MAY THE FLOSS
BE WITH YOU
While we’re at it, here’s some test day biology.

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**.

• Ecosystem ecologists view ecosystems as energy machines and matter processors.

• We can follow the transformation of energy by grouping the species in a community into **trophic levels** of feeding relationships.
1. Trophic relationships determine the routes of energy flow and chemical cycling in an ecosystem

- The autotrophs are the **primary producers**, and are usually photosynthetic (Photoautotrophs, which can be either ?, or ?, or?), but could be ?????
  - They use light energy to synthesize sugars and other organic compounds. Light, then, is a big limiting factor.
  - Chemoautotrophs are the producers in some ecosystems, like deep sea vents (they are strictly prokaryotic).
Predict the effects of a change in the community’s populations on the community. [LO 4.13, SP 6.4]

Predict the effects of a change of matter or energy availability on communities. [LO 4.16, SP 6.4]
• **Heterotrophs** are at trophic levels above the primary producers and depend on their photosynthetic output.

• **Decomposers**, or **detritivores**, feed on dead organisms of all types, helping recycle nutrients.
• An ecosystem’s main decomposers are fungi and prokaryotes, which secrete enzymes that digest organic material and then absorb the breakdown products, defining them as saprotrophs.
3. The laws of physics and chemistry apply to ecosystems

- 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.
2.A.1.f. Explain how changes in free energy availability can result in disruptions to an ecosystem by using one of the examples below:

Change in the producer level can affect the number and size of other trophic levels.

Change in energy resources levels such as sunlight can affect the number and size of the trophic levels.
The amount of light energy converted to chemical energy by an ecosystem’s autotrophs in a given time period is called **primary production**, and is measured in the DRY mass of autotroph tissue made in a certain amount of time.

Again, light availability is a **big** limiting factor.
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, about only 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):
  
• \[ \text{NPP} = \text{GPP} - \text{R} \]

• Practice?
The net annual primary productivity of a particular wetland ecosystem is found to be 8,000 kcal/m². If respiration by the aquatic producers is 12,000 kcal/m² per year, what is the gross annual primary productivity for this ecosystem, in kcal/m² per year? Round to the nearest whole number.
Q8

- NPP = GPP - R
- $8,000 = GPP - 12,000$
- $8,000 + 12,000 = GPP$
- $20,000 = GPP$
• Primary production can be expressed in terms of energy per unit area per unit time, or as bioma**ss** of vegetation added to the ecosystem per unit area per unit time. J/m\(^2\)/year, for example.

• This should not be confused with the total biomass of photosynthetic autotrophs present at a given time, called the *standing crop*. 
- Different ecosystems differ greatly in their production as well as in their contribution to the total production of the Earth. Light, water and temperature are the biggest limiting factors.
• 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.

• Hey, how about explaining that to us.

• POGIL?

1. Nutrient-rich water flows in.
2. Algae grow, feed and die.
3. Zooplankton eat algae.
4. Bacteria feed on fecal pellets and dead algae.
5. Bacteria deplete the water of oxygen.
6. Marine life flees (2.0 mg/l) or dies (1.0 mg/l).
Hypoxic/anoxic zone in the Gulf of Mexico
Another big issue – plastic in the ocean

• See [here](https://example.com) what you will find in the middle of the ocean.
3. In terrestrial ecosystems, temperature, moisture, and nutrients limit primary production

- Obviously, water availability varies among terrestrial ecosystems more than aquatic ones.

- On a large geographic scale, temperature and moisture are the key factors controlling primary production in ecosystems.
The amount of chemical energy in consumers’ food that is stored in their own new biomass during a given time period is called secondary production.

In other words, how much of that double cheeseburger and fries actually becomes part of you is secondary production.

10% rule is for SECONDARY productivity.

Primary productivity is LESS efficient.
1. The efficiency of energy transfer between trophic levels is usually close to 10%

• Production Efficiency.
• But….is that feces really not available?
• Who do we often leave out of food chains and webs?

Fig. 54.10
• 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.
• The dynamics of energy through ecosystems have important implications for the human population.

• Practice problem – last page of Equations and Formulas Review Sheet.
• **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 (10%)

![Diagram of biomass pyramid](Fig. 54.12a)
In some aquatic ecosystems, the pyramid is inverted.

In this example, phytoplankton grow, reproduce, and are consumed rapidly.

They have a short turnover time, which is a comparison of standing crop mass compared to production.
• **Pyramids of numbers** show how the levels in the pyramids of biomass are proportional to the number of individuals present in each trophic level.
3. 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, because they are non-biodegradeable.
  - These toxins become more concentrated in successive trophic levels of a food web, a process called biological magnification.
  - Useable energy decreases in the food chain, non-biodegradable things increase.
The pesticide DDT, before it was banned, showed this effect.
Fig. 54.25

DDT concentration: increase of 10 million times

DDT in fish-eating birds 25 ppm

DDT in large fish 2 ppm

DDT in small fish 0.5 ppm

DDT in zooplankton 0.04 ppm

DDT in water 0.000003 ppm
• The water cycle is mostly a physical process (evaporation, condensation), but part is biological, right?
Did you get it right?

- Respiration and dehydration synthesis creates new water, and photosynthesis and hydrolysis breaks water molecules apart.
1. Biological and geologic processes move nutrients between organic and inorganic compartments

• A general model of chemical cycling.

• 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, and whether or not the materials are directly usable by organisms.
Fig. 54.15

Organic materials available as nutrients

Living organisms, detritus

Fossilization

Coal, oil, peat

Inorganic materials available as nutrients

Assimilation, photosynthesis

Respiration, decomposition, excretion

Erosion, burning of fossil fuels

Weathering, erosion

Formation of sedimentary rock

Minerals in rocks

Inorganic materials unavailable as nutrients

Atmosphere, soil, water

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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.

Out of the air, fixed into an organisms molecules, back into the air.
• 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.
- Humus and soil particles bind phosphate, so the recycling of it tends to be localized.
1. The human population is disrupting chemical cycles throughout the biosphere

- Human activity intrudes in nutrient cycles by removing nutrients from one part of the biosphere and then adding them to another.
- Agricultural effects of nutrient cycling.
• In agricultural ecosystems, a large amount of nutrients are removed from the area in the crop biomass.

• After a while, the natural store of nutrients can become exhausted.
Recent studies indicate that human activities have approximately doubled the worldwide supply of fixed nitrogen, due to the use of fertilizers, cultivation of legumes, and burning.

This may increase the amount of nitrogen oxides in the atmosphere and contribute to atmospheric warming, depletion of ozone and possibly acid rain.
The burning of fossil fuels releases sulfur oxides and nitrogen that react with water in the atmosphere to produce sulfuric and nitric acids.

Fig. 54.23a
• These acids fall back to earth as **acid precipitation**, damaging ecosystems greatly.

• The acids can kill plants, and can kill aquatic organisms by changing the pH of the soil and water.
4. Human activities may be causing climate change by increasing carbon dioxide concentration in the atmosphere

- Rising atmospheric CO$_2$.
  - Since the Industrial Revolution, the concentration of CO$_2$ in the atmosphere has increased greatly as a result of burning fossil fuels.
  - This carbon would normally be “locked up” in coal and oil for long periods of time.
• Measurements in 1958 read 316 ppm and increased to 400 ppm in May 2013, highest in a few million years. Now 410 in 2016
The greenhouse effect.

- Rising levels of atmospheric CO$_2$ and methane may have an impact on Earth’s heat budget.

- When light energy hits the Earth, much of it is reflected off the surface.
  - CO$_2$, methane and other gases cause the Earth to retain some of the energy that would ordinarily escape the atmosphere.
  - This phenomenon is the **greenhouse effect**.

- The Earth needs this heat, but too much could be disastrous. Watch the [methane in Siberia](http://example.com/methane_in_siberia).
Methane in Arctic bubbling out 5 times faster than thought - warming Arctic temperature thaws permafrost (frozen soil remaining below 0°C for years) that seals methane (greenhouse gas 25 times more powerful than carbon dioxide).
Scientists continue to construct models to predict how increasing levels of CO₂ in the atmosphere will affect Earth.

- Several studies predict a doubling of CO₂ in the atmosphere will cause a 2º C increase in the average temperature of Earth.

- Rising temperatures can cause polar ice cap melting, which can flood coastal areas.

- It is important that humans attempt to stabilize their use of fossil fuels.
But here may be the biggest problem with carbon dioxide increase…

• Coming to an ocean near you. 3:10

• If sea level rises you can move to a different place.

• If food chains collapse you can’t move to a different food chain.
5. Human activities are depleting the atmospheric ozone

- Life on earth is protected from the damaging affects of ultraviolet radiation (UV-B) by a layer of O$_3$, or ozone.

- Studies suggest that the ozone layer has been gradually “thinning” since 1975.

- Seems to be getting better!

Fig. 54.27a
The destruction of ozone probably results from the accumulation of chlorofluorocarbons, chemicals used in refrigeration and aerosol cans, but now nitrogen oxides are the main cause.

The result of a reduction in the ozone layer may be increased levels of UV-B radiation that reach the surface of the Earth.

This radiation has been linked to skin cancer and cataracts and suppressed immune systems.

But this blocking of UV also traps its energy and contributes to global warming, Complicated, eh?

So ozone up high mostly good, down low, mostly bad.
Weighing the costs and benefits.

• The impact of human activity on the ozone layer is one more example of how much we are able to disrupt ecosystems and the entire biosphere. Are we entering the **Anthropocene Era?** 18 minutes if time.

• **So what to do???(9 min.)**