Ecosystems: An introduction

- An ecosystem consists of all the organisms living in a community as well as all the abiotic factors with which they interact.
- The dynamics of an ecosystem involve two processes: energy flow and chemical cycling.
- We can follow the transformation of energy by grouping the species in a community into **trophic levels** of feeding relationships.
- The law of conservation of energy applies to ecosystems.
  - We can potentially trace all the energy from its solar input to its release as heat by organisms.
- The second law of thermodynamics allows us to measure the efficiency of the energy conversions.

Trophic relationships determine the routes ofenergy flow and chemical cycling in an ecosystem

- The autotrophs are the **primary producers**, and are usually photosynthetic (plants or algae).
  - They use light energy to synthesize sugars and other organic compounds.
- **Heterotrophs** are at trophic levels above the primary producers and depend on their photosynthetic output.
  - Herbivores that eat primary producers are called **primary consumers**.
  - Carnivores that eat herbivores are called **secondary consumers**.
  - Carnivores that eat secondary producers are called **tertiary consumers**.
  - Another important group of heterotrophs is the **detritivores**, or **decomposers**.
    - They get energy from detritus, nonliving organic material and play an important role in material cycling.
- ***Decomposition connects all trophic levels.***
- The organisms that feed as detritivores often form a major link between the primary producers and the consumers in an ecosystem.
- The organic material that makes up the living organisms in an ecosystem gets recycled.
  - An ecosystem’s main decomposers are fungi and prokaryotes, which secrete enzymes that digest organic material and then absorb the breakdown products.

An ecosystem’s energy budget depends on primary production

- The amount of light energy converted to chemical energy by an ecosystem’s autotrophs in a given time period is called **primary production**.
- Most primary producers use light energy to synthesize organic molecules, which can be broken down to produce ATP; there is an energy budget in an ecosystem.
- The Global Energy Budget
  - Every day, Earth is bombarded by large amounts of solar radiation.
    - Much of this radiation lands on the water and land that either reflect or absorb it.
    - Of the visible light that reaches photosynthetic organisms, ***only about 1% is converted to chemical energy***.
      - Although this is a small amount, primary producers are capable of producing about 170 billion tons of organic material per year.

- Gross and Net Primary Production.
  - Total primary production is known as **gross primary production (GPP)**.
    - This is the amount of light energy that is converted into chemical energy.
  - The **net primary production (NPP)** is equal to gross primary production minus the energy used by the primary producers for respiration (R):
    - NPP = GPP – R
  - Primary production can be expressed in terms of energy per unit area per unit time, or as **biomass** of vegetation added to the ecosystem per unit area per unit time.
  - Different ecosystems differ greatly in their production as well as in their contribution to the total production of the Earth.
- Production in Freshwater Ecosystems.
  - Solar radiation and temperature are closely linked to primary production in freshwater lakes.
  - During the 1970s, sewage and fertilizer pollution added nutrients to lakes, which shifted many lakes from having phytoplankton communities to those dominated by diatoms and green algae.
  - This process is called **eutrophication**, and has undesirable impacts from a human perspective.
  - Controlling pollution may help control eutrophication.
  - Experiments are being done to study this process.

Secondary Production

- The amount of chemical energy in consumers' food that is converted to their own new biomass during a given time period is called **secondary production**.
- The efficiency of energy transfer between trophic levels is usually ***<u>less than 20%.</u>***
- Secondary Production Efficiency.
  - One way to understand secondary production is to examine the process in individual organisms.
  - If we view animals as ***<u>energy transformers</u>***, we can ask questions about their relative efficiencies.
    - Production efficiency = Net secondary production/assimilation of primary production
      - Net secondary production is the energy stored in biomass represented by growth and reproduction.
      - Assimilation consists of the total energy taken in and used for growth, reproduction, and respiration.
      - In other words production efficiency is the fraction of food energy that is not used for respiration.
      - This differs between organisms.
    - Trophic Efficiency and Ecological Pyramids.
      - **Trophic efficiency** is the percentage of production transferred from one trophic level to the next.
      - **Pyramids of production** represent the multiplicative loss of energy from a food chain.

    - **Pyramids of biomass** represent the ecological consequence of low trophic efficiencies.

      - Most biomass pyramids narrow sharply from primary producers to top-level carnivores because energy transfers are inefficient.

The Cycling of Chemical Elements in Ecosystems

- Nutrient circuits involve both biotic and abiotic components of ecosystems and are called **biogeochemical** cycles.
- Biological and geologic processes move nutrients between organic and inorganic compartments.
- There are four main reservoirs of elements and processes that transfer elements between reservoirs.
- Reservoirs are defined by ***two characteristics***:
    - whether it contains organic or inorganic materials
    - whether or not the materials are directly usable by organisms.
- The water cycle is more of a physical process than a chemical one.
- The carbon cycle fits the generalized scheme of biogeochemical cycles better than water.
- The nitrogen cycle.
    - Nitrogen enters ecosystems through two natural pathways.
    - Atmospheric deposition, where usable nitrogen is added to the soil by rain or dust.
    - **Nitrogen fixation**, where certain prokaryotes convert N_2 to minerals that can be used to synthesize nitrogenous organic compounds like amino acids.
    - In addition to the natural ways, industrial production of nitrogen-containing fertilizer contributes to nitrogenous materials in ecosystems.
    - The direct product of **nitrogen fixation** is ammonia, which picks up H^+ and becomes ammonium in the soil (**ammonification**), which plants can use.
    - Certain aerobic bacteria oxidize ammonium into nitrate, a process called **nitrification**.
    - Nitrate can also be used by plants.
    - Some bacteria get oxygen from the nitrate and release N_2 back into the atmosphere (**denitrification**).
- The phosphorous cycle.
    - Organisms require phosphorous for many things.
    - This cycle is simpler than the others because phosphorous does not come from the atmosphere.
- Phosphorus occurs only in ***phosphate***, which plants absorb and use for organic synthesis.

The human population is disrupting chemical cycles throughout the biosphere

- Human activity intrudes upon nutrient cycles by removing nutrients from one part of the biosphere and then adding them to another.
    - In agricultural ecosystems, a large amount of nutrients are removed from the area in the crop biomass.
        - After awhile, the natural store of nutrients can become exhausted.

Combustion of fossil fuels is the main cause of acid precipitation

- The burning of fossil fuels releases sulfur oxides and nitrogen that react with water in the atmosphere to produce sulfuric and nitric acids.
- These acids fall back to earth as **acid precipitation**, and can damage ecosystems greatly.
- The acids can kill plants, and can kill aquatic organisms by changing the pH of the soil and water.

Toxins can become concentrated in successive trophic levels of food webs

- Humans produce many toxic chemicals that are dumped into ecosystems.
  - These substances are ingested and metabolized by the organisms in the ecosystems and can accumulate in the fatty tissues of animals.
  - These toxins become more concentrated in successive trophic levels of a food web, a process called **biological magnification**.

Human activities are depleting the atmospheric ozone

- Life on earth is protected from the damaging affects of ultraviolet radiation (UV) by a layer of O_3, or ozone.
- Studies suggest that the ozone layer has been gradually"thinning" since 1975.
- The destruction of ozone probably results from the accumulation of chlorofluorocarbons, chemicals used in refrigeration and aerosol cans, and in certain manufacturing processes.
  - The result of a reduction in the ozone layer may be increased levels of UV radiation that reach the surface of the Earth.
    - This radiation has been linked to skin cancer and cataracts.

Dealing with the "*Human Induced*" Biodiversity Crisis

- **Conservation biology** is a goal-oriented science that seeks to counter the **biodiversity crisis**, the current rapid decrease in Earth's variety of life.
- The three levels of biodiversity are genetic diversity, species diversity, and ecosystem diversity.
- Loss of genetic diversity.
  - If a local population becomes extinct, then the entire population of that species has lost some genetic diversity.
    - The loss of this diversity is detrimental to the overall adaptive prospects of the species.
- Loss of species diversity.
  - Much of the discussion of the biodiversity crisis centers on species loss. Here are a few examples:
    - 13% of the known 9,040 bird species are threatened with extinction. ***That's 1,183 species!!!***
    - The Center for Plant Conservation estimates that 200 of the 20,000 known plant species in the U. S. have become extinct since records have been kept, and another 730 are endangered or threatened.
    - About 20% of the known freshwater species of fish in the world have become extinct or are seriously threatened.
  - Several researchers estimate that at the current rate of destruction, over half of all plant and animal species will be gone by the end of this new century.

- Loss of ecosystem diversity.
  - The local extinction of one species, like a keystone predator, can affect an entire community.
  - Some ecosystems are being erased from the Earth at an unbelievable pace.
    - For example, an area ***the size of the state of West Virginia*** is lost from tropical forests ***each year***.

So why should we care about biodiversity?

- Biodiversity is a crucial natural resource, and species that are threatened could provide crops, fibers, and medicines for human use.
- The loss of species also means the loss of genes.
  - Biodiversity represents the sum of all the genomes on Earth.

The four major threats to biodiversity are habitat destruction, introduced species, overexploitation and food chain disruption

- **Habitat destruction.**
  - Human alteration of habitat is the single greatest cause of habitat destruction.
  - Destruction of physical habitat is responsible for the 73% of species designated extinct, endangered, vulnerable, or rare.
  - About 93% of the world’s coral reefs have been damaged by humans.
- **Introduced species.**
  - **Introduced species** are those that humans move from native locations to new geographic regions.
  - The Nile perch was introduced into Lake Victoria as a food fish, but led to the extinction of several native species.
- **Overexploitation.**
  - This refers to the human harvesting of wild plants and animals at rates that exceed the ability of those populations to rebound.
    - The African elephant has been overhunted and the populations have declined dramatically.
    - The bluefin tuna is another example of an over-harvested species.
- **Disruption of food chains.**
  - The extinction of one species can doom its predators, but only if the predator feeds exclusively on this prey.
  - Much of the evidence for secondary extinctions of larger organisms due to loss of prey is circumstantial.

Restoring degraded areas is an increasingly important conservation effort

- **Restoration ecology** applies ecological principles in developing ways to return degraded areas to natural conditions.

- **Bioremediation** is the use of living organisms to detoxify polluted ecosystems.

  - Restoration ecologists use various types of organisms to *remove* many different types of toxins from ecosystems.