ENVIRONMENT

THE SCIENCE BEHIND THE STORIES

Jay Withgott • Scott Brennan

Ch 4

From Chemistry to Energy to Life

Part 1: Foundations of Environmental Science

PowerPoint® Slides prepared by
Jay Withgott and Heidi Marcum

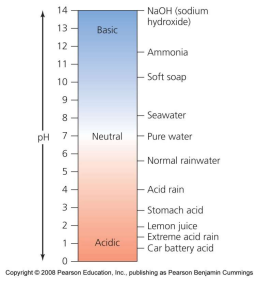
Third Edition

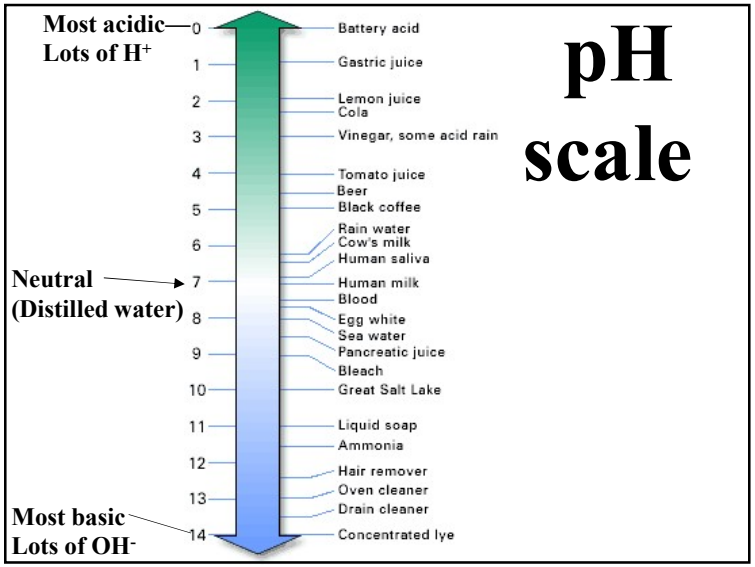
Chemical building blocks

- **Matter** = all material in the universe that has mass and occupies space
  - Can be transformed from one type of substance into others
  - But it cannot be destroyed or created which is…
  - The **law of conservation of matter**
    - Helps us understand that the amount of matter stays constant
    - It is recycled in nutrient cycles and ecosystems

Hydrogen ions determine acidity

- pH is the measurement of the concentration of H+ ions in a solution
  - **Acidic** solutions have a pH less than 7
  - **Basic** solutions have a pH greater than 7
  - **Neutral** solutions have a pH of 7
- A substance with pH of 6 contains 10 times as many hydrogen ions as a substance with pH of 7



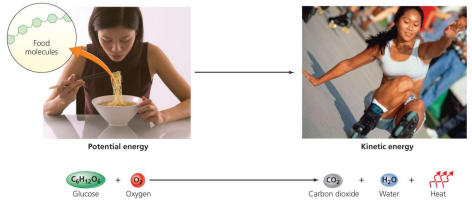


Macromolecules

- **Polymers =** long chains of repeated molecules
  - The building blocks of life
- **Macromolecules** = large-size molecules
  - Three types of polymers are essential to life
    - Proteins
    - Nucleic acids
    - Carbohydrates
  - Lipids (are not polymers, but are also essential)

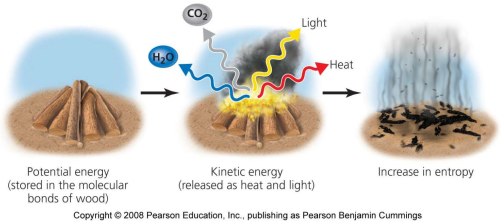
Energy fundamentals

- **Energy** = that which can change the position, physical composition or temperature of matter
  - **Potential energy** = energy of position
  - **Kinetic energy** = energy of motion
  - **Chemical energy** = potential energy held in the bonds between atoms
- Kinetic energy is changed into potential energy to produce motion, action, and heat

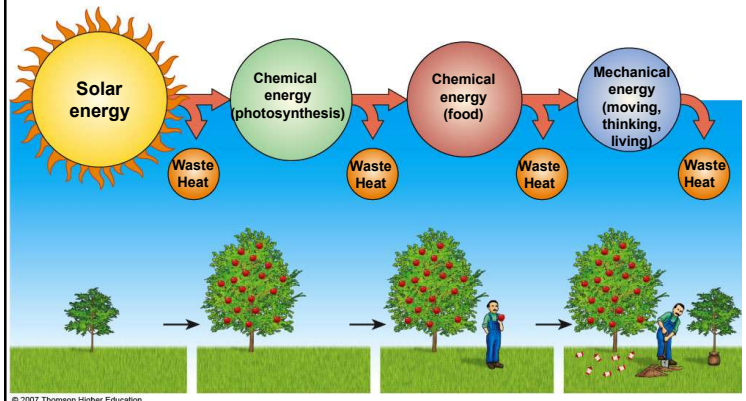


Energy is conserved...but changes in quality

- **First law of thermodynamics** = energy can change forms, but cannot be created or destroyed
- **Second law of thermodynamics** = the nature of energy changes from a more-ordered to a less-ordered state.
  - Energy quality always decreases
  - Entropy = an increasing state of disorder

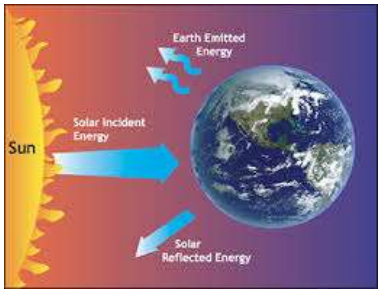


Energy is converted to biomass



The Earth's systems

- **System** = a network of relationships among parts elements or components that interact with and influence one another
- **Feedback loop** = a system's output serves as input to that same system

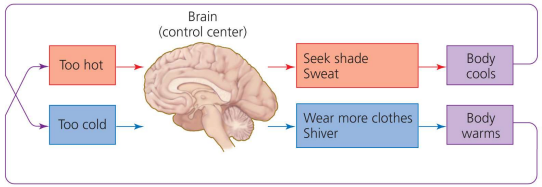


Earth is a closed system

Video clip

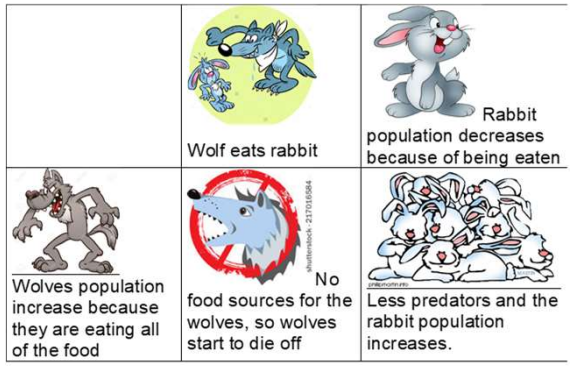
Negative feedback loop

- **Negative feedback loop** = output that results from a system moving in one direction acts as input that moves the system in the other direction.
  - Input and output essentially neutralize one another
  - Stabilizes the system
  - Example: body temperature
  - Most systems in nature

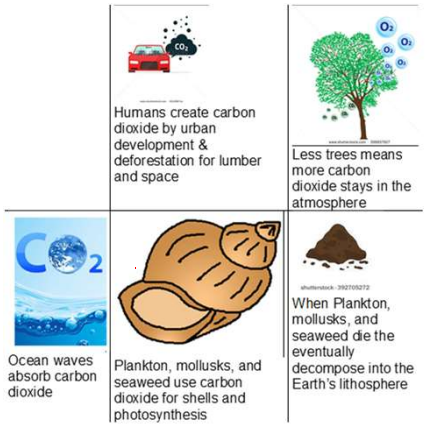


(a) Negative feedback

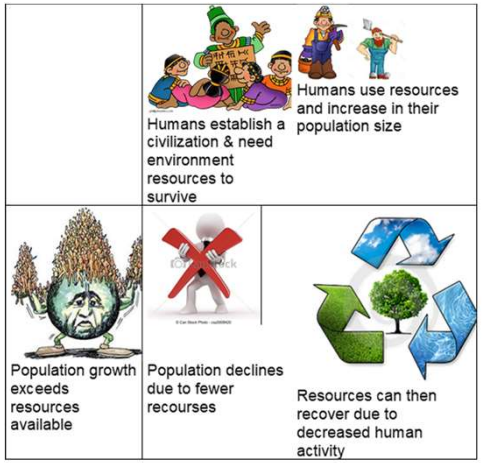
Negative feedback loop



Negative feedback loop

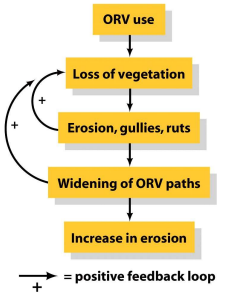


Negative feedback loop



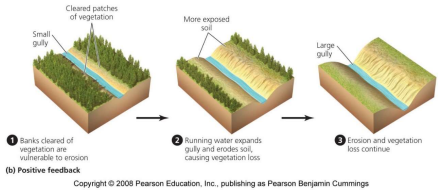
Positive feedback loop

- **Positive feedback loop** = instead of stabilizing a system, it drives it further toward one extreme or another
- Examples: exponential growth in human population, spread of cancer, erosion

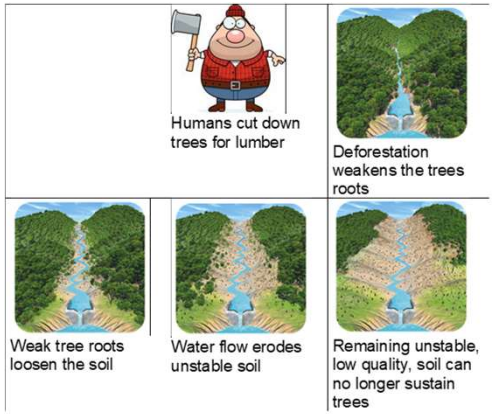


Rare in nature

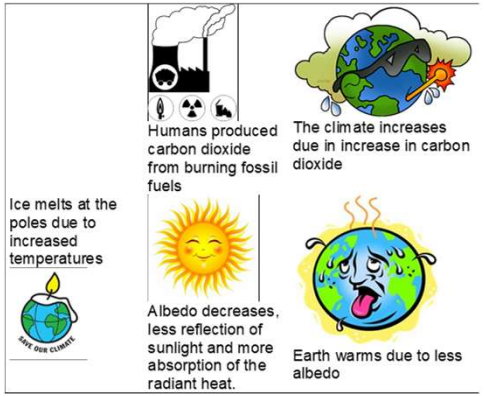
But are common in natural systems altered by human impact



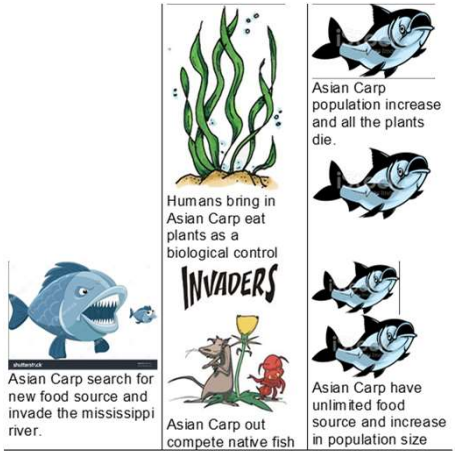
Positive feedback loop



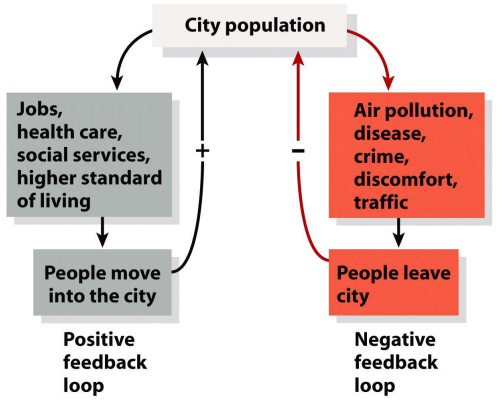
Positive feedback loop



Positive feedback loop



Feedback Loops



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Ch 6

Species Interactions and Community Ecology

Part 1: Foundations of Environmental Science

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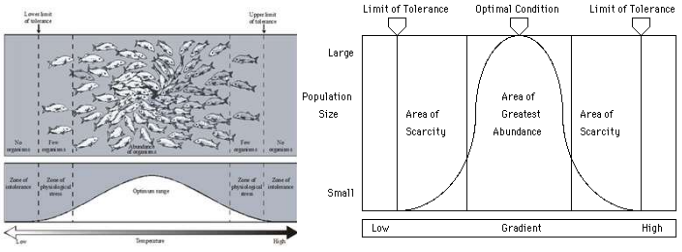
Ecosystem Ecology Examines Interactions Between the Living and Non-Living World

- Ecosystem- A particular location on Earth distinguished by its particular mix of interacting biotic and abiotic components.
- Biotic examples: animals, plants, algae,
- Abiotic examples: nutrients, temperature, solar energy, water

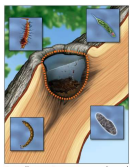
Ecosystem Ecology Examines Interactions Between the Living and Non-Living World

- Range of Tolerance: niche breadth, or the range of conditions that an organism can withstand.
- Optimum Range: the best or most favorable point, degree, amount, etc., as of temperature, light, and moisture for the growth or reproduction of an organism.



Ecosystem Boundaries

- Some ecosystems, such as a caves and lakes have very distinctive boundaries. However, in most ecosystems it is difficult to determine where one ecosystems stops and the next begins.



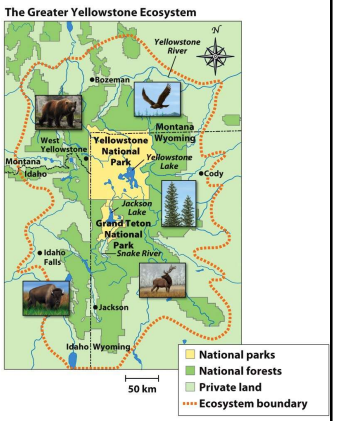


Figure 3.2a
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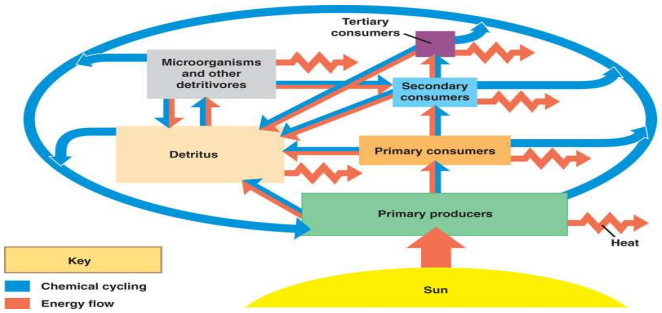
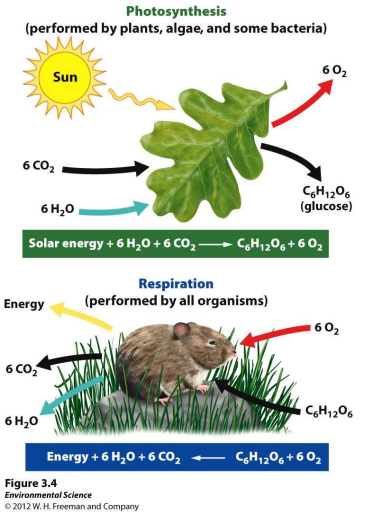
Energy Flows through Ecosystems



Photosynthesis & Respiration

- **Photosynthesis**: Process where autotrophs are able to use the suns energy to produce usable energy.
- **Cellular respiration** is the process by which other organisms gain energy from eating the tissues of producers.



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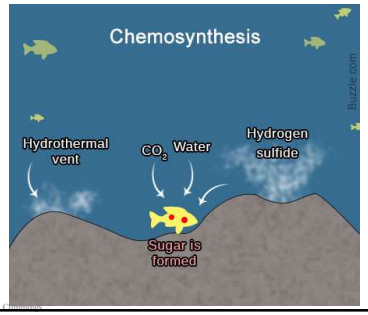
Chemosynthesis: Hydrothermal Vents

- Chemosynthetic bacteria use the geothermal energy in hot springs or deep-sea vents to produce their food
- No sunlight—ocean floor vents…
- Heat + $3H_2S + 6CO_2$ → $C_6H_{12}O_6 + 3H_2SO_4$

Sulfuric Acid

Hydrogen Sulfide



Trophic Levels, Food Chains, and Food Webs

- **Autotrophs** = Capture solar energy for photosynthesis to produce sugars (Plants, Algae, & Cyanobacteria)
- **Consumers (heterotrophs)-** obtain energy by consuming other organisms.
- **Primary Consumers (herbivores)** - consume producers.
- **Secondary Consumers (carnivores)** - obtain their energy by eating primary consumers.
- **Tertiary Consumers (carnivores)-** eat secondary consumers.
- **Detritivores:** Feed on detritus—dead organisms, waste of living organisms.
- **Decomposers:** Bacteria and Fungi—recycle organic material from dead organisms…to inorganic nutrients…

Trophic Levels, Food Chains, and Food Webs

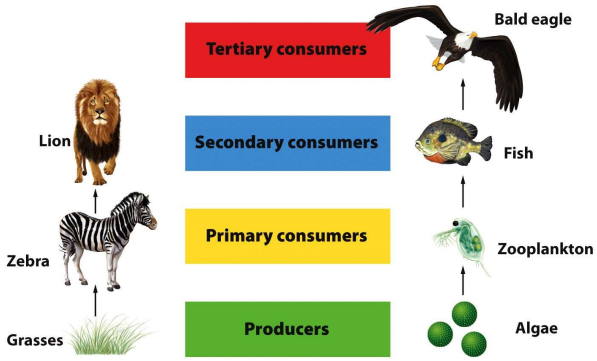


Figure 3.5
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Trophic Levels, Food Chains, and Food Webs

- Food Chain- The sequence of consumption from producers through tertiary consumers.

Vs.

- Food Web- A more realistic type of food chain that takes into account the complexity of nature.

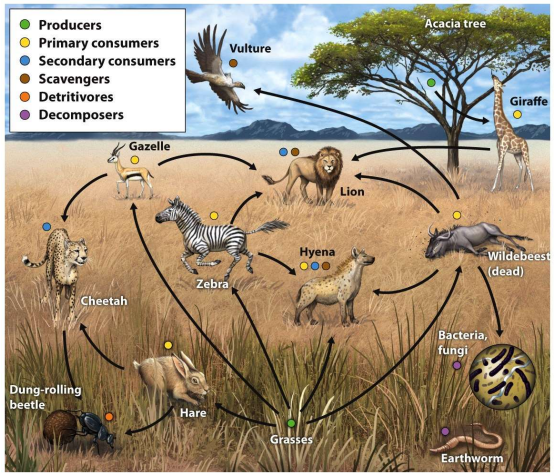

Figure 3.6
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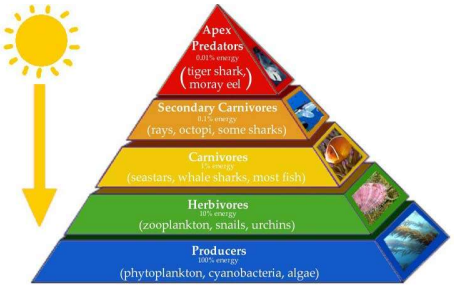
Trophic levels: Energy low

- Matter and energy move through the community
- **Trophic levels** = rank in the feeding hierarchy
  - Producers
  - Consumers
  - Detritivores
  - Decomposer



Energy Transfer Efficiency and Trophic Pyramids

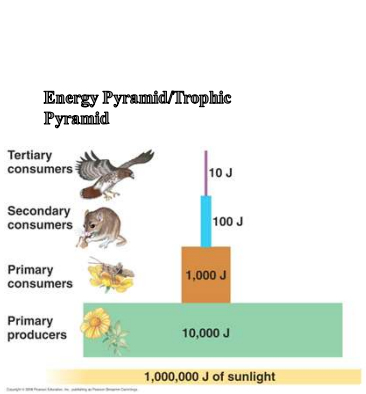
- **Biomass-** The energy in an ecosystem is measured in terms of biomass. (desert v. rainforest)
- **Ecological efficiency-** The proportion of consumed energy that can be passed from one trophic level to another.
- **Trophic pyramid-** The representation of the distribution of biomass among trophic levels.

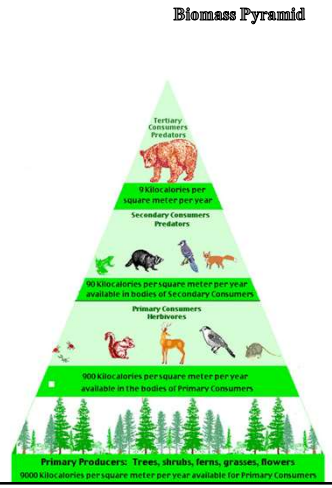
Energy, biomass, and numbers decrease

- Most energy organisms use is lost as waste heat through respiration
  - Less and less energy is available in each successive trophic level
  - Each level contains only 10% of the energy of the trophic level below it
- There are far fewer organisms at the highest trophic levels, with less energy available

A human vegetarian's ecological footprint is smaller than a meat-eater's footprint

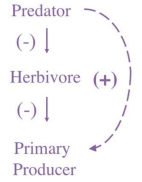
Pyramids

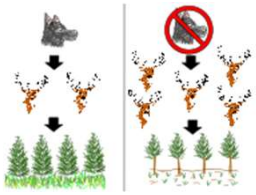




Species can change communities

- **Trophic Cascade** = predators at *high trophic levels* can indirectly affect populations of organisms at *low trophic levels* by keeping species at *intermediate trophic* levels in check
  - Extermination of wolves led to increased deer populations, which led to overgrazed vegetation and changed forest structure
- Ecosystem engineers = physically modify the environment
  - Beaver dams, prairie dogs, fungi

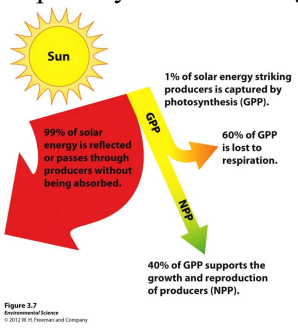




Energy is converted to biomass

Second law of thermo-dynamics

Gross primary production (GPP) = The total amount of solar energy that the producers in an ecosystem capture via photosynthesis over a given amount of time.



- **Net primary production (NPP)** = The energy captured (GPP) minus the energy respired by producers.

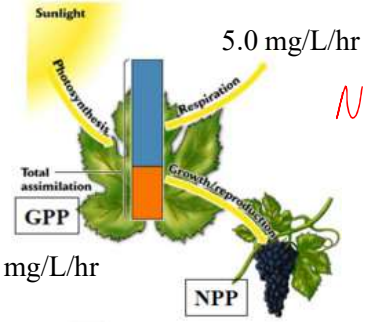
(NPP) = GPP – Respiration

Energy is converted to biomass

Figuring out Net primary production (NPP)

Formula: (NPP) = GPP – Respiration

- What is the NPP still available for heterotrophs?



5.0 mg/L/hr

2.2 mg/L/hr

NPP = GPP – Resp

GPP = NPP + Resp

What is the formula to figure out GPP?

7.2 mg/L/hr

GPP= NPP + Respiration

Figuring out Net primary production (NPP)

B)Using the simplified equation above, write the simplified equation for respiration:
CALCULATE the following problems – remember to include units into your setup and answer!
Place a box around your answers. Remember: NPP = GPP – Respiration $_{plants}$

1. The net annual primary productivity of a particular wetland ecosystem is found to be 8,000 kcal/m_2.If respiration by the aquatic producers is 12,000 kcal/m_2 per year, what is the gross annual primary productivity for this ecosystem, in kcal/m_2 per year?

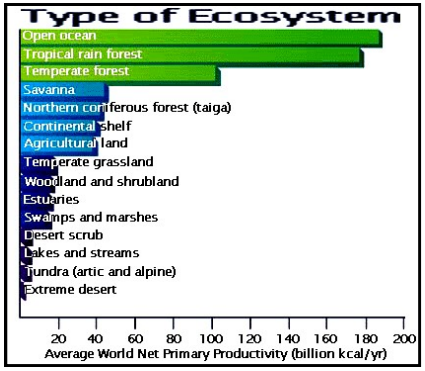
2. If you measure the available biomass for a patch of forest as 10 kg C/ m_2-year, and the amount of CO_2 given off into the atmosphere as 5 kg C/ m_2-year, what is the GPP?

3. In the patch of forest in problem #2, how much energy is ***available*** in the primary producer level for herbivore consumption? Assume 1 kg of carbon produces 10,000 kJ.

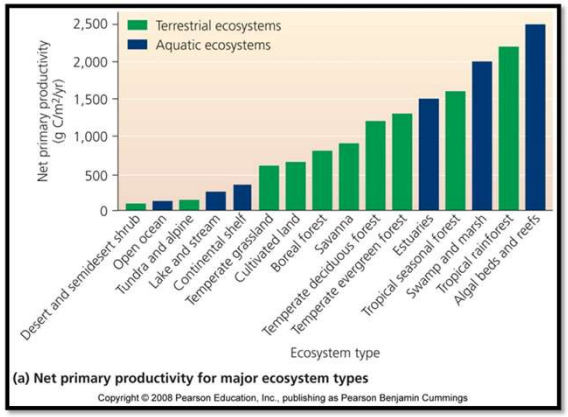
Net primary productivity of various ecosystems

High net primary productivity = ecosystems whose plants rapidly convert solar energy to biomass

What type of ecosystem has the highest NPP?



Net primary productivity of various ecosystems



(a) Net primary productivity for major ecosystem types

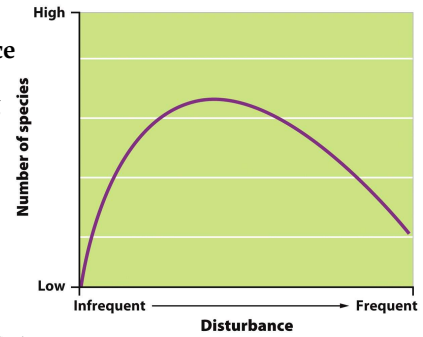
Resistance versus Resilience

- **Resistance**- A measure of how much a disturbance can affect its flows of energy and matter.
- **Resilience**- The rate at which an ecosystem returns to its original state after a disturbance.

Disturbance

- **Disturbance-** An event caused by physical, chemical or biological agents that results in changes in population size or community composition.

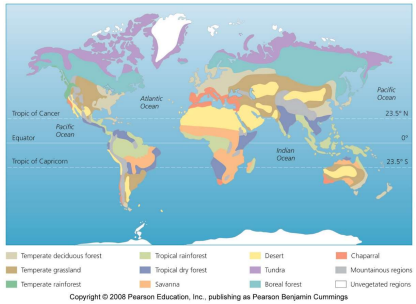
- **Intermediate disturbance hypothesis-** states that ecosystems experiencing intermediate levels of disturbance are more diverse than those with high or low disturbance levels.



Biomes

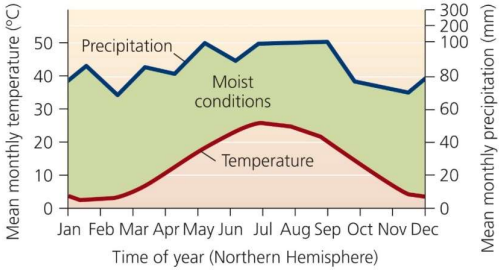
- Biome = major regional complex of similar communities recognized by
  - Plant type
  - Vegetation structure

- The biome in an area depends on a variety of abiotic factors
  - Temperature, precipitation, atmospheric circulation, soil



Climatograph

- **Climatographs**
  - Show an area's mean monthly **temperature** and **precipitation**
  - Similar biomes occupy similar latitudes

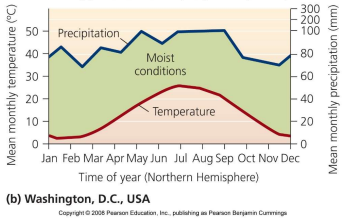


(b) Washington, D.C., USA

Temperate deciduous forest

- **Deciduous trees** lose their leaves each fall and remain dormant during winter
- Mid-latitude forests in Europe, East China, Eastern North America
- Fertile soils
- Forests = oak, beech, maple

(a) Temperate deciduous forest

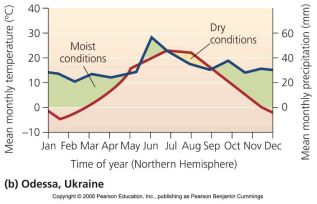


(b) Washington, D.C., USA

Temperate grasslands

- More extreme temperature difference between winter and summer
- Less precipitation
- Also called **steppe** or **prairie**
  - Once widespread throughout parts of North and South America and much of central Asia
  - Much was converted for agriculture
  - Bison, prairie dogs, antelope, and ground-nesting birds

(a) Temperate grassland

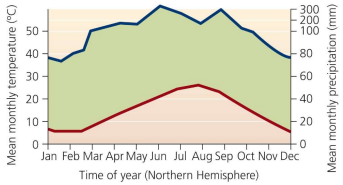


(b) Odessa, Ukraine

Temperate rainforest

- Coastal Pacific Northwest region
- Great deal of precipitation
- Coniferous trees: cedar, spruce, hemlock, fir
- Moisture-loving animals
  - Banana slug
- The fertile soil is susceptible to erosion and landslides
- Provides lumber and paper

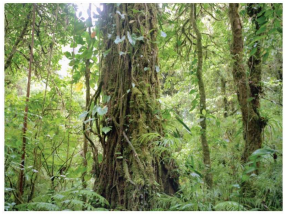
(a) Temperate rainforest



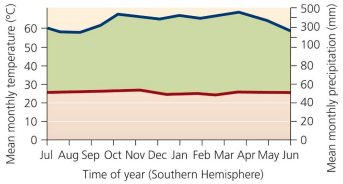
(b) Nagasaki, Japan

Tropical rainforest

- Central America, South America, southeast Asia, and west Africa
- Year-round rain and warm temperatures
- Dark and damp
- Lush vegetation
- Variety of animals and tree species, but in low numbers
- Very poor, acidic soils



(a) Tropical rainforest

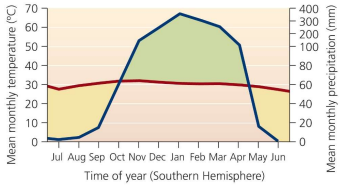


(b) Bogor, Java, Indonesia

Tropical dry forest

- Tropical deciduous forest
- India, Africa, South America, northern Australia
- Wet and dry seasons
- Warm, but less rainfall
- Converted to agriculture
- Erosion-prone soil

(a) Tropical dry forest

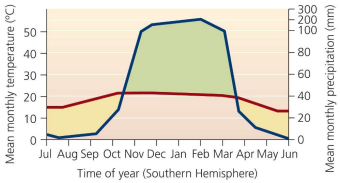


(b) Darwin, Australia

Savanna

- Grassland interspersed with trees
- Africa, South America, Australia, India
- Precipitation only during rainy season
- Water holes
- Zebras, gazelles, giraffes, lions, hyenas

(a) Savanna

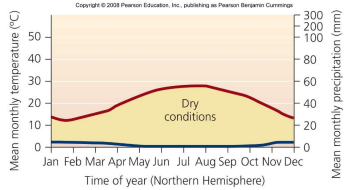


(b) Harare, Zimbabwe

Desert

- Minimal precipitation
- Some deserts are bare, with sand dunes (Sahara)
- Some deserts are heavily vegetated (Sonoran)
- They are not always hot
  - Temperatures vary widely
- Saline soils
- Nocturnal or nomadic animals
- Plants have thick skins or spines

(a) Desert

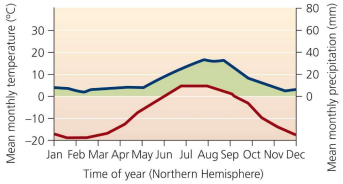


(b) Cairo, Egypt

Tundra

- Canada, Scandinavia, Russia
- Minimal precipitation
  - Nearly as dry as a desert
- Seasonal variation in temperature
  - Extremely cold winters
- Permafrost: permanently frozen soil
- Few animals: polar bears, musk oxen, caribou
- Lichens and low vegetation with few trees

(a) Tundra

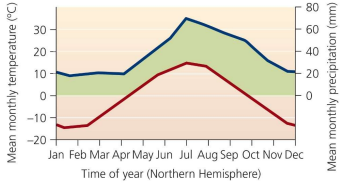


(b) Vaigach, Russia

Boreal forest (taiga)

- Canada, Alaska, Russia, Scandinavia
- Variation in temperature and precipitation
- Cool and dry climate
  - Long, cold winters
  - Short, cool summers
- Poor and acidic soil
- Few evergreen tree species
- Moose, wolves, bears, migratory birds

(a) Boreal forest

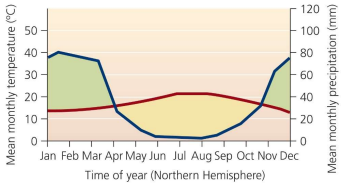


(b) Archangelsk, Russia

Chaparral

- Mediterranean Sea, California, Chile, and southern Australia
- High seasonal
  - Mild, wet winters
  - Warm, dry summers
- Frequent fires
- Densely thicketed, evergreen shrubs

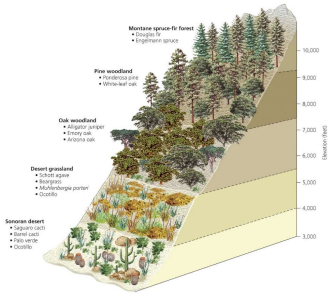
(a) Chaparral



(b) Los Angeles, California, USA

Altitudes create patterns

- Vegetative communities change along mountain slopes
  - In the Andes, a mountain climber would begin in the tropics and end up in a glacier



Hiking up a mountain in the southwest U.S. is analogous to walking from Mexico to Canada

Chapter 16

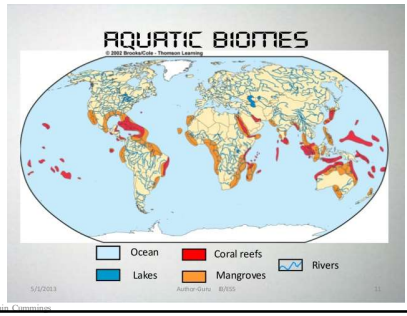
Aquatic Ecosystems

Video

Aquatic systems have biome-like patterns

- Aquatic systems are shaped by
  - Water temperature, salinity, and dissolved nutrients
  - Wave action, currents, depth
  - Substrate type, and animal and plant life

- Ocean
- Lakes
- Coral reefs
- Mangroves
- Rivers
- Kelp Forest

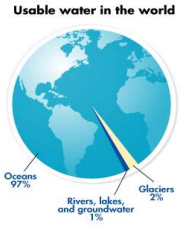


Marine Biomes

- **Consist of coastal ocean, open ocean, coral reefs, estuaries, coastal marshes, and mangrove swamps.**

- 71% of earth's surface
- Currents distribute solar heat and regulate the earth's climate
- participate in nutrient cycles
- reservoir for carbon dioxide - thus help regulate temperature of the troposphere

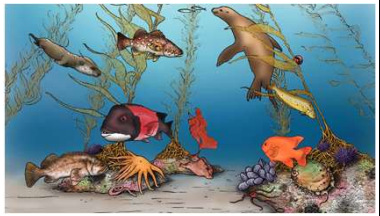
- 2/3rds of population live within 100 miles of the ocean



Open ocean systems

Kelp forests

- **Kelp** = large, dense, brown algae growing from the floor of continental shelves
- Cold temperatures
- Shelter and food for organisms
- Absorbs wave energy and protects shorelines from erosion
- Used cosmetics, paints, paper, and soaps
- High Biodiversity



Open ocean systems

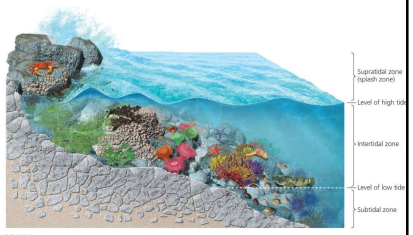
Coral reefs

- Highest areas of biodiversity and most abundant of ocean organisms
- Protect shoreline by absorbing waves
- Found in the Neritic Zone in tropical (warm) waters

- **Corals** = tiny colonial marine organisms
- **Coral reef** = a mass of calcium carbonate composed of the skeletons of corals

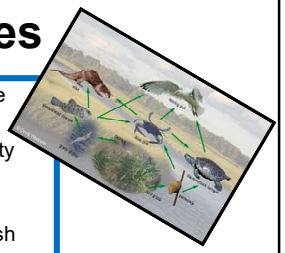
Intertidal zone

- Changing tides cause rocky shores to be completely covered with water at certain times and completely exposed to the air and sunlight at others.

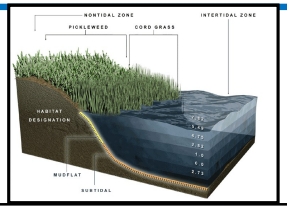


(a) Tidal zones

Salt marshes



- **Salt marsh** = occur along coasts at temperate latitude
  - Tides wash over gently sloping, sandy, silty substrates
  - High primary productivity
  - Critical habitat for birds and commercial fish and shellfish species
  - Filter pollution
  - Stabilize shorelines against storm surges



Mangrove forests

- In tropical and subtropical latitudes coast lines
- **Mangroves** = trees with unique roots
  - Curve upwards for oxygen
  - Curve downwards for support

- Nurseries for commercial fish and shellfish
- Nesting areas for birds
- Food, medicine, tools, construction materials

Estuaries

- **Estuaries** = water bodies where rivers flow into the ocean (freshwater mixes with saltwater)
  - Wide fluctuations in salinity
- Critical habitat for shorebirds and shellfish

- Transitional zone (Fish spawn in freshwater, mature in salt water) Ex: Salmon
- Affected by development, pollution, habitat alteration, and overfishing

- Chesapeake Bay
  - Largest estuary in the US.
  - Very productive
  - High amounts of pollution introduced
  - Restoration program introduced in the 80s