Ecosystems: Nutrient ‘Cycles’
Earth’s Life-Support Systems

Carbon cycle
Phosphorus cycle
Nitrogen cycle
Water cycle
Oxygen cycle

Heat in the environment

Fig. 3-6, p. 39
Greeks, Native Peoples, Buddhism, Hinduism use(d) Earth, Air, Fire, and Water as the main elements of their faith/culture.
Cycling in Ecosystems – the Hydrologic Cycle

• What are the three forms of water?
• Processes
  – Condensation
  – Precipitation
  – Transpiration
  – Evaporation
What happens when water hits a surface?

Depends on: permeability of the surface

- 50% of water that falls on soil or vegetation runs off
- 100% of water that falls on asphalt runs off
Carbon Cycle

Forms the basis of all living things

It all starts with…

Which creates…

Why is this important?
Carbon Cycle

Does this plant contain carbon?

What happens when the plant dies? Does it release carbon?
Carbon Cycle

Does this wood contain carbon?

What happens when you burn wood? Do you release carbon?
Sources of Organic Carbon in the Hudson River

Information taken from Stanne, Panetta, and Florist. 2007. The Hudson.
Carbon Cycle

• Can be stored in five major areas:
  1. Living and dead organisms
  2. Atmosphere (carbon dioxide)
  3. Organic matter in soil
  4. Lithosphere as fossil fuels and rock deposits
  5. Oceans as dissolved CO2 and shells
Atmosphere Carbon Store

Biosphere Carbon Store

Lithosphere Carbon Store

Fossil Fuel Emissions

Photosynthesis

Respiration & Decomposition

Diffusion

Coal, Oil & Gas

Biomass

Aquatic Biomass

Carbon

Limestone & Dolomite

Marine Deposits
## Estimated major stores of carbon on the Earth

<table>
<thead>
<tr>
<th>Sink</th>
<th>Amounts in Billions of Metric Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>766</td>
</tr>
<tr>
<td>Soil Organic Matter</td>
<td>1500-1600</td>
</tr>
<tr>
<td>Ocean</td>
<td>38,000-40,000</td>
</tr>
<tr>
<td>Marine sediments and sedimentary rocks</td>
<td>66,000,000 to 100,000,000</td>
</tr>
<tr>
<td>Terrestrial plants</td>
<td>540-610</td>
</tr>
<tr>
<td>Fossil Fuel Deposits</td>
<td>4000</td>
</tr>
</tbody>
</table>
Carbon in Ecosystems: Photosynthesis and Respiration

- **Forms of C**: CO$_2$, organic C compounds like glucose

- **Processes**
  - Photosynthesis: Carbon dioxide + water + solar energy $\xrightarrow{\text{chlorophyll}}$ glucose (sugar) + oxygen
  - Respiration: Glucose + oxygen $\Rightarrow$ Carbon dioxide + water + E
Carbon in Oceans

• Enters through diffusion (creates carbonic acid)
• Some sea life use bicarbonate to produce shells and body parts (coral, clams, some algae)
Carbon cycle in the lithosphere

- Inorganic: coal, oil, natural gas, oil shale, limestone
- Created from organisms (both plant and animal) that died a long time ago and accumulated on the bottom of oceans or lakes
Carbon cycle in the soil

- Organic: litter, humic substances found in soil
Humans and the Carbon Cycle

• Until recently: none
• Now: 6.5 billion metric tons of carbon are transferred from fossil fuel storage pool to the atmosphere
The Greenhouse effect

Some solar radiation is reflected by the atmosphere and earth's surface.

Outgoing solar radiation: 108 wan per m²

Net incoming solar radiation

Some of the infrared radiation passes through the atmosphere and is lost in space.

Net outgoing infrared radiation at m²

Solar radiation passes through the clear atmosphere.

Incoming solar radiation: 343 Watt per m²

Solar energy is absorbed by the earth's surface and warms it...

...and is converted into heat causing the emission of longwave (infrared) radiation back to the atmosphere.

168 Watt per m²

Greenhouse gases

Some of the incoming radiation is absorbed and re-emitted by the greenhouse gases, particularly carbon dioxide and water vapor.
Geologic Cycle

- Takes place over millions of years
- CO2 from the atmosphere combines with water to create a weak acid, which reacts with compounds in the earth’s surface and eventually settles into the ocean floor
- This carbon is eventually released back into the atmosphere during volcanic eruptions
- What else might cause the carbon to be released back into the atmosphere?
Biologic Cycle

- Very rapid process: days to years
- Photosynthesis: makes carbohydrates and oxygen
- About half of the CO2 is released and half is stored in the plant biomass
- Biomass becomes part of the soil carbon cycle, which is ultimately released through erosion, fire, or decomposition
- Average residence time of carbon in soil is 20-30 years
- What are anthropogenic sources of CO2?
Nitrogen Cycle

• Why is nitrogen important?
• What uses can you think of for nitrogen?
• It is considered a ‘limiting’ factor in many ecosystems...without it, plants would not be able to grow
• Including phytoplankton
Nitrogen Cycle

Do you contain nitrogen?

Does the air contain nitrogen?
Nitrogen Cycle

- The atmosphere is made up of 79% N gas
- This gas is not useable by living things
- It must be converted to form compounds such as ammonia (NH4) or nitrate (NO3) which can be taken up by living things
- There is natural and human fixation of N2
  - Natural: lightning, bacteria
  - Human: fossil fuel combustion, fertilizer manufacturing
Nitrogen Cycle

- Organisms cannot use N₂
- Nitrogen fixing bacteria
  - Root nodules of legumes (mutualism)
  - Soil
- Plants use nitrate (NO₃⁻)--FERTILIZERS
Nitrogen Cycle

In an undisturbed forest most of the nitrogen cycles between living plants and dead organic matter in the soil. Plants take up nitrogen through their roots; microbes release the nitrogen from dead leaves and branches to the soil. Small amounts enter the cycle through nitrogen fixation, and even smaller amounts leave in stream water.
Nitrogen Cycle

Nitrogen Cycle in a Developed Watershed:

- **$N_2$** Atmospheric nitrogen
- **$NO_x$** Nitrogen oxides
- **$NH_4^+$** Ammonium ion
- **$NO_3^-$** Nitrate ion
- **$SO_2$** Sulfur dioxide

 desenvolved watershed import nitrogen in food and fertilizer. They also receive nitrogen from acid rain which in turn gets its nitrogen from the nitrogen oxides produced by furnaces, boilers, and engines. About half the nitrogen a watershed receives is stored in the soil or in trees; exported as crops. The flows into rivers.
Nitrogen cycle...so what?

• Plants and animals need nitrogen
• But...there can be too much of a good thing!
• Too much nitrogen results in: eutrophication of aquatic systems

There is both cultural (human) and natural eutrophication
Eutrophication: excess nutrients stimulate plant growth (algal bloom); when these plants die, decomposers use up the available oxygen during decomposition.

Source: www.algae.info

Source: http://serc.carleton.edu
Nitrogen in the Hudson

Where does it come from?
- human waste
- acid deposition
- fertilizer
- agriculture: fixation and feed

Where does it go?
INPUTS TO WYJERS HED

Add d'eposition, <0.4 kg N/ha-yr

Nitrogen Wexon
2.8 kg, N/ha-yr

Hudson Watershed

Animal feed, 1.4 kg N/ha-yr

Fertilizer, 4 kg N/ha-yr

Food, 19.2 kg N/ha-yr

Raritan Watershed

Outputs from
Watershed is:

Acid Deposition

Agricultural

Food

Urban \\

Deposition

Agricultural

Acid Deposition

Seawage

19 kg of nitrogen per hectare of watershed per year

INPUTS TO NESUAR

Nitrogen Cycle

Nitrogen: Why so much from the middle of the USA?

Potential delivery of nitrogen to surface waters

Note: The potential for cropland within a watershed to discharge nitrogen in surface water is determined by runoff factors (climate, distance from water, erosion) and nitrogen source factors (total inorganic and organic fertilizer applications), which are influenced by the economic choices farmers make.

Source: Compiled from Landsat Thematic Mapper satellite imagery, Iowa Dept. of Natural Resources.
Humans and the Nitrogen Cycle

Last 100 years: humans have more than doubled the amount of fixed nitrogen that is pumped into the atmosphere every year.

Consequences: acid rain, creation of ground level ozone, groundwater contamination, and eutrophication.
Phosphorous

• Where does it come from?
  - not a gas
  - weathers from rock
  - reuse from already present phosphorous in detritus

• Why is it important?
  - less abundant and available than N
  - often the limiting nutrient in freshwater ecosystems
Phosphorus Cycle

• Inorganic phosphate in rocks
  – Dissolves in water
  – Plants take up inorganic phosphate
  – FERTILIZERS
• Converted to organic phosphates found in organisms
• Decomposers convert organic waste back to inorganic P in the soil
Phosphorous in the Hudson

- Main source: detritus
- Used by plants during the growing season
- Some P is lost to the ocean and some becomes buried in sediment
Summary: Humans, Nutrients, and the Hudson

- Sewage: contributes nitrogen, phosphorous, and carbon
- Fertilizer runoff
- Laundry water that contains phosphates
- Deposition of nitrogen from acid rain
- Consequences for the New York Harbor

Q: Why doesn’t the Hudson have more algal blooms?