Biogeochemical Cycles

I don't understand why when we destroy something created by man we call it vandalism, but when we destroy something created by nature we call it progress.
- Ed Begley, Jr.

Objectives:

- Define the term **biogeochemical cycles**.
- Compare and contrast how carbon, phosphorus, nitrogen, and water cycle through the environment.
- Explain how human impact is affecting biogeochemical cycles

Biogeochemical Cycle: The comprehensive set of cyclical pathways by which a given nutrient moves through the environment.

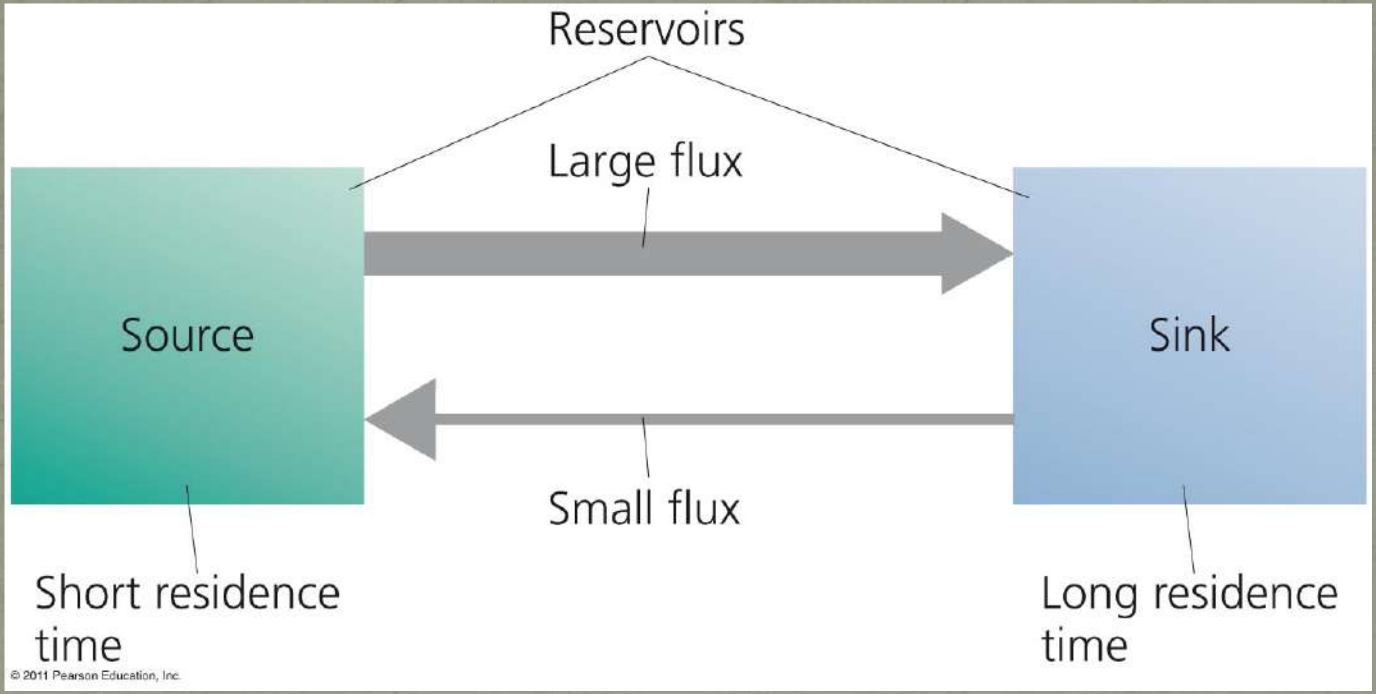
Compare and contrast how carbon, phosphorus, nitrogen, and water cycle through the environment.

- A source is a reservoir that contributes more of a material than it receives, and a sink is one that receives more than it provides.
- Water moves widely through the environment in the water (hydrological) cycle.
- Most carbon is contained in sedimentary rock. Substantial amounts also occur in the oceans and in soil. Carbon flux between organisms and the atmosphere occurs via photosynthesis and respiration.
- Nitrogen in a vital nutrient for plant growth. Most nitrogen is in the atmosphere, so it must be "fixed" by specialized bacteria or lightning before plants can use it.
- Phosphorus is most abundant in sedimentary rock, with substantial amounts in soil and the oceans. Phosphorus has no appreciable atmospheric pool. It is a key nutrient for plant growth.

Nutrients circulate through ecosystems

- Matter is continually circulated in ecosystems
- **Nutrient (biogeochemical) cycles**: the movement of nutrients through ecosystems
  - Atmosphere, hydrosphere, lithosphere, and biosphere
- **Pools (reservoirs)**: where nutrients reside for varying amounts of time (called the **residence time**)
- **Flux**: the rate at which materials move between pools
  - Can change over time
  - Is influenced by human activities

Main components of a biogeochemical cycle



- **Source**: a pool that releases more nutrients than it accepts
- **Sinks**: a pool that accepts more nutrients than it releases

The hydrologic cycle

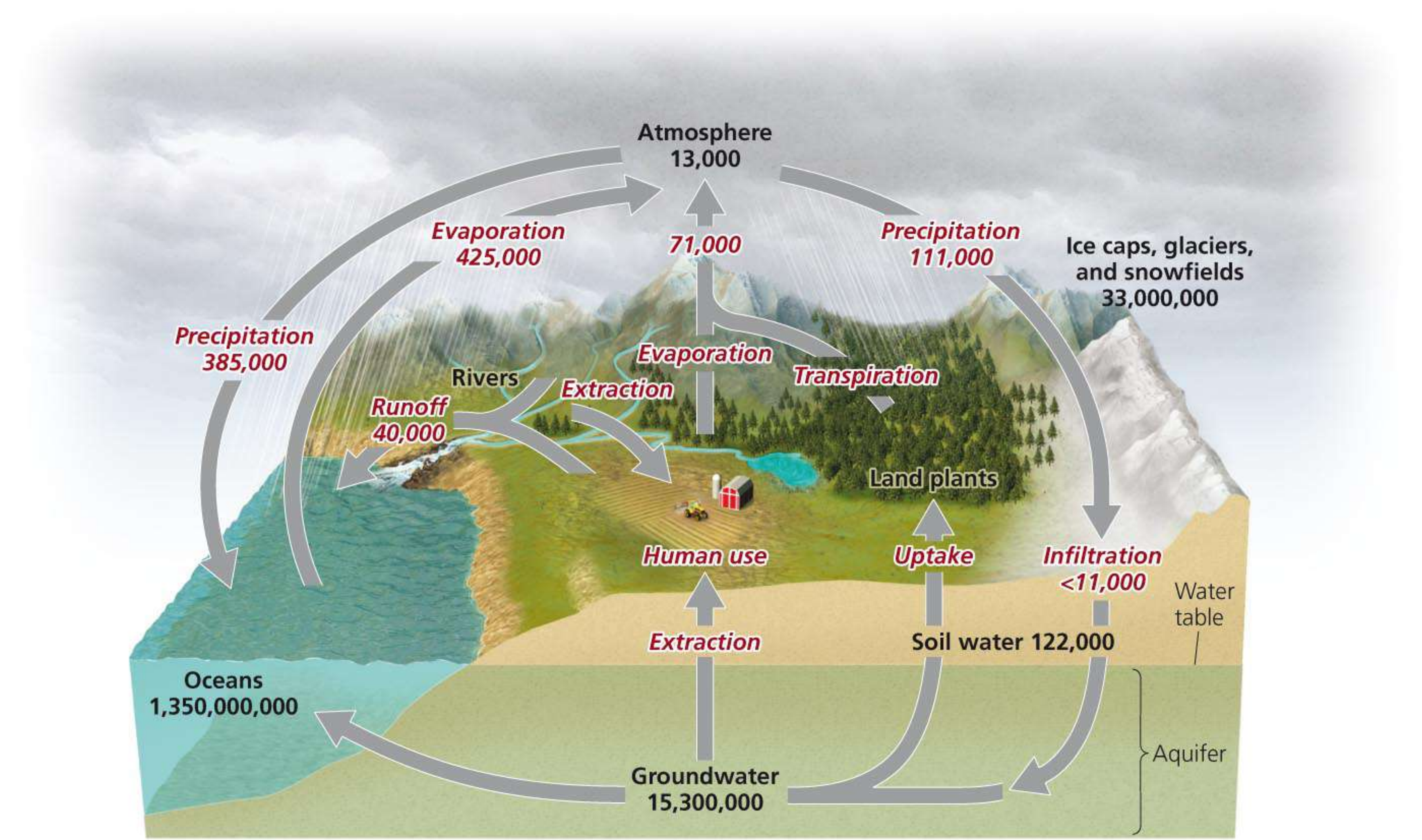
- Water is essential for biochemical reactions
  - It is involved in nearly every environmental system
- **Hydrologic cycle**: summarizes how liquid, gaseous and solid water flows through the environment
  - Oceans are the main reservoir
- **Evaporation**: water moves from aquatic and land systems into the atmosphere
- **Transpiration**: release of water vapor by plants
- **Condensation**: water vapor changes phase into liquid water (clouds)
- **Precipitation**, **runoff**, and **surface water:** water returns to Earth as rain or snow and flows into streams, oceans, etc.

Transpiration

Groundwater

- **Aquifers**: underground reservoirs of sponge-like regions of rock and soil that hold…
  - **Groundwater**: water found underground beneath layers of soil, either within rock or unconsolidated sediments
- **Water table**: the upper limit of groundwater in an aquifer (the interface between the zone of aeration and zone of saturation)
  - Water is ancient (thousands to millions of years old)
- Groundwater becomes exposed to the air where the water table reaches the surface (streams, rivers, ponds, etc.)
  - Exposed water runs off to the ocean or evaporates

The hydrologic cycle



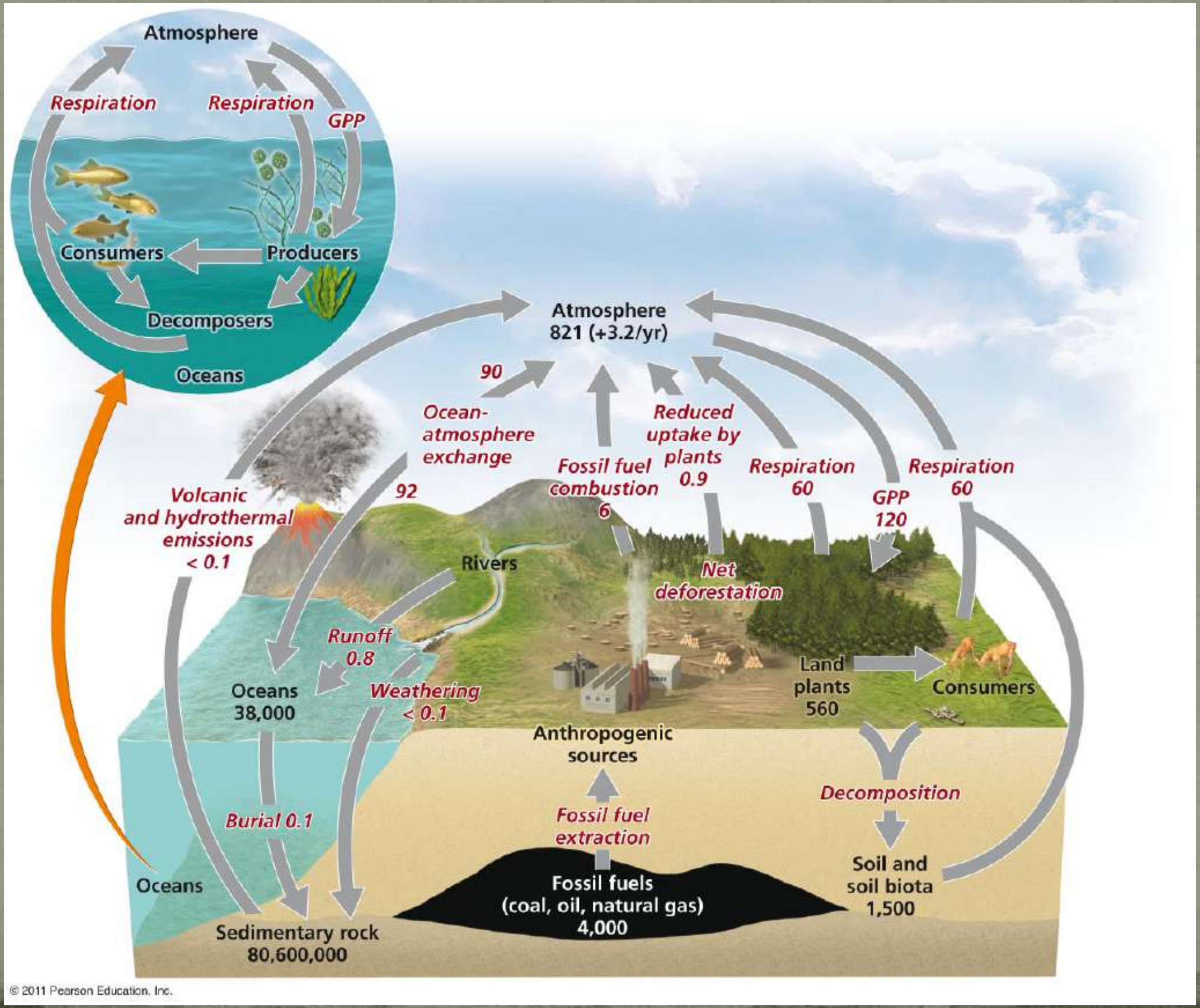
The carbon cycle

- Carbon is a vital life sustaining nutrient. It is found in carbohydrates, fats, proteins, bones, cartilage and shells
- **Carbon cycle**: describes the route of carbon atoms through the environment
- Photosynthesis by plants, algae and cyanobacteria
  - Removes carbon dioxide from air and water
  - Produces oxygen and carbohydrates
  - Plants are a major reservoir of carbon
- Respiration returns carbon to the air and oceans
  - Plants, consumers and decomposers

Sediment storage of carbon

- Decomposition returns carbon to the sediment
  - The largest reservoir of carbon
  - May be trapped for hundreds of millions of years
- Aquatic organisms die and settle in the sediment
  - Older layers are buried deeply and undergo high pressure
  - Ultimately, it may be converted into fossil fuels
- Oceans are the second largest reservoir of carbon

The carbon cycle



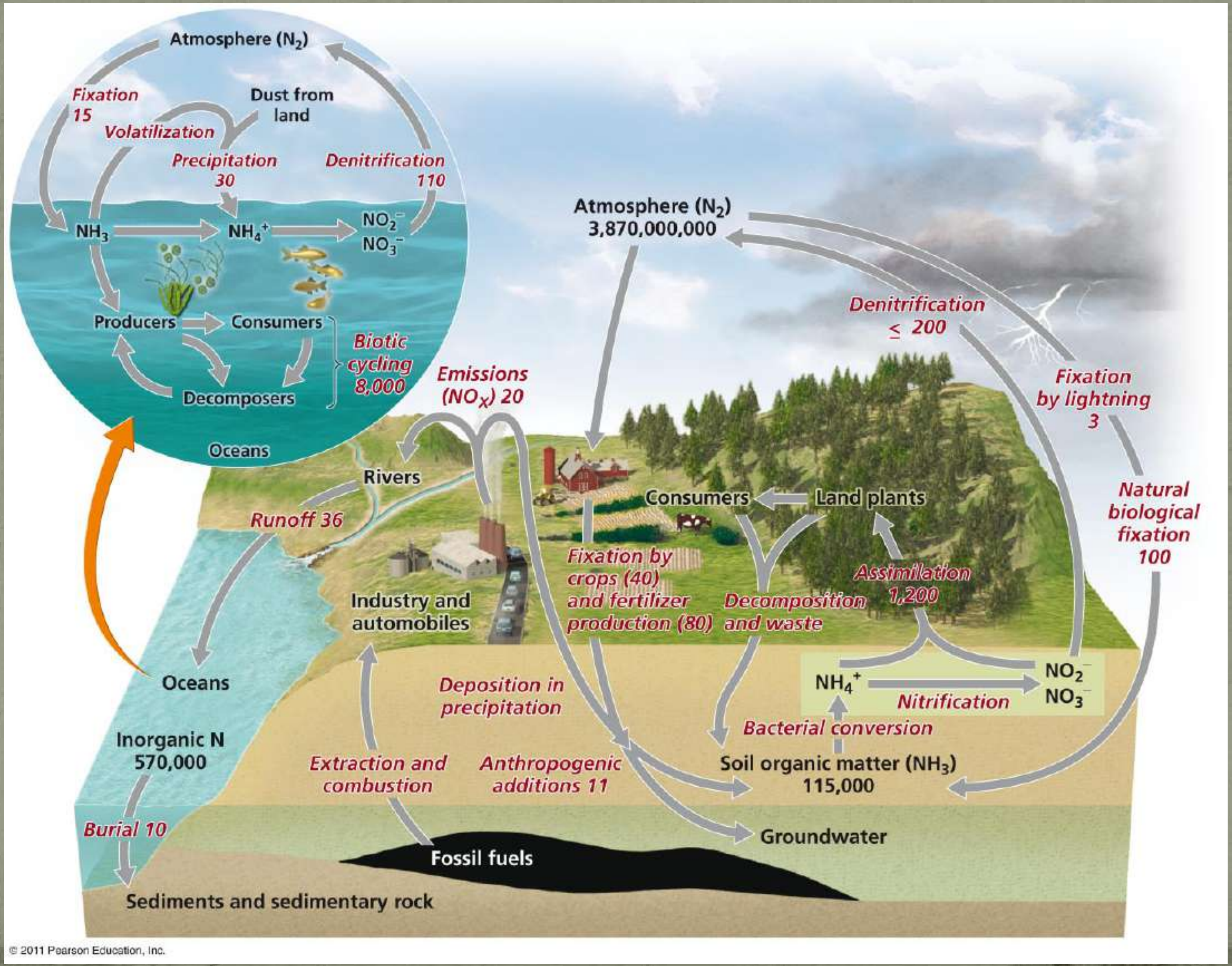
The nitrogen cycle

- Nitrogen comprises 78% of our atmosphere
  - It is contained in proteins, DNA and RNA
- **Nitrogen cycle**: describes the routes that nitrogen atoms take through the environment
  - Nitrogen gas cannot be used by most organisms (it’s an inert gas, so it doesn’t react and the bonds are super strong)
- **Nitrogen fixation**: lightning or nitrogen-fixing bacteria combine (fix) nitrogen with hydrogen
  - To form ammonium
  - Which can be used by plants

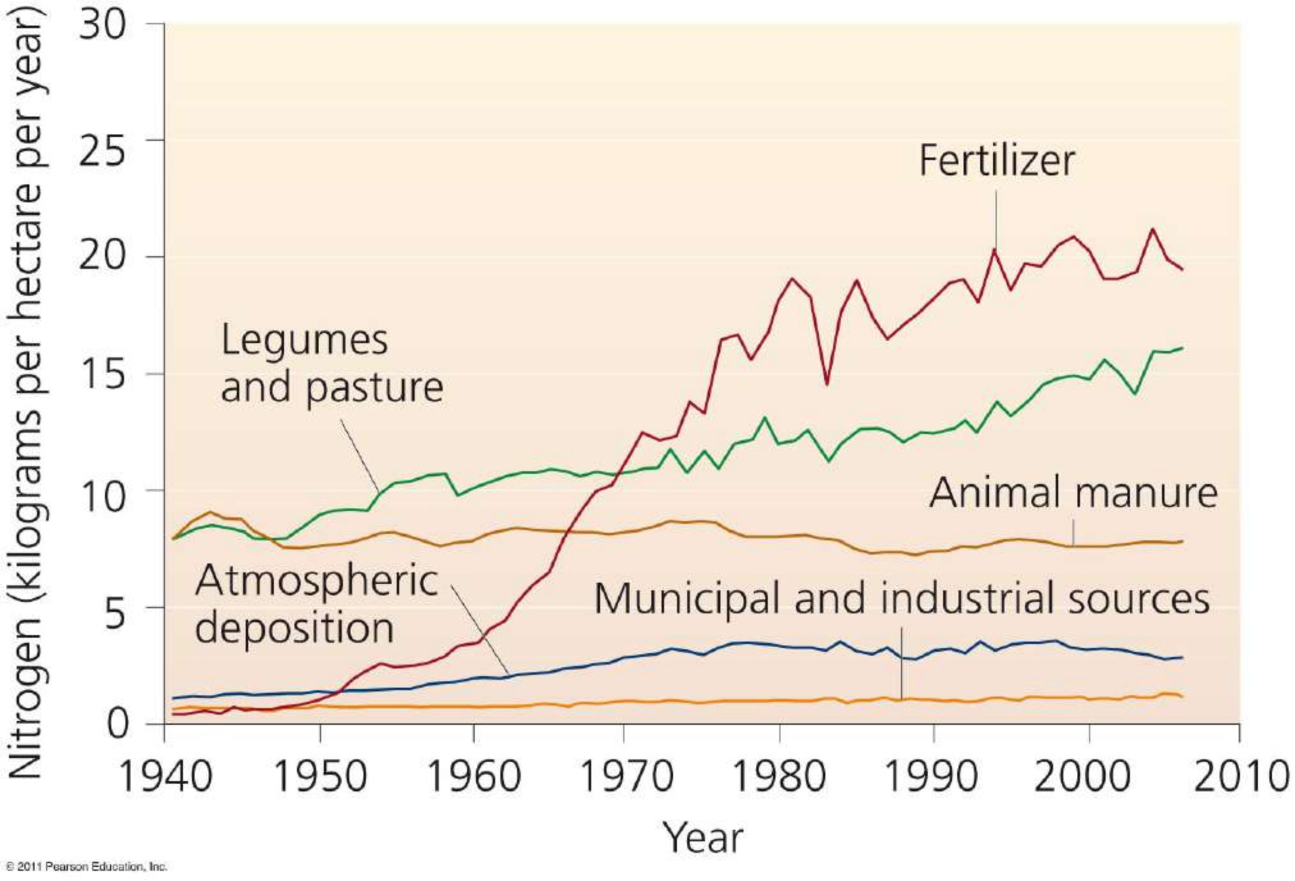
Nitrification and denitrification

- **Nitrification**: bacteria convert ammonium ions first into nitrite ions then into nitrate ions
  - Plants can take up these ions
- Animals obtain nitrogen by eating plants or other animals
- Decomposers get it from dead and decaying plants or other animals
  - Releasing ammonium ions to nitrifying bacteria
- **Denitrifying bacteria**: convert nitrates in soil or water to gaseous nitrogen
  - Releasing it back into the atmosphere

The nitrogen cycle



Humans add nitrogen to the env

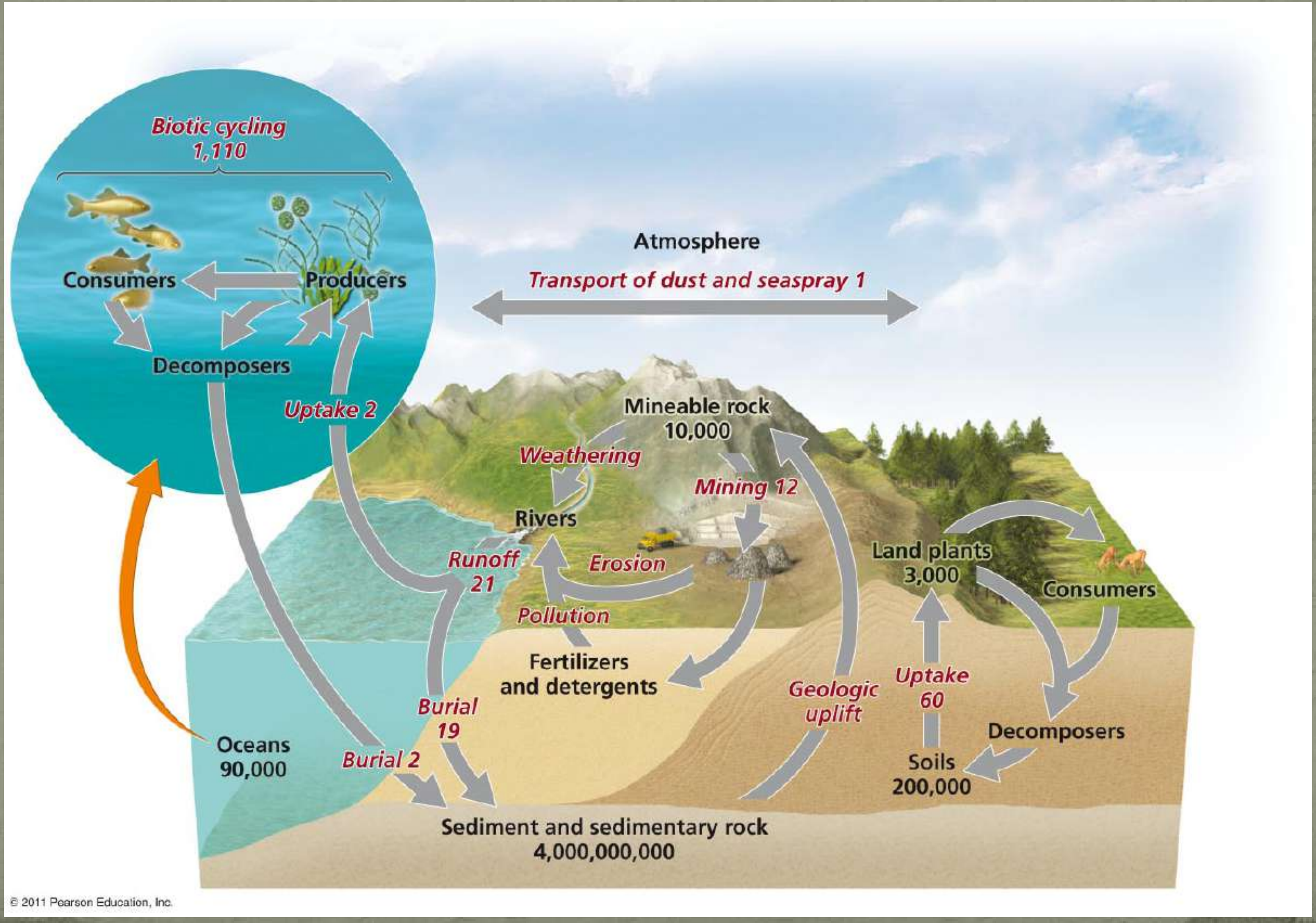


Fully half of nitrogen entering the environment is of human origin

The phosphorus cycle

- Phosphorus (P) is a key component of cell membranes, DNA, RNA, ATP and ADP
- **Phosphorus cycle:** describes the routes that phosphorus atoms take through the environment
- Most phosphorus is within rocks
  - It is released by weathering
  - There is no atmospheric component
- With naturally low environmental concentrations
  - Phosphorus is a limiting factor for plant growth
  - A limiting factor is environmental conditions that limit the growth, abundance and distribution of organisms or populations of organisms within an ecosystem

The phosphorus cycle



Explain how human impact is affecting biogeochemical cycles.

- People are affecting Earth's biogeochemical cycles by shifting carbon from fossil fuel reservoirs into the atmosphere, shifting nitrogen from the atmosphere to the planet's surface, and depleting groundwater supplies, among other impacts
- Policy can help us address problems with nutrient pollution.

Human impacts on the hydrologic cycle

- Removing forests and vegetation increases runoff and erosion, reduces transpiration and lowers water tables
- Irrigating agricultural fields depletes rivers, lakes and streams and increases evaporation
- Damming rivers increases evaporation and infiltration
- Emitting pollutants changes the nature of precipitation
- The most threatening impact: overdrawing groundwater for drinking, irrigation, and industrial use
  - Water shortages create worldwide conflicts

Humans affect the carbon cycle

- Burning fossil fuels moves carbon from the ground to the air
- Cutting forests and burning fields moves carbon from vegetation to the air
- Today's atmospheric carbon dioxide reservoir is the largest in the past 800,000 years
  - It is the driving force behind climate change
- The missing carbon sink: 1-2 billion metric tons of carbon are unaccounted for
  - It may be taken up by plants or soils of northern temperate and boreal forests

Humans affect the nitrogen cycle

- **Haber-Bosch process** : production of fertilizers by combining nitrogen and hydrogen to synthesize ammonia
  - Humans overcame the limits on crop productivity
- Fixing atmospheric nitrogen with fertilizers
  - Increases emissions of greenhouse gases and smog
  - Washes calcium and potassium out of soil
  - Acidifies water and soils
  - Moves nitrogen into terrestrial systems and oceans
  - Reduces diversity of plants adapted to low-nitrogen soils
  - Changed estuaries and coastal ecosystems and fisheries

Humans affect the phosphorus cycle

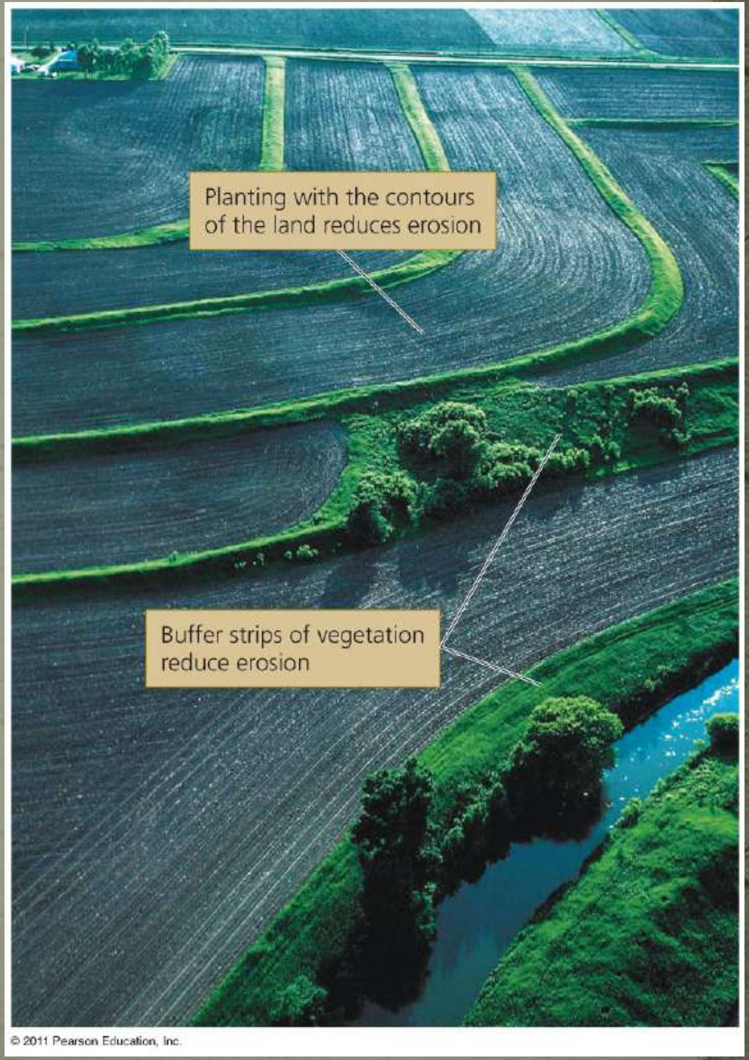
- Mining rocks for fertilizer moves phosphorus from the soil to water systems
- Wastewater discharge also releases phosphorus
- Runoff containing phosphorus causes eutrophication of aquatic systems
  - Produces murkier waters
  - Alters the structure and function of aquatic systems
  - Do not buy detergents that contain phosphate

Solutions to the dead zone

- The Harmful Algal Bloom and Hypoxia Research and Control Act (1998)
  - Called for an assessment of hypoxia in the dead zone
- Solutions outlined included:
  - Reduce nitrogen fertilizer use in Midwestern farms
  - Apply fertilizer at times which minimize runoff
  - Use alternative crops and manage manure better
  - Restore wetlands and create artificial ones
  - Improve sewage treatment technologies
  - Evaluate these approaches

Decreasing pollution

- Scientists, farmers and policymakers are encouraged to
  - Decrease fertilizer use
  - While safeguarding agriculture
- Offering insurance and incentives
- Using new farming methods
- Planting cover crops
- Maintaining wetlands
- There have been some successes
  - Despite a lack of funding



TED Video

Human growth has strained the Earth's resources, but as Johan Rockstrom reminds us, our advances also give us the science to recognize this and change behavior. His research has found nine "planetary boundaries" that can guide us in protecting our planet's many overlapping ecosystems.

"Rockstrom has managed in an easy, yet always scientifically based way, to convey our dependence of the planet's resources, the risk of transgressing planetary boundaries and what changes are needed in order to allow humanity to continue to develop."

Anna Ritter, Fokus magazine

[Johan Rockstrom: Let the environment guide our development (18:11)]