

Chapt. 54 – Ecosystems

Ecosystem – all the organisms living in a community, plus all the abiotic factors with which they interact

From a small “closed system” to the biosphere

Two principal ecosystem processes: energy flow & chemical cycling [Fig. 54.2]

Energy flows through an ecosystem (energy from the sun ultimately dissipates into space as heat)

Chemical elements are continually recycled

Physical laws govern these processes

1st Law of Thermodynamics: Conservation of Energy

2nd Law of Thermodynamics: Energy transformation is inefficient (between trophic levels)

Primary producers take elements in **inorganic molecules** and incorporate them into **organic molecules**

Additional **organic molecules** are produced at other trophic levels

Organic molecules are broken down into **inorganic molecules** by **metabolism** and **decomposition of detritus**

Energy budgets

Gross primary production (GPP) → the amount of **light energy** converted to **chemical energy** per unit time (by **primary producers** through **photosynthesis**)

Net primary production (NPP) → GPP minus energy used by **primary producers** for **respiration**

$$\text{NPP} = \text{GPP} - \text{R}$$

Different ecosystems vary in overall size (Fig. a), NPP (Fig. b), and their contributions to total NPP on Earth (Fig. c) [Fig. 54.4]

Terrestrial ecosystems contribute about 2/3 and marine ecosystems about 1/3 of global NPP

Resources limit **primary production** (just as they limit population growth)

Resources = light, water, nutrients

For example, large-scale manipulations often demonstrate N or P limitation of NPP
[Fig. 54.7]

For example, **actual evapotranspiration** correlates well with NPP across biomes
[Fig. 54.8]

Actual evapotranspiration is the amount of water transpired plus evaporated
(a function of water availability and solar energy)

Secondary production is the amount of chemical energy in consumers' food converted to
consumer biomass [Fig. 54.10]

Some energy at each trophic level remains unassimilated (uneaten; not shown in the fig.)

Some assimilated energy is passed in waste, some is used in respiration, and the rest is
net secondary production

In this example, <17% is used for secondary production

Trophic efficiency is the percentage of production transferred from one trophic level to
another

Primary producers only convert ~1% of sunlight

Other trophic levels ~10% (5% to 20%)

Pyramid of net production [Fig. 54.11]

Pyramid of biomass [Fig. 54.12]

The **standing crop** at each trophic level

Usually narrows from the base upwards

But sometimes increases upwards if primary producers turn over rapidly

Pyramid of numbers [Fig. 54.13]

Predators tend to be larger than prey, so pyramids of numbers nearly always narrow
upwards

For a given amount of grain, carnivorous humans fair worse than vegetarians!

Biogeochemical cycles

Earth is nearly a **closed system** with respect to amounts of elements (with the exception of minor additions and losses, *e.g.*, meteorites)

The general **biogeochemical cycle** of an element [Fig. 54.16]

Elements cycle among **pools** that vary in whether they are: (1) incorporated in **organic** vs. **inorganic molecules**, or (2) **available** vs. **unavailable** to organisms

SEE Fig. 54.17

The Water Cycle

Major reservoir is the ocean (which contains about 97% of Earth's water)

Key processes include evaporation, transpiration, condensation in clouds, and precipitation

The Carbon Cycle

Major reservoirs with "fast" turnover include fossil fuels, soils, dissolved carbon compounds in the oceans, biomass, CO₂

The largest pool is sedimentary rock, but turnover is very slow

Key processes are photosynthesis, respiration, burning of fossil fuels, volcanoes

The Phosphorus Cycle

Major reservoirs are sedimentary rocks, soils, oceans, and biomass

Key processes include weathering of rocks and decomposition; little cycling in the atmosphere

The Nitrogen Cycle

Major reservoir is the atmosphere (which is about 80% N₂)

Key process for N to enter an ecosystem is fixation, the conversion of N₂ by bacteria (or lightning) to forms usable by plants

Humans have dramatically altered biogeochemical cycles and ecosystems

For example...

The Hubbard Brook, NH experiment demonstrates the importance of forests for nutrient cycling **[Fig. 54.19]**

Whole watersheds were experimentally deforested or not

Weirs measured nutrient loss from watersheds

Deforested watersheds lost nutrients at prodigious rates

For example...

Oxides of sulfur and nitrogen from burning of fossil fuels have formed sulfuric and nitric acid, which have acidified soils **[Fig. 54.22]**

For example...

Anthropogenic CO₂ is the direct cause of global warming and various other manifestations of climate change **[Fig. 54.24]**