use a variety of methods to extract fossil fuels from the earth for energy generation.
- Hydrologic fracturing (fracking) can cause groundwater contamination and the release of volatile organic compounds.

7.1 Introduction to Air Pollution

Coal combustion releases air pollutants including carbon dioxide, sulfur dioxide, toxic metals, and particulates.

- The combustion of fossil fuels releases nitrogen oxides into the atmosphere. They lead to the production of ozone, formation of photochemical smog, and convert to nitric acid in the atmosphere, causing acid rain. Other pollutants produced by fossil fuel combustion include carbon monoxide, hydrocarbons, and particulate matter.
- Air quality can be affected through the release of sulfur dioxide during the burning of fossil fuels, mainly diesel fuels.
- Through the Clean Air Act, the Environmental Protection Agency (EPA) regulated the use of lead, particularly in fuels, which dramatically decreased the amount of lead in the atmosphere.
- Air pollutants can be primary or secondary pollutants.

9.4 Increases in Greenhouse Gases (Modules 2, 7, 12, 35, 38, 46, 62, 63)

- Global climate change, caused by excess greenhouse gases in the atmosphere, can lead to a variety of environmental problems including rising sea levels resulting from melting ice sheets and ocean water expansion, and disease vectors spreading from the tropics toward the poles. These problems can lead to changes in population dynamics and population movements in response.

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Fossil Fuel Formation

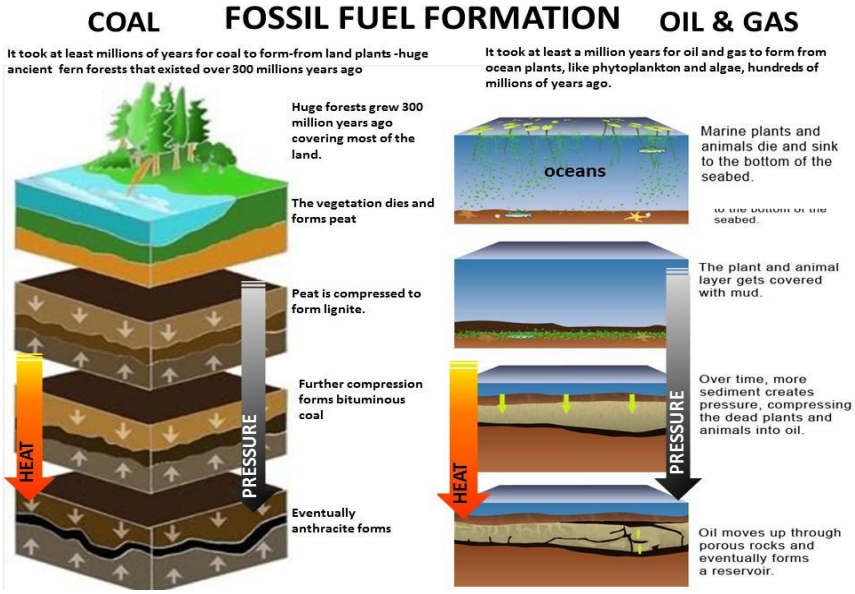
The formation of fossil fuels requires the burial and compression of organic materials under anaerobic conditions → prevents decomposition.
Three Types of Fossil Fuels:

- Coal (solid), Oil/Petroleum (liquid), Natural gas (gas),

Terrestrial life → coal
Aquatic life → oil/natural gas

Fossil Fuel Formation:

- Coal vs. Oil and Natural Gas



Three primary types of coal:

- Lignite (lowest energy and lowest %carbon)
- Bituminous (US has the most, but high sulfur content)
- Anthracite (highest energy and most %carbon)
    - More carbon = fewer impurities, cleaner

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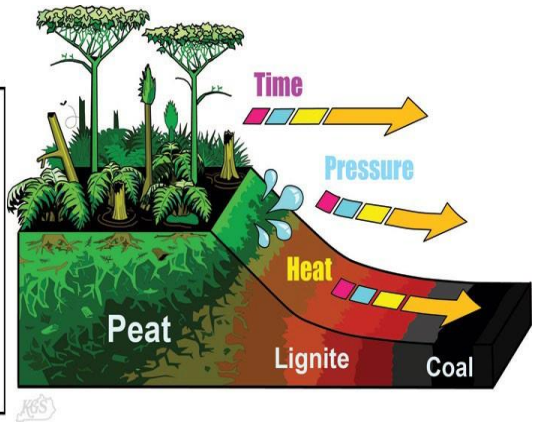


Peat is a precursor to coal and is composed of partially decomposed organic matter, Coal requires mining, usually strip mining

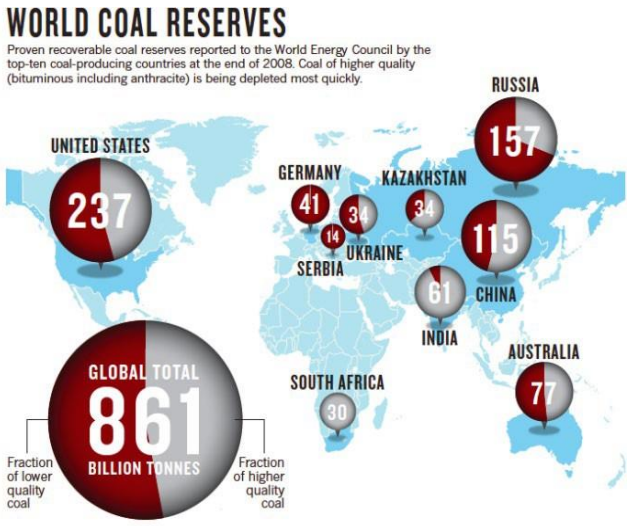
Coal Formation

When vegetation is rapidly buried and compressed it forms peat → lignite → coal

Peat: soil-like material consisting of partly decomposed vegetable matter.

Lignite: a soft brownish coal showing traces of plant structure, intermediate between bituminous coal and peat.

Coal: a combustible rock consisting mainly of carbonized plant matter, found mainly in underground deposits and widely used as fuel.



- Coal Reserves Top 5: US, Russia, China, India, Australia

Coal Advantages and Disadvantages

Advantages: Cheap, plentiful, easily mined

Disadvantages: Combustion of coal produces CO_2, Very dirty- lots of impurities like sulfur → acid rain and other ecological effects, Produces lots of ash as waste

Petroleum Types

Crude oil: liquid petroleum pumped from the ground

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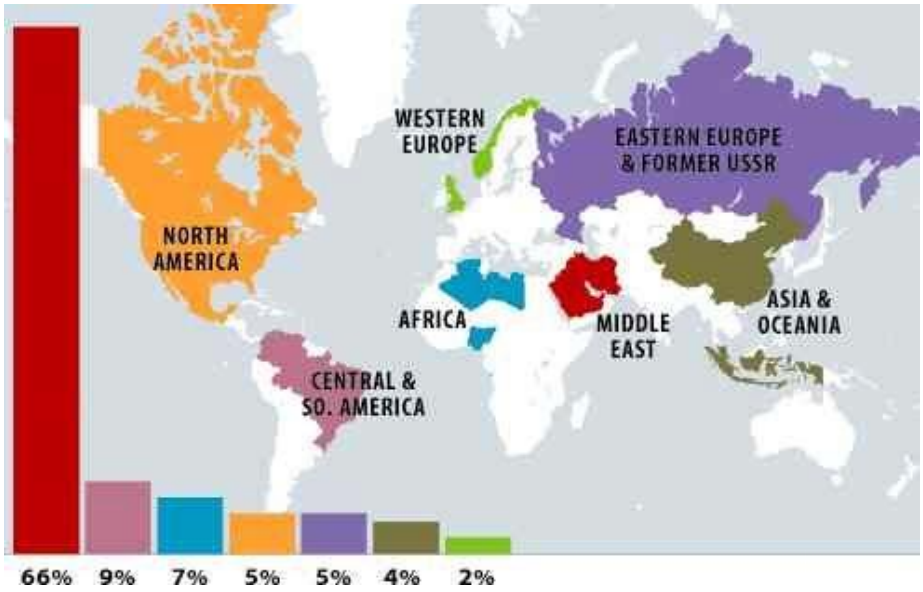
Oil sands and oil shale: "solid petroleum", petroleum mixed with soil. Heavy and viscous form of oil. Also called tar sand.

Petroleum Reserves



Petroleum forms in a similar manner to coal. Requires burial, compression and time. The other major difference is that petroleum is liquid, but coal is solid and petroleum forms from phytoplankton.

The Middle East has the greatest reserves of petroleum and has dominated the market for decades.

- Peak Oil

There is effectively a fixed amount of oil available on Earth.

Oil production will increase until we reach the 50% mark (50% of oil has been extracted) and then reduce continually. Price of oil decreases before the 50% mark and then increases continuously after the 50% mark. This is similar to the concept of maximum sustainable yield, except the population (oil) has no growth rate

Hubbert Curve

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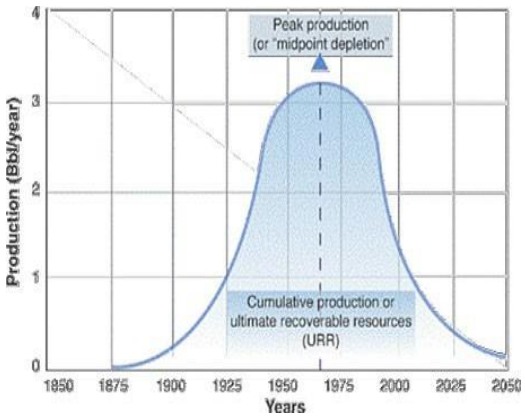
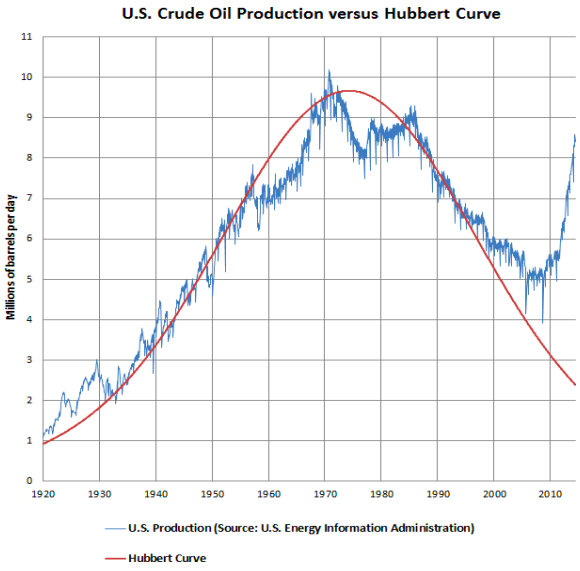




- Production of any resource will increase until it reaches peak production. This model predicts that peak production occurs when 50% of the resource has been extracted. After this point, production will decrease.

Increasing production increases supply and lowers price. The opposite is also true.

Hubbert Curve vs.Real World

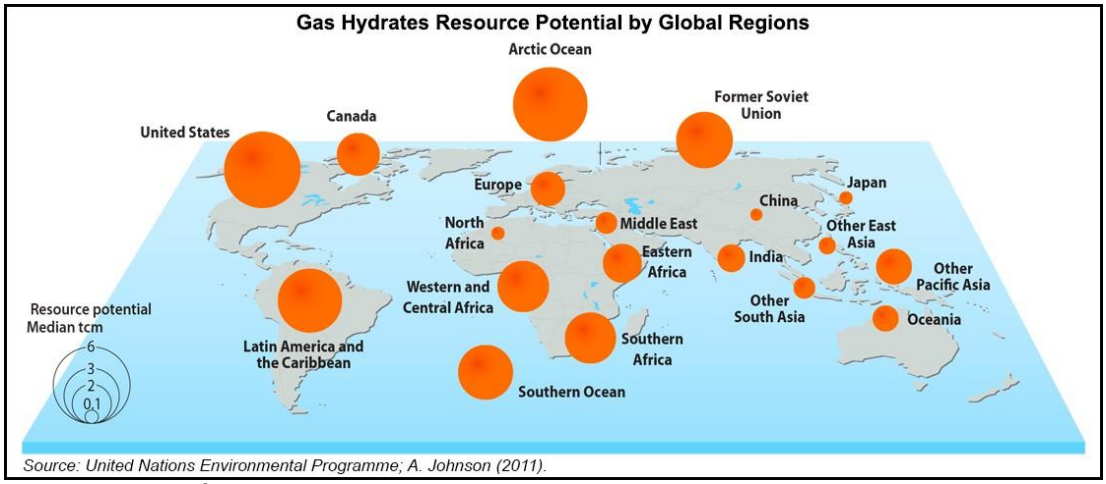
How has technology prevented the predictions of the Hubbert Curve from becoming true?

- **Petroleum Advantages and Disadvantages**

Advantages: Liquid → easy to transport, Cleaner and more energy dense than coal

Disadvantages: Still has impurities, More mobile → oil spills, Greenhouse gases produced by combustion

- Natural Gas



The primary ingredient of natural gas is methane (80-95%). The remaining portion is a combination of ethane, propane and butane.

- Natural Gas Extraction

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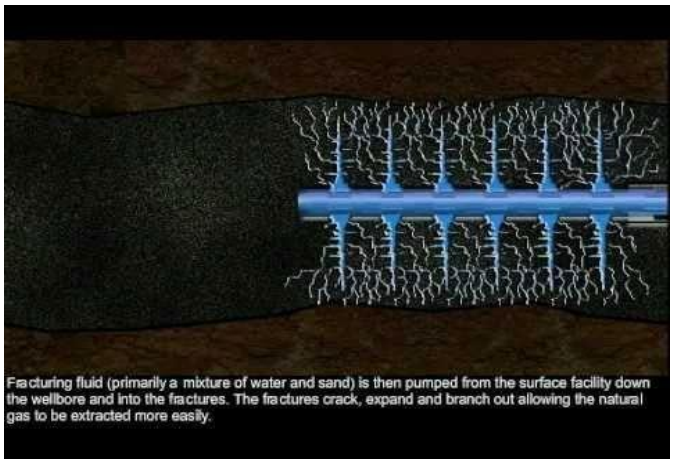

Natural gas is recovered through wells. These are generally drilled into shale rock.
In what kind of rock is natural gas found? Defend your answer.

- **Natural Gas Advantages and Disadvantages**

Advantages: Great for heating (cogeneration), Cleaner than oil or coal (fewer impurities), Less CO_2 released than other fossil fuels
Disadvantages: Methane (primary component of natural gas) is a terrible greenhouse gas, Exploration is disruptive (thumper trucks), Extraction is damaging (fracking)

Nuclear Energy Resources **Important Concepts to Know:** Nuclear Fission, Fuel Rods, Control Rods, Radioactive Waste, Nuclear Accidents, Nuclear Fusion, Advantages and Disadvantages to Nuclear Power

6.4 Distribution of Natural Energy Resources

- The global distribution of natural energy resources, such as ores, coal, crude oil, and gas, is not uniform and depends on regions' geologic history.

6.5 Fossil Fuels

- The combustion of fossil fuels is a chemical reaction between the fuel and oxygen that yields carbon dioxide and water and releases energy.
- Energy from fossil fuels is produced by burning those fuels to generate heat, which then turns water into steam. That steam turns a turbine, which generates electricity.
- Humans use a variety of methods to extract fossil fuels from the earth for energy generation.
- Hydrologic fracturing (fracking) can cause groundwater contamination and the release of volatile organic compounds.

6.6 Nuclear Power

- Nuclear power is generated through fission, where atoms of Uranium-235, which are stored in fuel rods, are split into smaller parts after being struck by a neutron. Nuclear fission releases a large amount of heat, which is used to generate steam, which powers a turbine and generates electricity.

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- Radioactivity occurs when the nucleus of a radioactive isotope loses energy by emitting radiation.
- Uranium-235 remains radioactive for a long time, which leads to the problems associated with the disposal of nuclear waste.
- Nuclear power generation is a nonrenewable energy source. Nuclear power is considered a cleaner energy source because it does not produce air pollutants, but it does release thermal pollution and hazardous solid waste.
- Three Mile Island, Chernobyl, and Fukushima are three cases where accidents or natural disasters led to the release of radiation. These releases have had short- and long-term impacts on the environment.
- A radioactive element's half-life can be used to calculate a variety of things, including the rate of decay and the radioactivity level at specific points in time.

Nuclear Power

Developed from nuclear weapons technology

Originally deemed risky/expensive compared to fossil fuels. But interested peaked in 1970s with the gas crisis, Accidents limited public interest

- Light Water Nuclear Reactors

Cheaper than other types of reactors though not as effective (1% efficiency)

Fuel source = U-235

Neutrons bombard the Uranium causing fission and the release of energy which is used to heat up the water. This produces steam which can be used by a turbine to produce electricity.

Water moderates the reaction, keeping it controlled. Failure to do so results in a meltdown (not unlike a nuclear bomb)

Not the safest, most efficient or most advanced type of nuclear reactor

- Disadvantages to Nuclear Energy
  1. Nuclear Weapons Proliferation
     - Nuclear reactor technology is intimately tied to nuclear weapons technology.
  2. Nuclear Waste
     - Radioactive and long-lived (long half life)
     - Secure storage is difficult
     - Security for transportation of waste to storage
  3. Nuclear Accidents
     - Three-Mile Island (1979)
     - Chernobyl (1986)
     - Fukushima (2011)
- Advantages to Nuclear Energy

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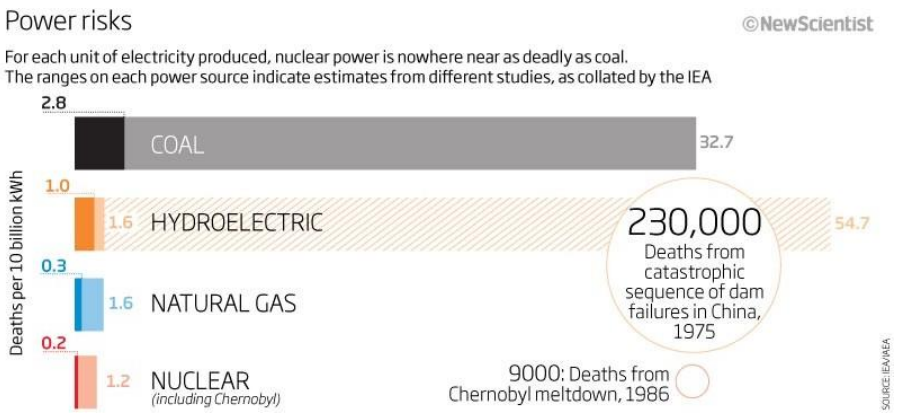

1. Nuclear Energy Saves Lives
   - Produces fewer pollutants and the pollutants (radioactive waste) is more regulated and stored
2. Nuclear Energy reduces CO_2 emissions
   - Nuclear reactions are not a combustion reaction → no CO_2 produced
3. New Technologies (Fast Reactors)
   - Light Water Reactors are out of date
   - Breeder reactors can use Thorium which is not used in nuclear weapons

- Types of Radioactive Waste

Low-Level

- Low-level waste (LLW) is generated from hospitals and industry
- Low radioactivity level and short half life
- Makes up 90% of the bulk of radioactive waste, but only 1% of the radioactivity.
- No shielding is required, ideal for shallow burial.

High-Level

- High-level waste (HLW) is generated from the use of uranium in light water nuclear reactors.
- High radioactivity and long half life (tens of thousands of years compared to hundreds of years for LLW)
- Requires cooling and shielding.

Dealing with nuclear wastes

- Shallow burial
- Deep geological burial
  - Yucca Mountain (2010)
- Vitrification

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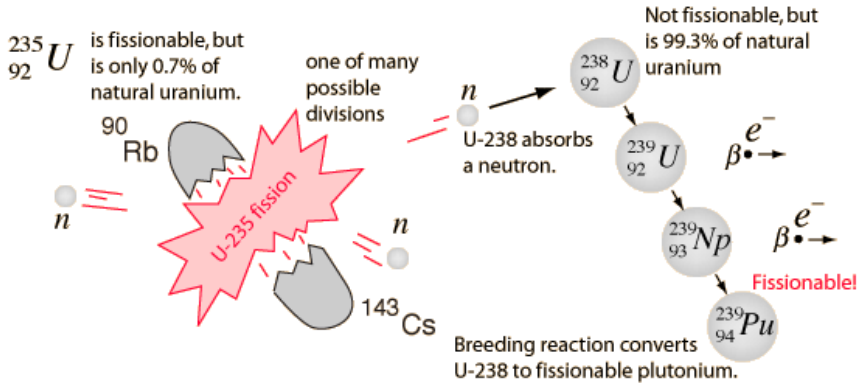
- Nuclear waste is mixed with sugar or slag to form a glass like substance that is safer and easier to store. The drawback is that this is a very expensive process.

- Breeder reactors



- Use uranium and thorium as fuel (thorium is not weaponizable)
- High neutron economy breeds fissile materials from more stable isotopes of uranium and thorium
- Breeder reactors require 1/100 of the fuel needed for traditional light water reactors
- Result in 1/100 of the nuclear waste and 100x the energy
- Theoretically, we could use sea water uranium extraction to fuel this reactor type → uranium reserves for 5 billion years

- Breeder Reactors

Stable isotopes of uranium (U-238) and thorium are converted to fissile materials like Plutonium-239
The reaction "breeds" its own fuel increasing efficiency
These are "fast" reactions compared to "slow" reactions in light water reactors

Deep Geological Disposal
High-level radioactive wastes require deep burial

- The site should be isolated from human settlements to prevent contamination and/or exposure to radioactivity
- Natural/engineered barriers (rock, salt and clay)
- Yucca mountain was to be the site for nuclear storage in US, but was discontinued
- Other options (though not feasible)
- Launch into space/into the sun
- Store in the moon
- Storage under ice sheets in Greenland and/or Antarctica
- Deep sea or ocean storage

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- Dump into subduction zones
- Storage in above ground buildings

Conservation, Efficiency and Renewable Energy **Important Concepts to Know:** Energy Conservation, Tiered Rate System, Peak Demand, Passive Solar Design, Thermal Mass, Potentially Renewable, Nondepletable, Renewable

5.12 Introduction to Sustainability

Sustainability refers to humans living on Earth and their use of resources without depletion of the resources for future generations. Environmental indicators that can guide humans to sustainability include biological diversity, food production, average global surface temperatures and CO_2 concentrations, human population, and resource depletion.

- Sustainable yield is the amount of a renewable resource that can be taken without reducing the available supply.

6.2 Global Energy Consumption

- The use of energy resources is not evenly distributed between developed and developing countries.
- The most widely used sources of energy globally are fossil fuels.
- As developing countries become more developed, their reliance on fossil fuels for energy increases.
- As the world becomes more industrialized, the demand for energy increases.
- Availability, price, and governmental regulations influence which energy sources people use and how they use them.

6.13 Energy Conservation

- Some of the methods for conserving energy around a home include adjusting the thermostat to reduce the use of heat and air conditioning, conserving water, use of energy-efficient appliances, and conservation landscaping.
- Methods for conserving energy on a large scale include improving fuel economy for vehicles, using BEVs (battery electric vehicles) and hybrid vehicles, using public transportation, and implementing green building design features.

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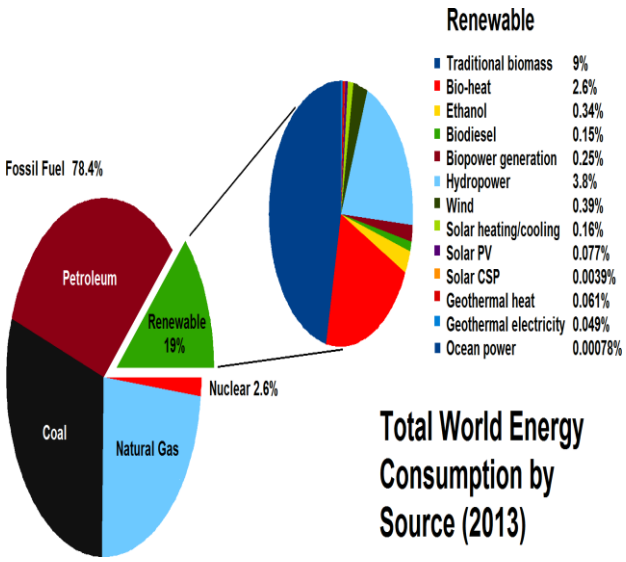
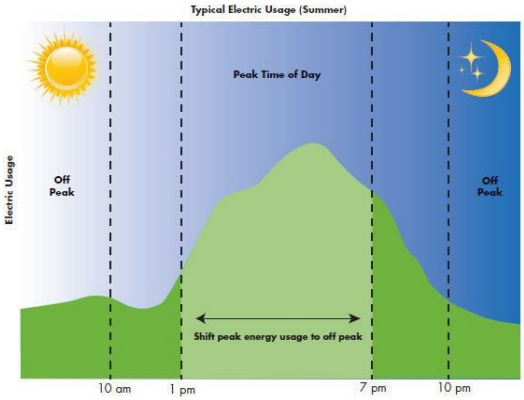




Energy Reduction

Humans use 17.7 TW (terrawatts) of electricity

Conservation and efficiency will help reduce our overall energy demands

Reducing Energy Demands

Peak Demand occurs during the day.

To reduce energy consumption, electric companies charge higher rates as customers use more energy or charge more during peak demand.

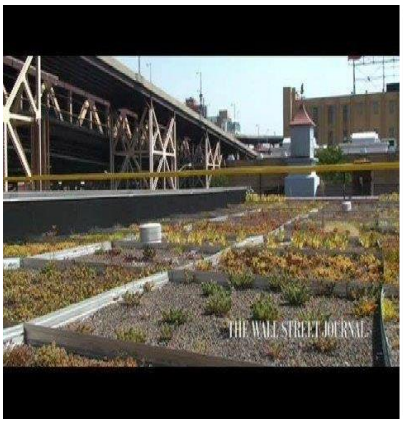
Conservation and Efficiency both feed into reducing energy needs.

Sustainable Designs

Sustainable design helps to, use passive heating heat and solar designs.

The fact that the design is passive means that we do not need to input as much energy into the upkeep of the building; takes advantage of natural processes

Green Roofs

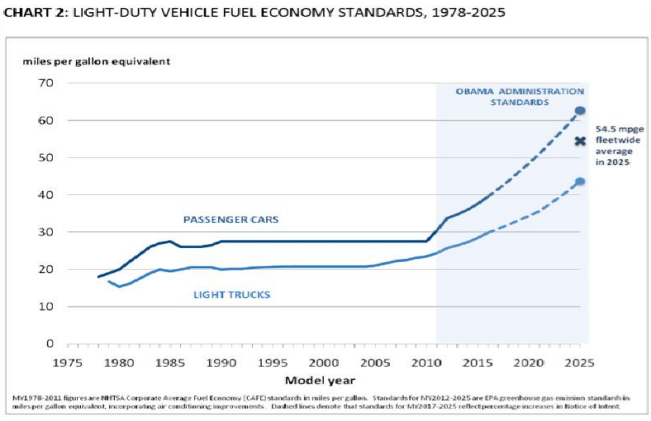


Plants are grown on the roof of a building

The high albedo of the plants absorbs sunlight, keeping the buildings cool

The plants also take up water, reducing rainwater flow

CAFE Standards



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CAFE Standards

Enacted in the US in 1975 in response to the OPEC oil crisis (73-74)
Focused on efficiency of automobiles, raising standards → less dependence on oil and greater economic security.
Hybrids and electric vehicles help bridge the gap

Biomass and Water. **Important Concepts to Know:** Biofuel, Ethanol, Biodiesel, Modern vs. Fossil Carbon, Carbon Neutral, Net Removal, Flex-Fuel Vehicle, Hydroelectricity, Run-of-the-River, Water Impoundment, Tidal Energy, Siltation

6.7 Energy from Biomass

- Burning of biomass produces heat for energy at a relatively low cost, but it also produces carbon dioxide, carbon monoxide, nitrogen oxides, particulates, and volatile organic compounds. The overharvesting of trees for fuel also causes deforestation.
- Ethanol can be used as a substitute for gasoline. Burning ethanol does not introduce additional carbon into the atmosphere via combustion, but the energy return on energy investment for ethanol is low.

6.9 Hydroelectric Power Hydroelectric power can be generated in several ways. Dams built across rivers collect water in reservoirs. The moving water can be used to spin a turbine. Turbines can also be placed in small rivers, where the flowing water spins the turbine.

- Tidal energy uses the energy produced by tidal flows to turn a turbine.
- Hydroelectric power does not generate air pollution or waste, but construction of the power plants can be expensive, and there may be a loss of or change in habitats following the construction of dams.

9.4 Increases in Greenhouse Gases

- Global climate change, caused by excess greenhouse gases in the atmosphere, can lead to a variety of environmental problems including rising sea levels resulting from melting ice sheets and ocean water expansion, and disease vectors spreading from the tropics toward the poles. These problems can lead to changes in population dynamics and population movements in response.

Biomass

Biomass refers to energy derived from living organisms→ biomass fuel sources are derived from living tissues generally plants.
Wood and charcoal are types of biomass energy as is biofuel
Combustion is the primary way of extracting energy from biomass

Biofuel

Biofuels are liquid fuels similar to petroleum but derived from biomass
Ethanol and biodiesel are examples.
Ethanol can be used directly or as an additive to gas (gasohol), effectively increasing our petroleum supplies. Biodiesel can be used in a similar manner but with diesel.
How are gas and diesel different?
Ethanol

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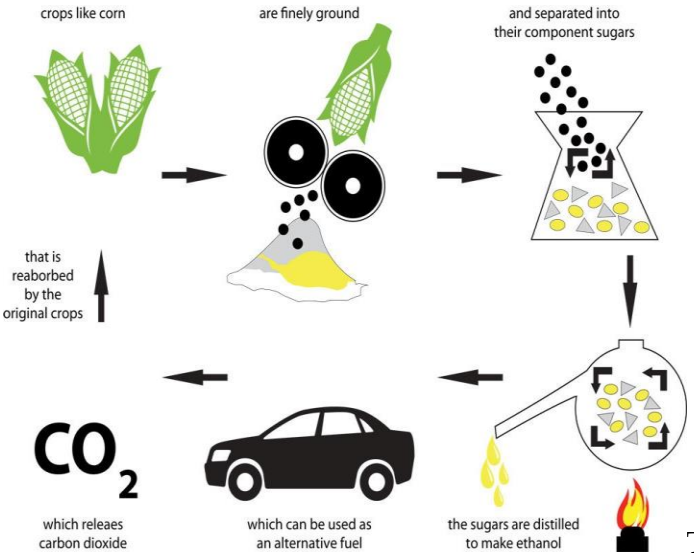

Typically derived from corn

Ethanol + gas → gasohol (90% gas and 10% ethanol)

E85 is 85% ethanol and 15% gas and can be used in flex fuel vehicles along with traditional gas

Because ethanol is renewable it extends of reserves of petroleum

- The downsides to ethanol

Derived from cellulose and other plant tissues- that must be broken down into simpler sugars.

Requires processing with enzymes

Ethanol comes primarily from corn so we are using food to make fuel.

Corn is the foundation of most of our food infrastructure, prices will go up universally

Switchgrass may be an alternative to corn, but still requires land to grow again competing for space with our food. Plus growing these plant requires...fossil fuels. So are we actually conserving our resources?

Hydroelectric Power

Converts kinetic energy → electrical energy

7% of renewable energy comes from hydropower l<u>argest source of renewable energy</u>

Impoundment systems capture water and divert water flow

Solar, Wind, Geothermal and Hydrogen. **<u>Important Concepts to Know:</u>** Active Solar Design, Photovoltaic Cell, Wind Energy, Wind Turbine, Geothermal Energy, Ground Source Heat Pump, Fuel Cell, Electrolysis

6.8 Solar Energy

- Photovoltaic solar cells capture light energy from the sun and transform it directly into electrical energy. Their use is limited by the availability of sunlight.
- Active solar energy systems use solar energy to heat a liquid through mechanical and electric equipment to collect and store the energy captured from the sun.
- Passive solar energy systems absorb heat directly from the sun without the use of mechanical and electric equipment, and energy cannot be collected or stored.

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- Solar energy systems have low environmental impact and produce clean energy, but they can be expensive. Large solar energy farms may negatively impact desert ecosystems.

6.10 Geothermal Energy

- Geothermal energy is obtained by using the heat stored in the Earth's interior to heat up water, which is brought back to the surface as steam. The steam is used to drive an electric generator.
- The cost of accessing geothermal energy can be prohibitively expensive, as is not easily accessible in many parts of the world. In addition, it can cause the release of hydrogen sulfide.

6.11 Hydrogen Fuel Cell

- Hydrogen fuel cells are an alternate to nonrenewable fuel sources. They use hydrogen as fuel, combining the hydrogen and oxygen in the air to form water and release energy (electricity) in the process. Water is the product (emission) of a fuel cell.
- Hydrogen fuel cells have low environmental impact and produce no carbon dioxide when the hydrogen is produced from water. However, the technology is expensive and energy is still needed to create the hydrogen gas used in the fuel cell.

6.12 Wind Energy

- Wind turbines use the kinetic energy of moving air to spin a turbine, which in turn converts the mechanical energy of the turbine into electricity.
- Wind energy is a renewable, clean source of energy. However, birds and bats may be killed if they fly into the spinning turbine blades.

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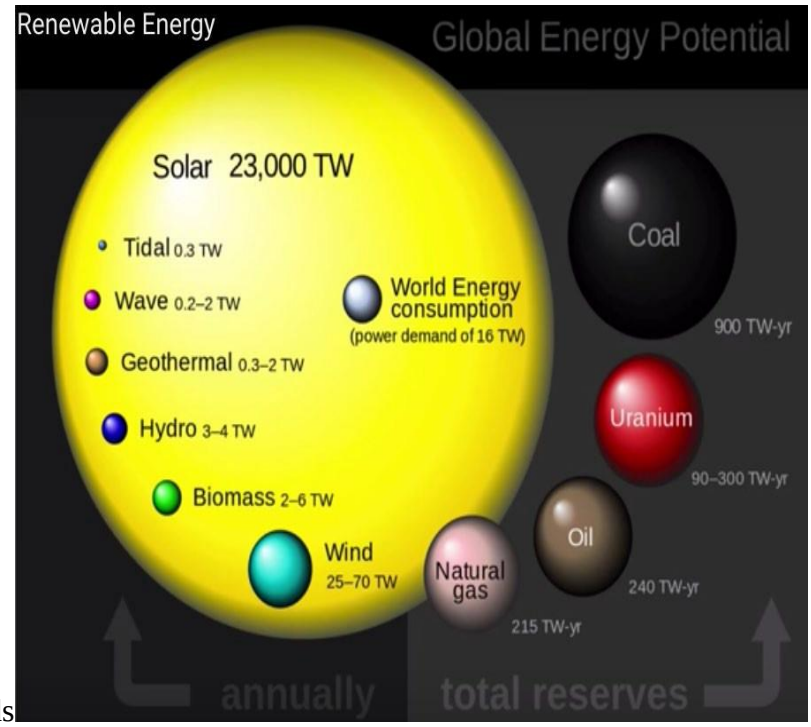

World Energy Needs

Currently the world consumes 16 TW-years of energy annually.
Fossil fuels can easily meet that demand, but are being depleted.
In the long run, we will need renewable energy.

Biomass energy includes biofuels, wood and charcoal and while very effective and renewable they are depletable (net removal). For instance Haiti used to covered by 60% forests...now down to just 2%.

Energy Return on Energy Investment

To be economically viable, an energy source needs a minimum EROEI of 3:1.

Nonrenewable	EROEI	Renewable	EROEI
Coal	80:1	Corn Ethanol	1.3:1
Petroleum	40:1	Sugar Cane Ethanol	US 3:1 Brazil 8:1
Natural Gas	15:1	Biodiesel	1.3:1
Uranium	15:1	Biomass (Wood)	25:1
		Hydroelectric (Tidal and Wave)	15:1
		Hydroelectric (Large Scale)	100:1

To be economically viable, an energy source needs a minimum EROEI of 3:1.

Solar Energy

Thermal Solar ERORI = 1.9:1

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Photovolatics ERORI = 6.8:1
Solar Farms ERORI = 9:1
Advantages: essentially unlimited supply of free energy
Disadvantages: Requires advanced technology and availability fluctuates

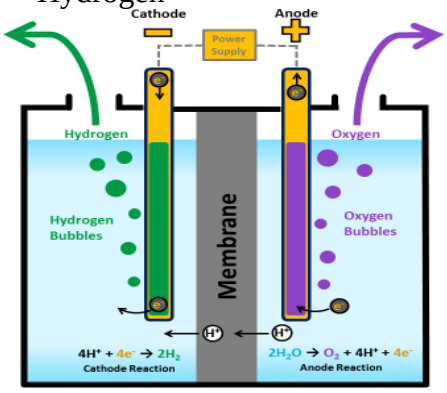
Wind Energy

Wind EROEI = 18:1
Advantages: non-depletable, no CO_2 emissions from use
Disadvantages: noise pollution, fluctuations in availability, threat to wildlife, can be considered "an eyesore"

Geothermal Energy

Geothermal EROEI = 9:1
Advantages: no CO_2 emissions from use, can cool air in summer
Disadvantages: not universally available, requires advanced technology and deep drilling (risky)

Hydrogen



Hydrogen Fuel EROEI is very low currently because it takes energy to break water down into oxygen and hydrogen gas.
Advantages: hydrogen gas contains lots of energy (3x compared to gas); no CO_2 from combustion
Disadvantages: requires lots of energy to produce, highly flammable

Photosynthesis and Hydrogenase

Genetic modification???

Planning Our Energy Future

- **Important Concepts to Know:** Smart Grid, Efficiency, Conservation and the Development of Renewable and Nonrenewable Energy Resources, Renewable Energy Present Challenges, Table 40.1: Comparison of Renewable Energy Resources

6.1 Renewable and Nonrenewable Energy Sources

- Nonrenewable energy sources are those that exist in a fixed amount and involve energy transformation that cannot be easily replaced.
- Renewable energy sources are those that can be replenished naturally, at or near the rate of consumption, and reused.

6.13 Energy Conservation

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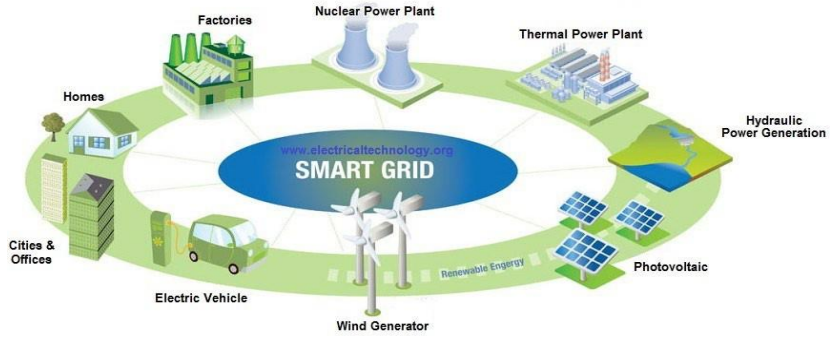
Some of the methods for conserving energy around a home include adjusting the thermostat to reduce the use of heat and air conditioning, conserving water, use of energy-efficient appliances, and conservation landscaping.

- Methods for conserving energy on a large scale include improving fuel economy for vehicles, using BEVs (battery electric vehicles) and hybrid vehicles, using public transportation, and implementing green building design features.

We Need a Smart Grid

Our current electrical grid is out of date and wasteful.
As we expand our energy economy to include renewable energy, electricity will need to be moved between locations more often.
A self-regulating, more efficient **smart grid** will better regulate this exchange and prevent blackouts and burnouts.

Smart Grid



Switching to renewable energies means diversification. A smart grid will better coordinate our power consumption.
Needs to be able to utilize all sources of electricity, renewable and nonrenewable

- Energy Storage

Wind, solar and tidal energy are renewable and have the smallest environmental impact, but they represent a “boom or bust” economy- energy is not always available. To make this more efficient and useful, we need to capitalize on opportunities when energy is available and store energy for later use.
Improving our efficiency and storage will ultimately translate to cheaper electricity as supply increases.

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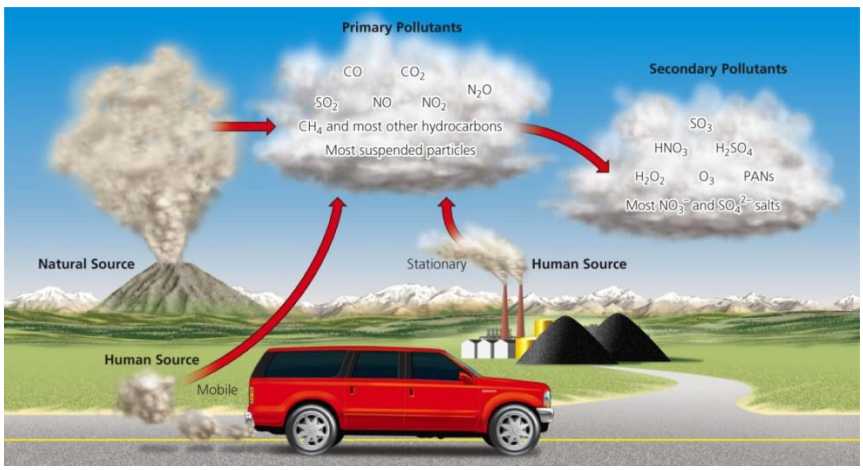
Unit 7: Atmospheric Pollution

7.1 Introduction to Air Pollution

- Air pollution is the introduction of chemicals, particulate matter, or microorganisms into the atmosphere at concentrations high enough to harm plants, animals, and materials such as buildings, or to alter ecosystems
- *Ground-level pollution* occurs in the troposphere (bottom layer of the atmosphere), which is what we generally mean when we refer to *air pollution*
- The Clean Air Act (1970) identified the following as significant threats to human well-being, ecosystems, and structures (VOCs, CO_2, and Hg are being considered for the list)
- Sulfur Dioxide: SO_2 is a corrosive gas that comes primarily from combustion of fuels like coal and oil
- Nitrogen Oxides: Generically described as NO_x; NO is a colorless, odorless gas, NO_2 is a pungent, reddish-brown gas
- Carbon Oxides: CO is a colorless, odorless gas that is formed during incomplete combustion, CO_2 is a colorless, odorless gas that is formed during complete combustion (of fossil fuels & biomass)

7.2 Photochemical Smog

- Photochemical oxidants are formed as a result of sunlight acting on compounds such as NO_x and SO_2; Ozone is the most abundant photochemical oxidant in the troposphere
- Smog (*smoke* + *fog*) is a mixture of oxidants and particulate matter; Photochemical smog, Los Angeles-type smog, brown smog is mostly composed of oxidants like ozone, Sulfurous smog, London-type smog, gray smog is mostly SO_2, and sulfate compounds (from burning coal)
- Mercury is also found in coal and oil, causes CNS damage; released primarily from the combustion of fossil fuels (especially coal), coal-fired power plants are the largest uncontrolled source
- Volatile organic compounds (VOCs) are organic compounds that become vapors at typical atmospheric temperatures**;** many are hydrocarbons—gasoline, lighter fluid, dry-cleaning fluid, oil-based paints, perfumes
- Primary pollutants come directly out of the smoke-stack, exhaust pipe, or natural emission source**;** include CO, CO_2, SO_2, NO_x, VOCs
- Secondary pollutants are primary pollutants that have undergone transformation in the presence of sunlight, H_2O, O_2, or other compounds**; i**ncludes O_3, H_2SO_4, HNO_3
- On-road vehicles (*transportation*) are the largest source of CO and NO_x
- Electricity production by coal is the largest producer of SO_2



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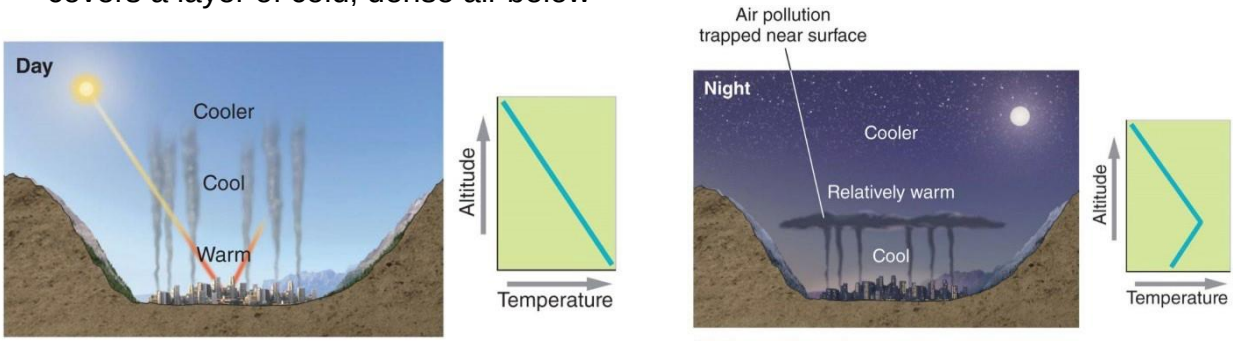
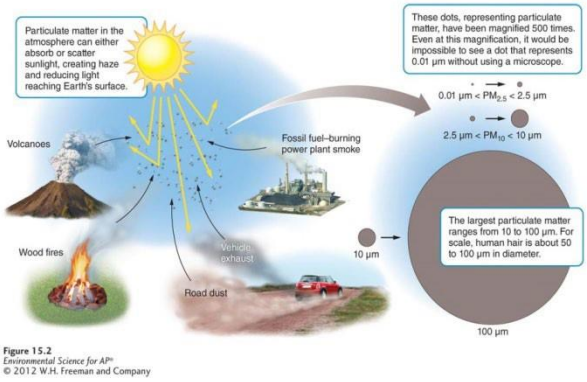
7.3 Thermal Inversion

- A thermal inversion occurs when a relatively warm layer of air at mid-altitude covers a layer of cold, dense air below



7.4 Atmospheric CO_2 and Particulates

- CO_2 is a colorless, odorless gas that is formed during complete combustion (of fossil fuels & biomass)
- Particulate matter (PM), particulates, particles can be solids or liquids suspended in the air**;** comes from the combustion of wood, animal manure, fossil fuels (especially coal and oil), biofuels



7.5 Indoor Air Pollutants

- Asbestos is a long, thin, fibrous silicate mineral with insulating properties
- People who mined asbestos have high rates of asbestosis (scarring of the lungs caused by inhaled fibers) and lung cancer
- Radon-222 is a naturally occurring radioactive gas that is produced by the decay of uranium. It can seep into homes through cracks in the foundation, or soil, or drinking water.
- Buildings that are more tightly sealed and insulated allow toxic compounds and pollutants to build up in the airtight space; indoor levels of VOCs, hydrocarbons, and other compounds can be quite high in these buildings

7.6 Reduction of Air Pollutants

- **Control of Particulate Matter**
  - Simplest method is gravitational settling in the smokestack of particles
  - The three following methods all require electricity to operate:
    - Fabric filters (aka baghouse filters) allow gases to pass through but trap particles (almost 100%)
    - Electrostatic precipitators, use an electrical charge to make particles stick to negatively or positively charged plates so they can be removed

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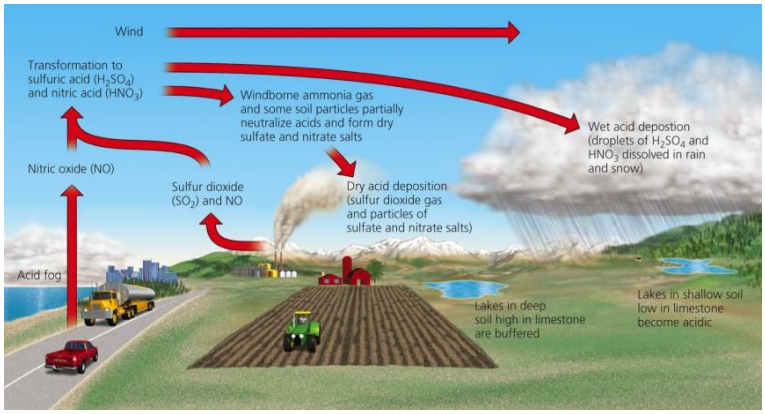
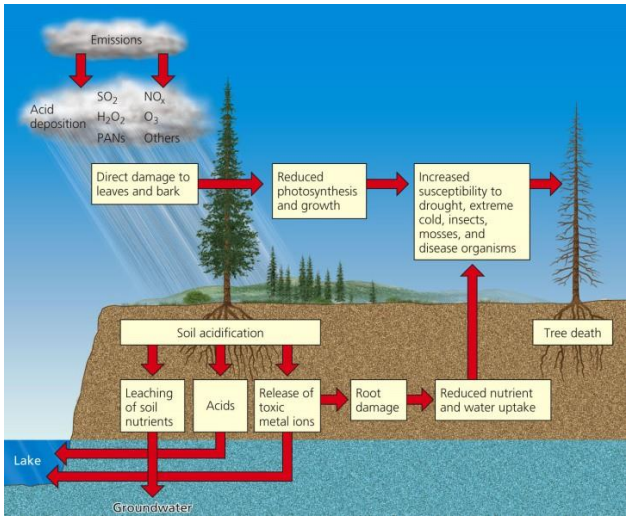
- Scrubbers use a combination of water and air that separates and removes particles (they become liquid or sludge)

7.7 Acid Rain

- Greatest effects have been directly on aquatic ecosystems**; l**ower pH in lakes and streams has decreased biodiversity (especially amphibians)
- Indirectly, lower pH allows metals bound in soils and sediments to be released (Aluminum, Mercury)**; h**arms aquatic life, their food supply, trees at high elevations





7.8 Noise Pollution

- Noise pollution is caused by unnecessary sounds that commonly travel through the air
- Can cause loss of hearing, high blood pressure, stress and loss of sleep