All organisms require free energy and matter to maintain order, grow, and reproduce. Different organisms employ various strategies to capture, use, and store free energy and exchange matter with the environment.

Importantly: Energy flows Matter cycles.

In accordance with the laws of thermodynamics, to offset entropy, energy input must exceed energy lost from and used by an organism to maintain order. This is why energy flows: energy enters the system, and leaves the system. Energy does not cycle. Instead, energy can be converted from one type to another, e.g. energy available in sunlight is converted to chemical bond energy via photosynthesis.

Energy deficiencies are not only detrimental to individual organisms; they also can cause disruptions at the population and ecosystem levels.

Classifying Organisms by Role

Autotrophs

- **Autotrophs**: capture energy and use it, along with inorganic nutrients, to produce organic compounds
- Also called **producers** (sometimes called **primary producers**)
- Types of Autotrophs:
  - Photosynthetic organisms: possess pigments to absorb light and carry on photosynthesis
  - Chemoautotrophs: prokaryotes that capture free energy from small inorganic molecules present in their environment (e.g. ammonia, nitrites, sulfides); can occur in the absence of oxygen
    - Synthesize carbohydrates and are found in cave communities and ocean depths
- Note: these organisms must still break down these compounds for energy in the form of ATP (fermentation, cellular respiration)

Examples of Autotrophs


Plants


Algae


Protists (e.g. *Euglena*)


Bacteria

Heterotrophs

- **Heterotrophs**: need a source of preformed organic nutrients and consume tissues of other organisms
- Also called **consumers**
- Types of Heterotrophs:
  - Herbivores: eat producers
  - Carnivores: eat other consumers
  - Omnivores: eat both producers and consumers
  - Scavengers: eat dead animals and plants
  - Detritivores: feed on detritus & the decomposing products of organisms

  } Generally refer to animals

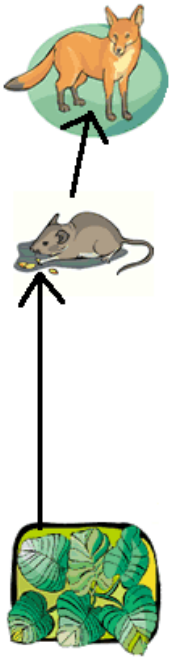
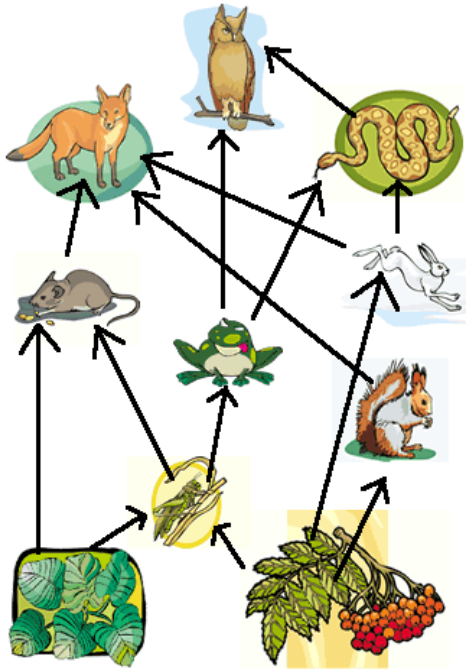
  - Decomposers: non-photosynthetic bacteria and fungi that extract energy from dead matter, including animal wastes in the soil, and make nutrients available
    - Critical for nutrient cycling
- Metabolize carbohydrates, lipids, and proteins by hydrolysis as sources of free energy

Examples of Heterotrophs

					
Herbivore	Carnivore	Omnivore	Scavenger	Detritivore	Decomposer

Representing Energy Flow

We use food chains and food webs to represent how energy flows through an ecosystem.

Food Chain Follows a single path of energy flow	**Food Web** Follows many paths of energy flow
	

The food web is the more accurate depiction, as it shows:

- How all organisms are interdependent on the others
- The multiple means by which organisms obtain energy
- The dependence on producers

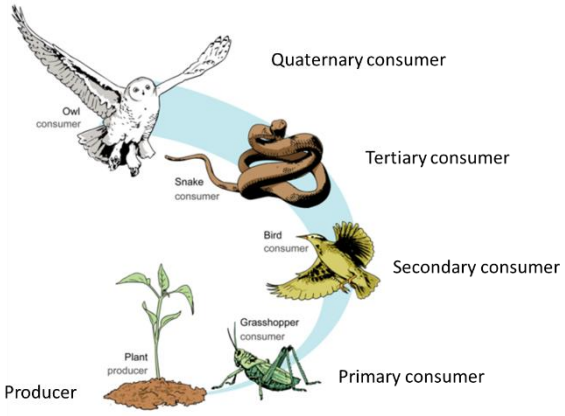
Food webs, like many models, allow you to predict the effects of a change to the system.

Modified from Maerna Kauffman

Trophic Levels

Trophic level is an indicator of feeding level. We typically use the following labels:

1. (Primary) producer
2. Primary consumer
3. Secondary consumer
4. Tertiary consumer
5. Quaternary consumer, etc…



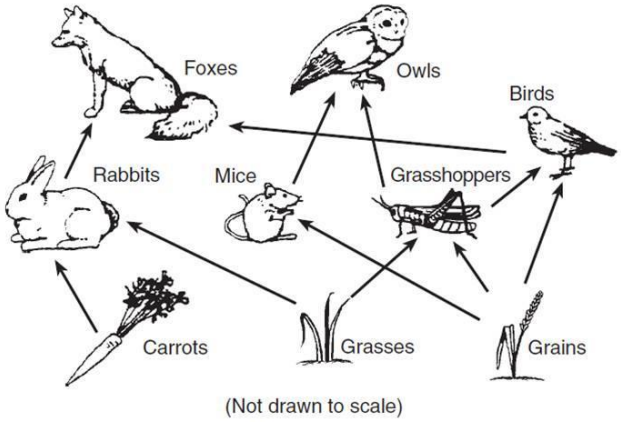
Depending on the food chain, organisms might have multiple trophic levels. For example, a mouse might eat seeds (making it a primary consumer) and eat insects (making it a secondary consumer). Food webs are thus hard to label by trophic level.

Dependency on Primary Productivity

Food webs and food chains are dependent on primary productivity. This means that the producers (plants and bacteria, photosynthetic and chemosynthetic organisms) are the base of all food chains and webs. Without these organisms, no new energy would be captured and would enter the system. Thus, a change in the producer level can affect the number and size of other trophic levels.

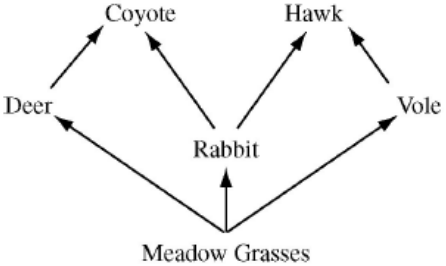
QUESTIONS:

1. Look at the food web in the figure to the right. What is the role of mice in this ecosystem?
   A. primary producer
   B. primary consumer
   C. secondary consumer
   D. decomposer



(Not drawn to scale)

2. The following is a food web for a meadow habitat that occupies 25.6 km^2. The primary producers' biomass is uniformly distributed throughout the habitat and totals 1,500 kg/km^2.



Developers have approved a project that will permanently reduce the primary producers' biomass by 50 percent and remove all rabbits and deer.

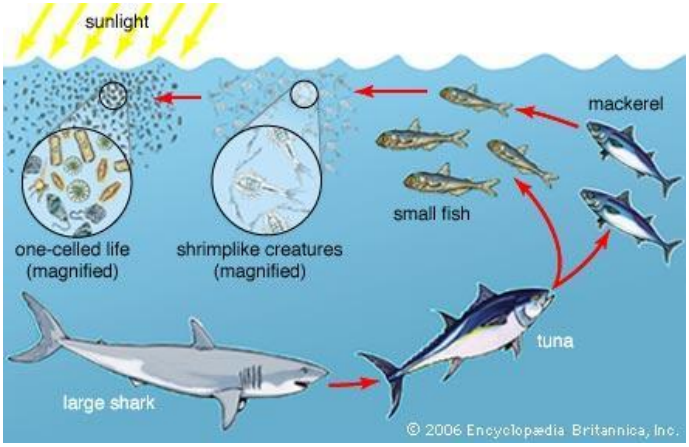
Which of the following is the most likely result at the completion of the project?

A. The biomass of coyotes will be 6 kg, and the biomass of hawks will be 0.5 kg.
B. The biomass of coyotes will be dramatically reduced.
C. The coyotes will switch prey preferences and outcompetes the hawks.
D. There will be 50 percent fewer voles and 90 percent fewer hawks.

Modified from Maerna Kauffman

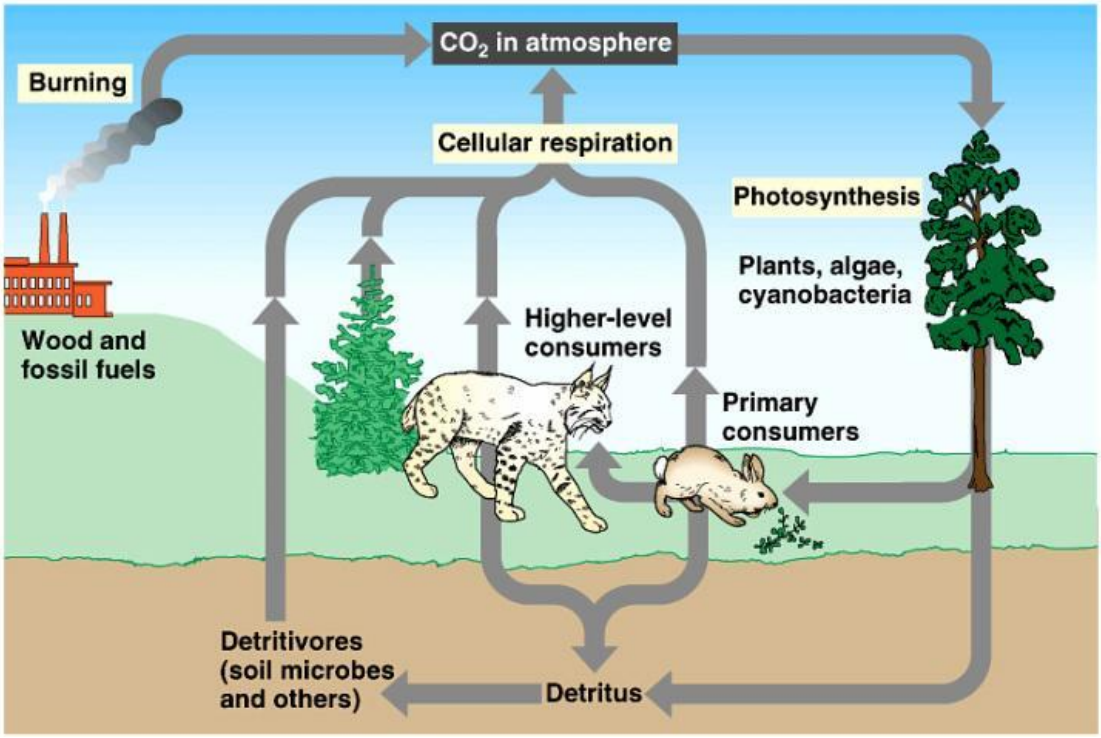
3. Which statement about decomposers is *not* true?
    A. An example of a decomposer is a vulture.
    B. Decomposers interact with every trophic level.
    C. They help reduce the overall biomass on Earth.
    D. They break down dead organisms and return nutrients to the soil.

4. Most overfishing management has been on large fish like tuna. Small fish, like anchovies and sardines, are commonly fished as well. Using the figure to the right, make a prediction about what would happen to tuna if anchovies and sardines were overfished, and explain why you came up with that prediction



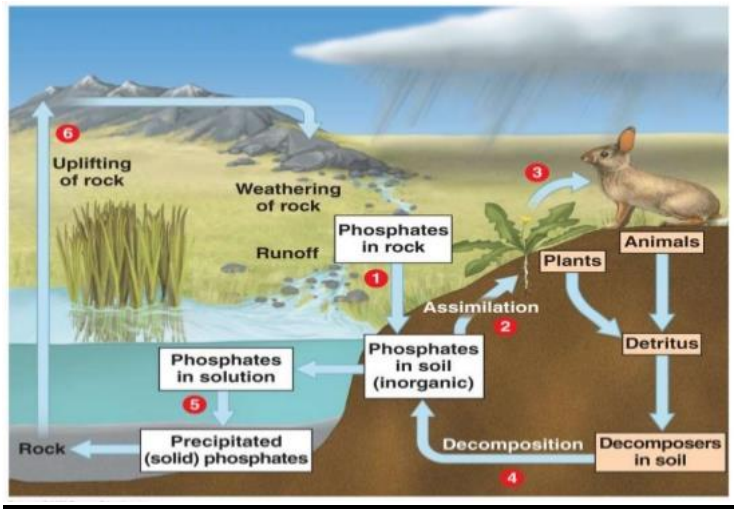
Energy flows through systems (sun ➔ producer ➔ consumers), being released as heat along the way. Matter, however, is *recycled*. We see this in the cycles of different elements and molecules.

Carbon Cycle



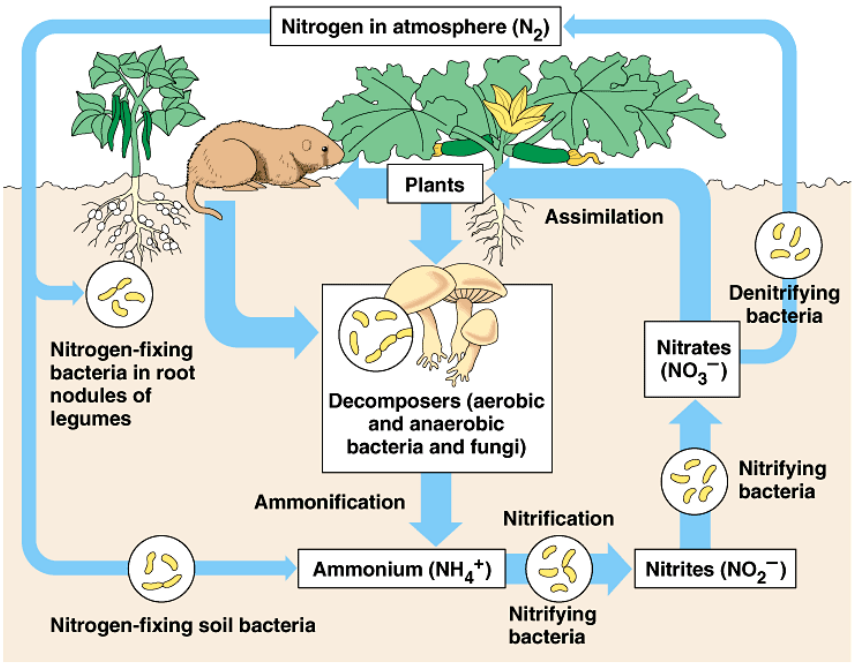
- All organisms put out carbon dioxide into the atmosphere (respiration, some fermentation)
- Living and dead organisms act as reservoirs for carbon
  - They contain organic carbon
- Human activities increase the level of CO_2 (e.g. burning fossil fuels)
  - Contributes to climate change

Phosphorus Cycle



- Geological upheavals move phosphorus from the ocean to land
- Slow weathering of rocks returns phosphorus to the soil
- Most phosphorus is recycled within a community
- Phosphorus is a limiting nutrient

Nitrogen Cycle



- Nitrogen gets passed through the food web, as expected
  Plants have nitrogen, which animals and decomposers use
- Any nitrogen that is released into the atmosphere (N_2) *cannot* be used by plants, animals, or fungi
- Bacteria fix nitrogen into a useable form
  - These bacteria exist in the soil or in root nodules of legumes
  - Other bacteria change nitrogen from ammonium into nitrites and nitrates
- This shows why you need crop rotation
  - Plants use up all the nitrogen in the soil, soil is now nitrogen-poor
  - Rotate legumes into the field, which will fix nitrogen and increase nitrogen levels in the soil
- Processes:
  - Nitrogen fixation: N_2 ➋ ammonium
  - Nitrification: production of nitrates

Modified from Maerna Kauffman

- Denitrification: nitrate ➔ N_2
- Human activities increase transfer rates in nitrogen cycle, e.g. fertilizations & run-off algae blooms

QUESTIONS:

1. What macromolecules need carbon? _____
2. What macromolecules need nitrogen? _____
3. What macromolecules need phosphorus? _____
4. What do you think the source of hydrogen is? _____
5. What do you think the source of oxygen is? _____
6. During chemical cycling, inorganic nutrients are typically returned to the soil by
   A. autotrophs
   B. detritivores
   C. decomposers
   D. tertiary consumers
7. Which of the following could not be a component of the nitrogen cycle?
   A. proteins
   B. ammonium
   C. decomposers
   D. photosynthesis
   E. bacteria in root nodules
8. How do plants contribute to the carbon cycle?
   A. When plants respire, they release CO_2 into the atmosphere
   B. When plants photosynthesize, they consume CO_2 from the atmosphere
   C. When plants photosynthesize, they provide oxygen to heterotrophs
   D. Both a and b are correct
9. Do nutrients cycle or flow (enter and then leave) through an ecosystem?
   A. Cycle
   B. Flow
10. Which nutrient cycle does *not* have an atmospheric component?
    A. carbon
    B. nitrogen
    C. phosphorus
    D. water

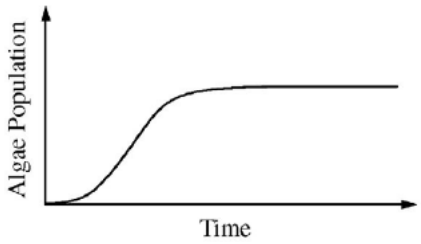


Figure I

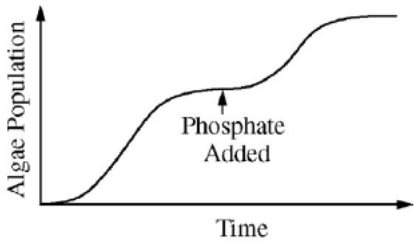
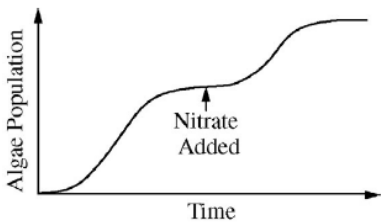


Figure II

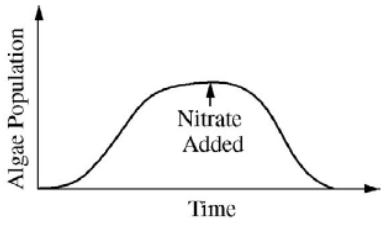
11. Figure I shows the growth of an algal species in a flask of sterilized pond water. If phosphate is added as indicated, the growth curve changes as shown in Figure II.

    Which of the following is the best prediction of the algal growth if nitrate is added instead of phosphate?

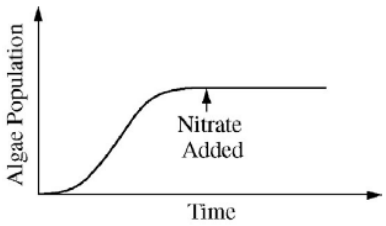
(A)



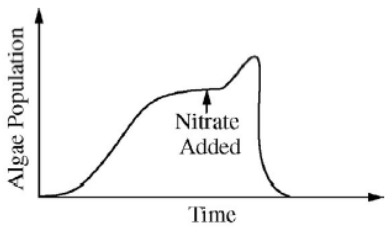
(B)



(C)

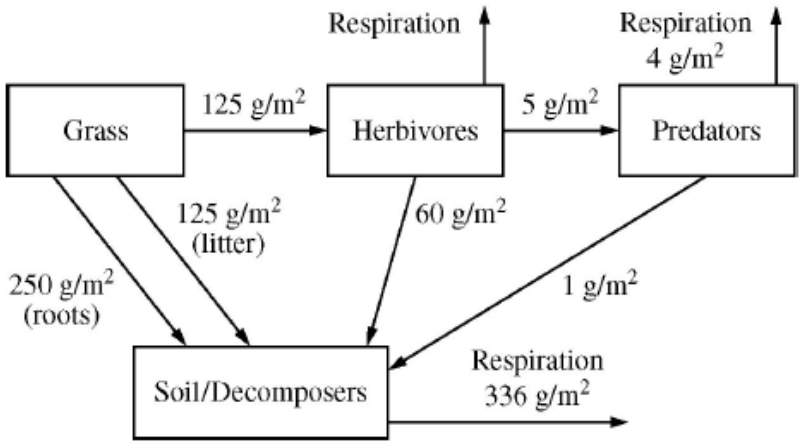


(D)



Modified from Maerna Kauffman

CARBON FLOW IN A GRASSLAND ECOSYSTEM



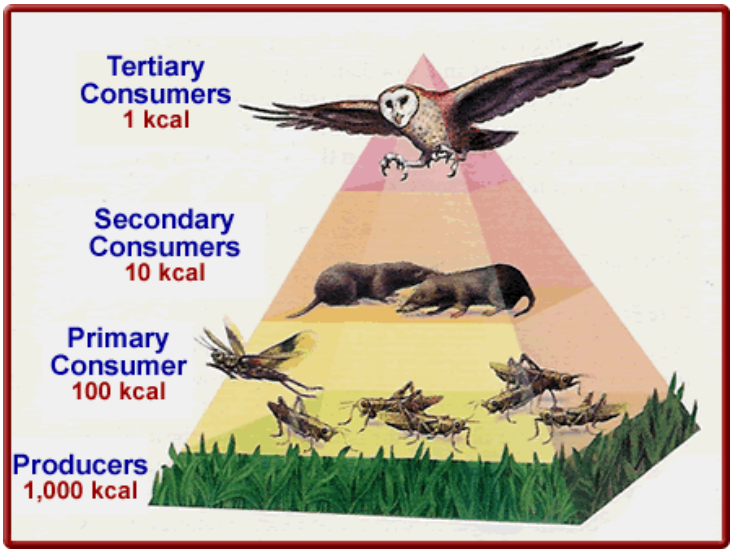
Hint: Look at how much carbon is flowing into the

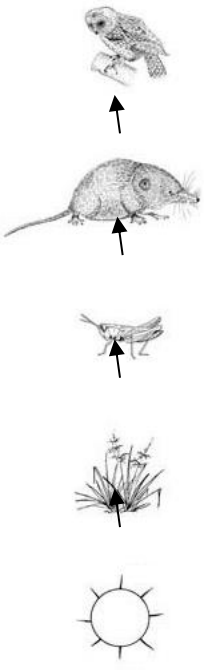
12. How much carbon (in g/m2) is released into the atmosphere as a result of the metabolic activity of herbivores? Give your answer to the nearest whole number.
    A. _____

3C Pyramids **3. Ecosystem Ecology**

In ecology, pyramids are representations of the flow of energy and matter in an ecosystem. Generally, they represent a single food chain. They are organized by trophic level.

- Producers are on the 1st level/bottom
- Primary consumers are on the 2nd level
- Secondary consumers are on the 3rd level…

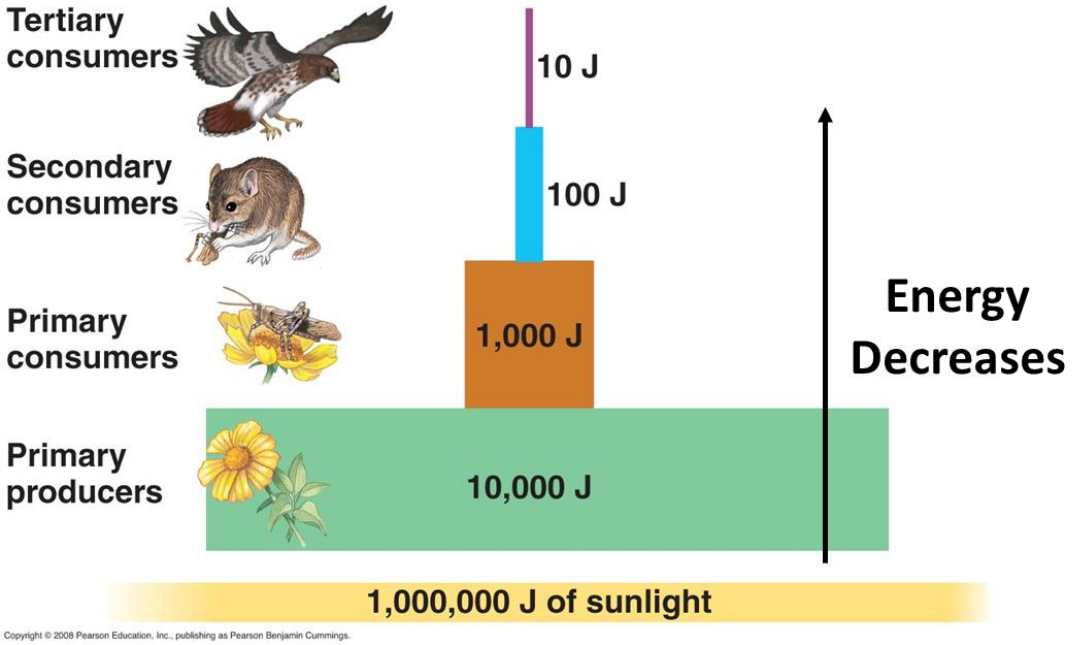




Pyramids of Energy

Energy is lost at each trophic level. The 1st level (producers) has the most energy. As you move up the pyramid, each level has less energy. This energy is lost as heat due to metabolic processes.

Think of all of the metabolic processes that lose energy in the form of **heat** – any time a bond is broken, some of that energy cannot be used by the organism.



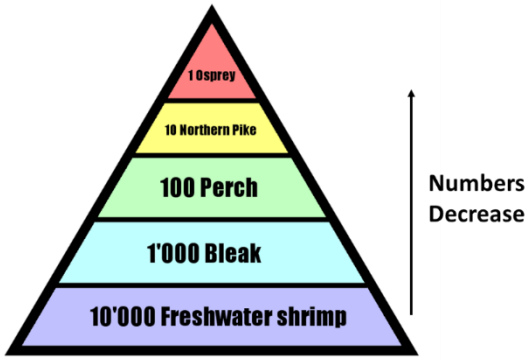
Modified from Maerna Kauffman

Each level only has ~ 10% of the energy of the previous level.

Pyramids of Numbers

The largest population is found at the bottom of the pyramid (note that this pyramid is missing the producer level, which would be the largest). There are fewer and fewer individuals at each level, and this is related to the loss of energy.

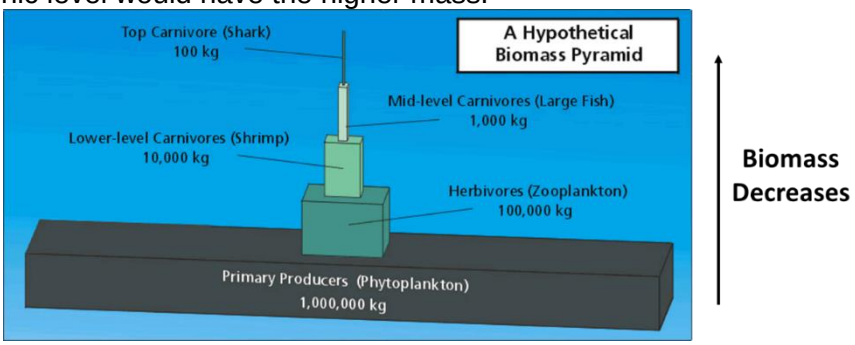
This is why you see so few large carnivores (think lions, tigers, bears, oh my!). This is because there is not a large enough population of prey to support a large population above them.



Pyramids of Biomass

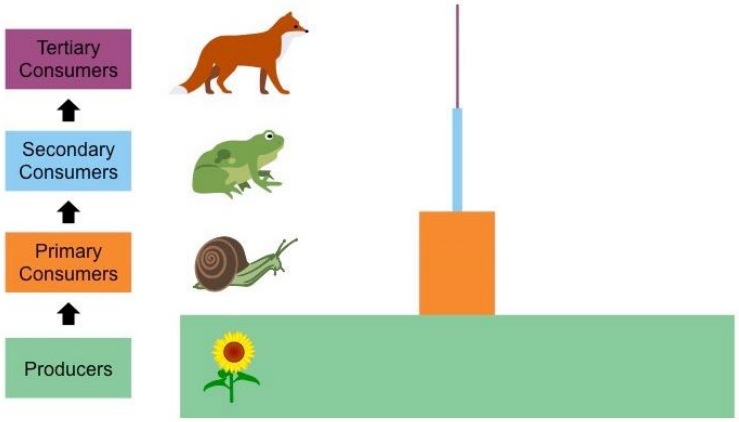
- Biomass – how much matter is made up by living organisms

The amount of biomass decreases at each level. This is related to both loss of energy and loss of numbers. If you took the mass of all of the phytoplankton in an ecosystem, compared to the mass of all sharks in an ecosystem, the lower trophic level would have the higher mass.



QUESTIONS:

1. If the primary consumer in this pyramid has 20,000 J of energy, which statement correctly describes the flow of energy in this system?
   A. The producers have 2,000,000 J of available energy.
   B. The secondary consumers have 10,000 J of available energy.
   C. The tertiary consumer has 2,000 J of available energy.
   D. The tertiary consumer has 200 J of available energy.

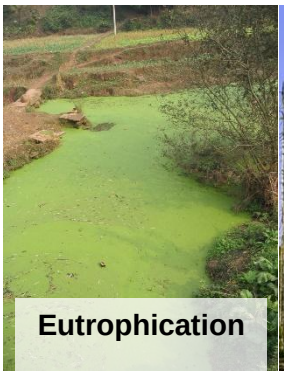


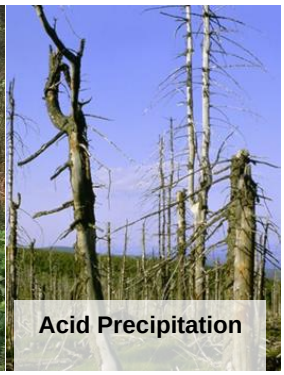
Modified from Maerna Kauffman

2. If an herbivore population consumes 3,000 kg of plant material, how much energy is available to that herbivore? the first level carnivores? second level carnivores?
    A. All of the energy consumed by the herbivore is available to all successive trophic levels at the same level.
    B. 1,500kg; 150kg; 15kg
    C. 300kg; 30kg; 3kg
    D. 3000kg; 300kg; 30kg

As human populations have increased in numbers, their impact on habitats for other species have been magnified. In turn, this has often reduced the population size of the affected species and resulted in habitat destruction and, in some cases, the extinction of species.

Nutrient Cycling


Eutrophication


Acid Precipitation

Fertilizers, animal waste, and sewage are adding more nitrogen and phosphates to our water. This can lead to eutrophication.

- **Eutrophication** – water pollution from nitrogen-rich and phosphorus-rich substances flowing into waterways, causing algal overgrowth

When fossil fuels are burned, sulfur dioxide and nitrogen dioxide are released into the atmosphere. This reacts with water to form acid precipitation:

- **Acid precipitation** – sulfur dioxide and nitrogen dioxide react with water to form sulfuric acid and nitric acid, which falls to the earth in rain, sleet, snow, or fog
    - Acid precipitation removes calcium, potassium, and other nutrients from the soil, and makes water acidic

Climate Change

Climate change refers to the broad range of changes seen in our planet. The cause is the **greenhouse effect**.

- We naturally live in a greenhouse effect, or else the planet would be much colder.
- Certain gases block heat from escape (water vapor, carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons, or CFCs)
- Burning of fossil fuels increases concentration of greenhouse gases, which block heat from escaping.
- This greenhouse effect is changing our climate.

Why does it matter?

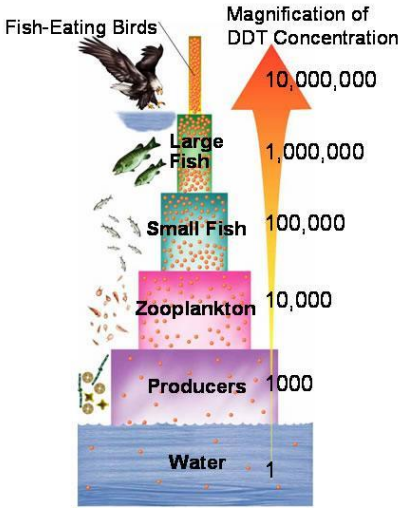
- Temperatures will continue to rise
- Frost-free season (and growing season) will lengthen
- Changes in precipitation patterns
- More droughts and heat waves
- Hurricanes will become stronger and more intense
- Sea level will rise 1-4 feet by 2100
- Arctic likely to become ice-free

Pesticides and Chemicals

We use pesticides and chemicals every day. **Runoff** (movement of land water) usually carries these pesticides from the fields into the watershed.

- Rachel Carson: wrote the book *Silent Spring* in 1962, which kick-started the environmental movement. She warned against the misuse of pesticides like DDT. She directly affected government policy (every one of the toxic chemicals named in the book were either banned or severely restricted in the US by 1975).
    - Launched the modern global environmental movement
- Tyrone Hayes: studies the herbicide atrazine and the effect of frogs. He found that atrazine is an endocrine disrupt and makes male frogs express female characteristics. He is working to get this herbicide banned in the US, as humans working on farms are exposed to more atrazine than the frogs in his experiment.

Biomagnification



All individuals are part of a food chain. As a result, toxins stored in the tissues of an organism at one trophic level are passed on to the organisms at the next trophic level.

Toxic substances become increasingly concentrated within living organisms as they move up the food chain. The toxin accumulates because organisms eat many other organisms and the toxic substance builds up.

Invasive Species

As seen in our species interactions pages, **invasive species** are organisms that are introduced, by human action, to an area where they do not naturally live and where they do not naturally breed. They often devastate ecosystems where they are introduced because they have no natural predators and prey lack effective defense mechanisms against the introduced species.

Generally, invasive species reduce genetic diversity in areas where they are introduced.

Sixth Major Extinction Event

TABLE 1 MAJOR EVENTS IN THE HISTORY OF LIFE

Event	Date (Ma)	Description
Great Oxygenation Event	2,450	earliest oxygenation of atmosphere
Cambrian Explosion	542	rapid diversification of animal life
End-Ordovician extinction	446	86% of species lost
Late Devonian extinction	372	75% of species lost
End-Permian extinction	252	95% of species lost
End-Triassic extinction	201	80% of species lost
End-Cretaceous extinction	65	76% of species lost
Sixth extinction?	??	

Ma: Millions of years ago

There are always background extinction rates ("normal" extinction) However, modern extinction rates are exceptionally high and they are increasing.

- The background rate should have been 9 vertebrate extinctions since 1900
- Instead, we have seen 477 vertebrates go extinct since 1900 (this is 53 times as much as expected!)
    - This is also a very *low* estimate
- Ecosystems become more fragile when high numbers of animals go extinct

QUESTIONS:

1. In general, humans' effects on ecosystems lead to an increase in genetic diversity.
    A. True
    B. False

2. When greenhouse gases contribute significantly to an overall rise in the Earth's ambient temperature, then:
    A. global warming occurs.
    B. the greenhouse effect is minimized.
    C. it is assumed that methane, nitrous oxide, and carbon dioxide levels are decreasing and water vapor is increasing.
    D. sea level will fall and rainfall will decrease along the coastal areas of continents and increase in the interior of the continent.

Modified from Maerna Kauffman

3. Eutrophication is caused by runoff containing nutrients that kills fish in a lake. How do you think this is achieved?
    A. Algae overproduce and die; bacteria use up all the oxygen so fish die
    B. Algae overproduce and crowd out fish and other species
    C. Fish overproduce and eat all possible sources of food, then starve
    D. Algae overproduce oxygen, which is toxic to fish in high quantities

4. When molecules such as DDT are not degraded by natural processes, they accumulate as they move up the food chain, a process called _____.
    A. inversion
    B. eutrophication
    C. deposition
    D. biomagnification
    E. phosphorus cycling

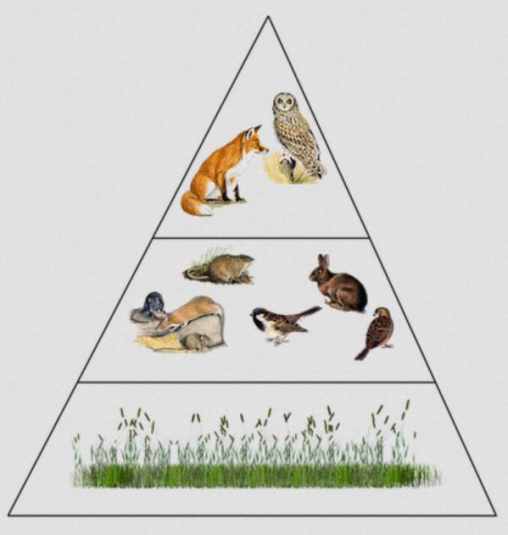


Figure A.

5. Look at Figure A. If a toxin were introduced and the plants absorbed it, which level would have the *highest* concentration of the toxin?
    A. top
    B. middle
    C. bottom
    D. they would all have the same amount of toxin