Domain 7: Interactions

7.1: Organisms exhibit complex properties due to interactions between their constituent parts.

1. PHYSIOLOGICAL ORGANIZATION

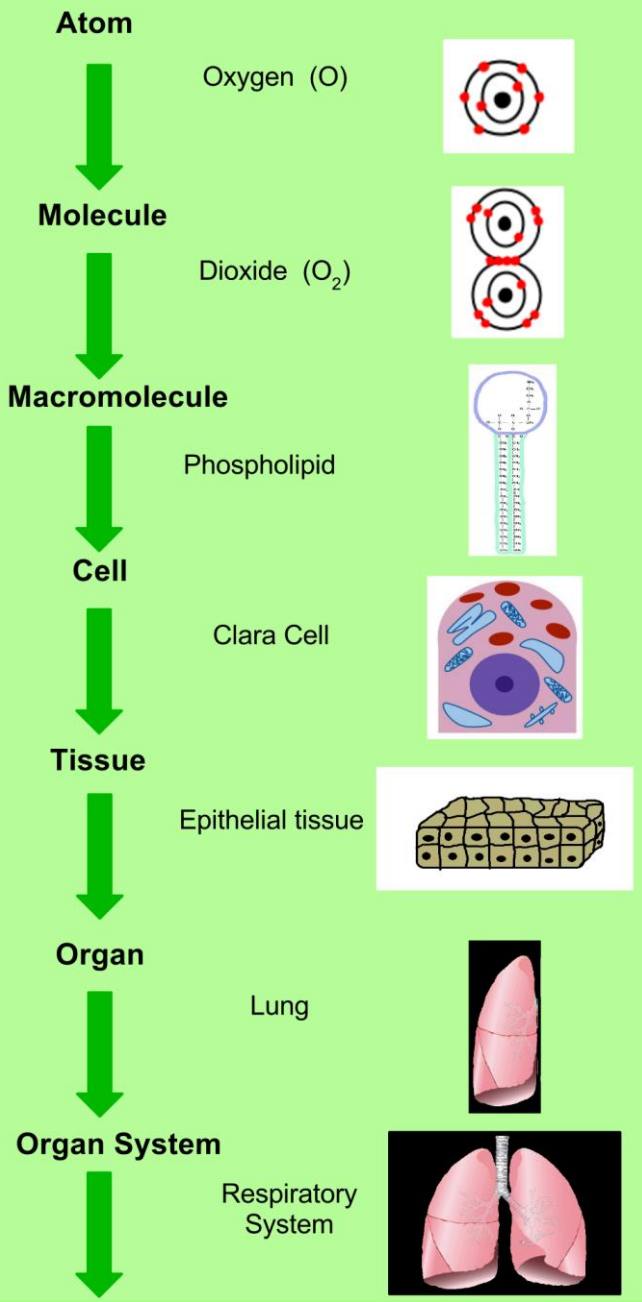
Biology is a Hierarchy

Every level of biological organization is built on the level below it.

Cells cooperate in **tissues**.

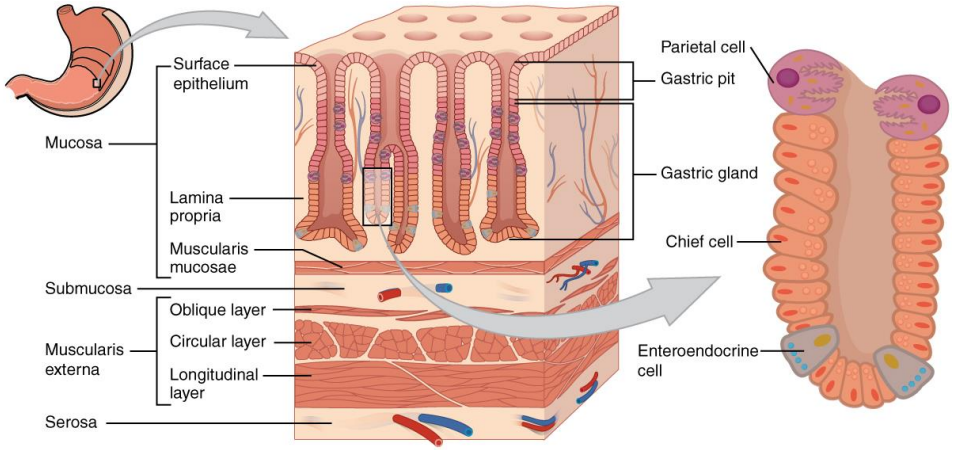
Tissues cooperate in **organs**.

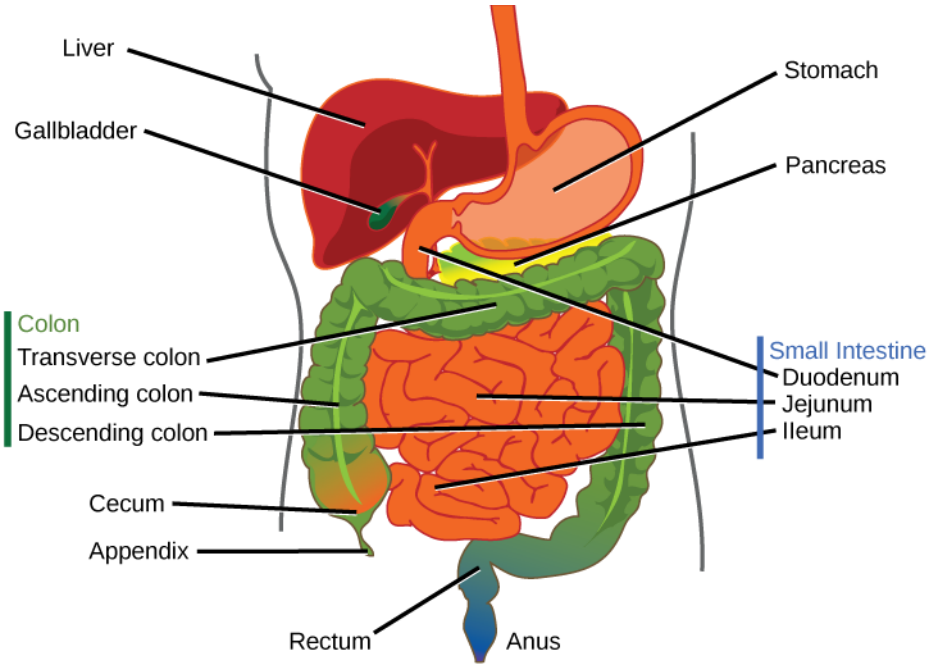
Organs cooperate in **organ systems.**

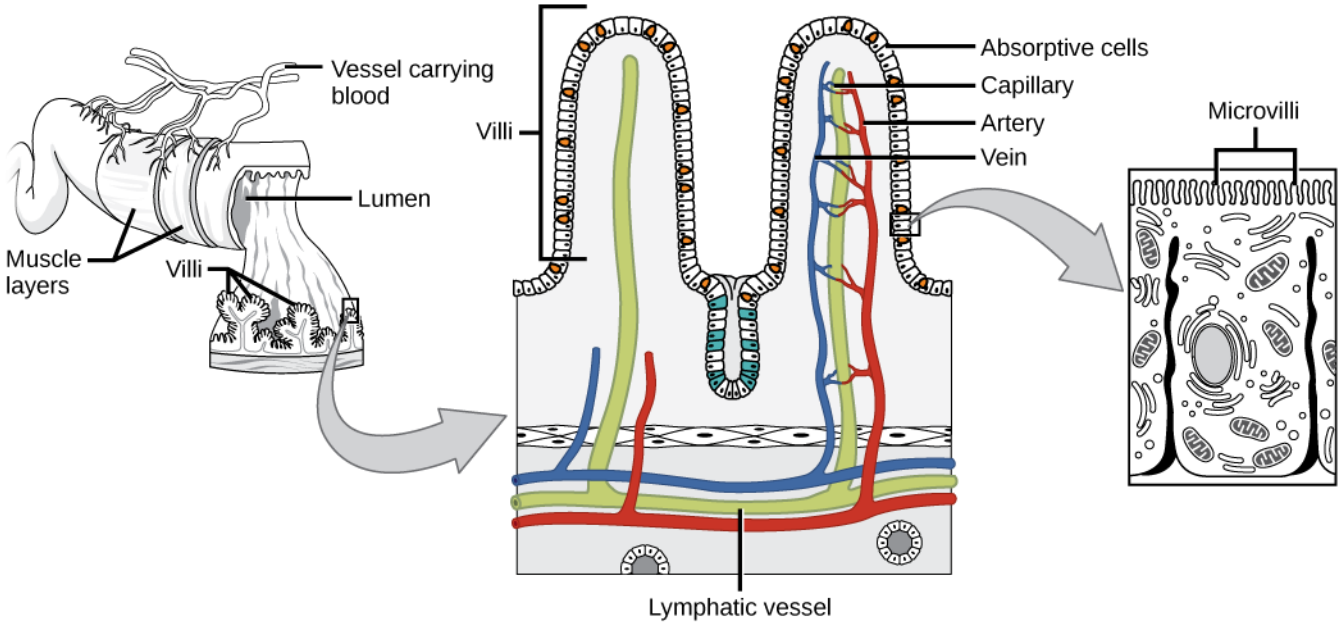


Organs cooperate to accomplish life processes.

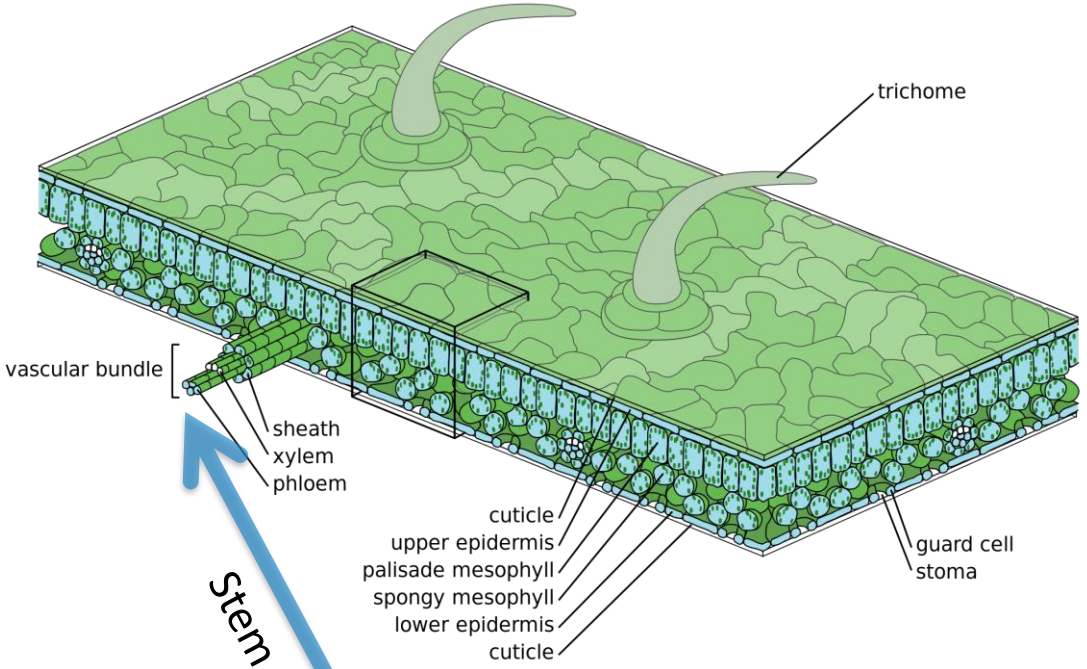
Ex. Stomach & Small Intestine







Ex. Plant Organs.



into the stele

water and mineral uptake in roots

1 Water and minerals are taken up by the hydrophilic walls of the **root epidermis**. They diffuse along the permeable cell walls into the **root cortex**.

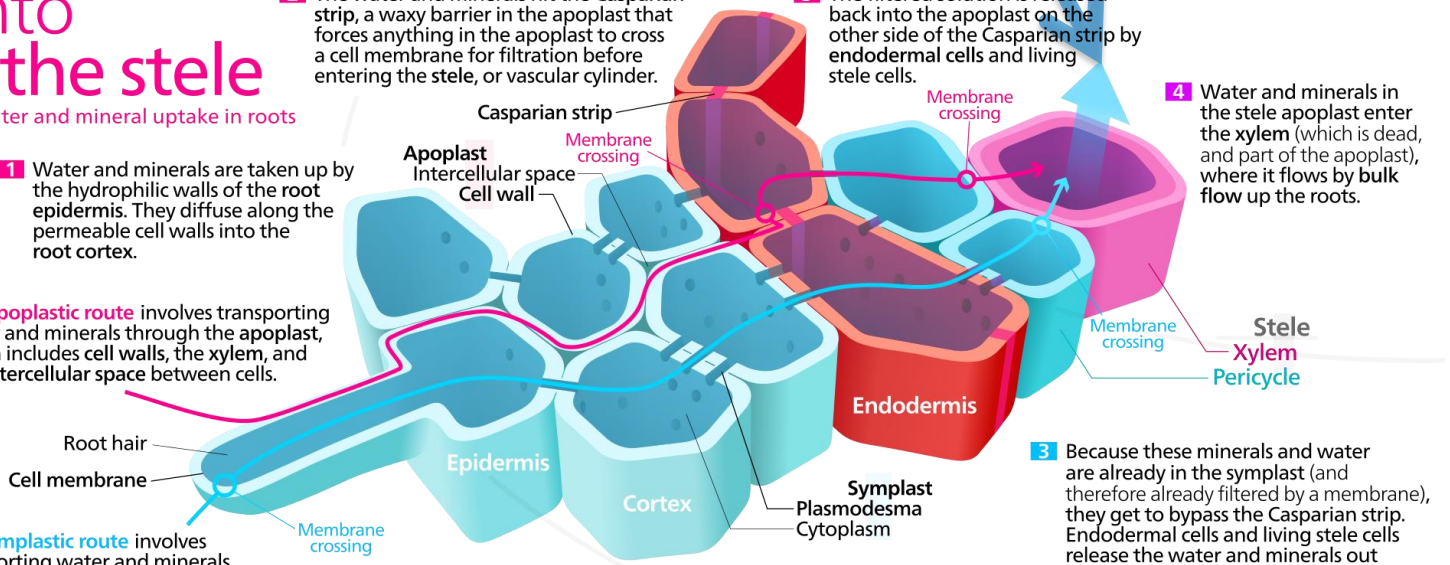
2 The water and minerals hit the **Casparian strip**, a waxy barrier in the apoplast that forces anything in the apoplast to cross a cell membrane for filtration before entering the **stele**, or vascular cylinder.

3 The filtered solution is released back into the apoplast on the other side of the Casparian strip by **endodermal cells** and living stele cells.

4 Water and minerals in the stele apoplast enter the **xylem** (which is dead, and part of the apoplast), where it flows by **bulk flow** up the roots.

The **apoplastic route** involves transporting water and minerals through the **apoplast**, which includes **cell walls**, the **xylem**, and the **intercellular space** between cells.

The **symplastic route** involves transporting water and minerals through the **symplast**, or cell **cytoplasm**, which is linked by **plasmodesmata**.



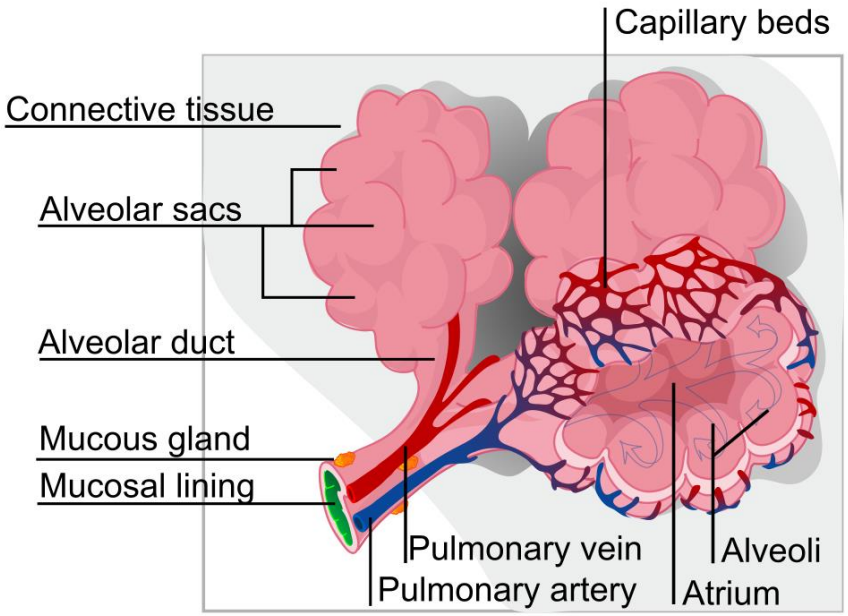
1 Water and minerals are immediately filtered as they cross a root hair cell's **cell membrane**, entering the **symplast**.

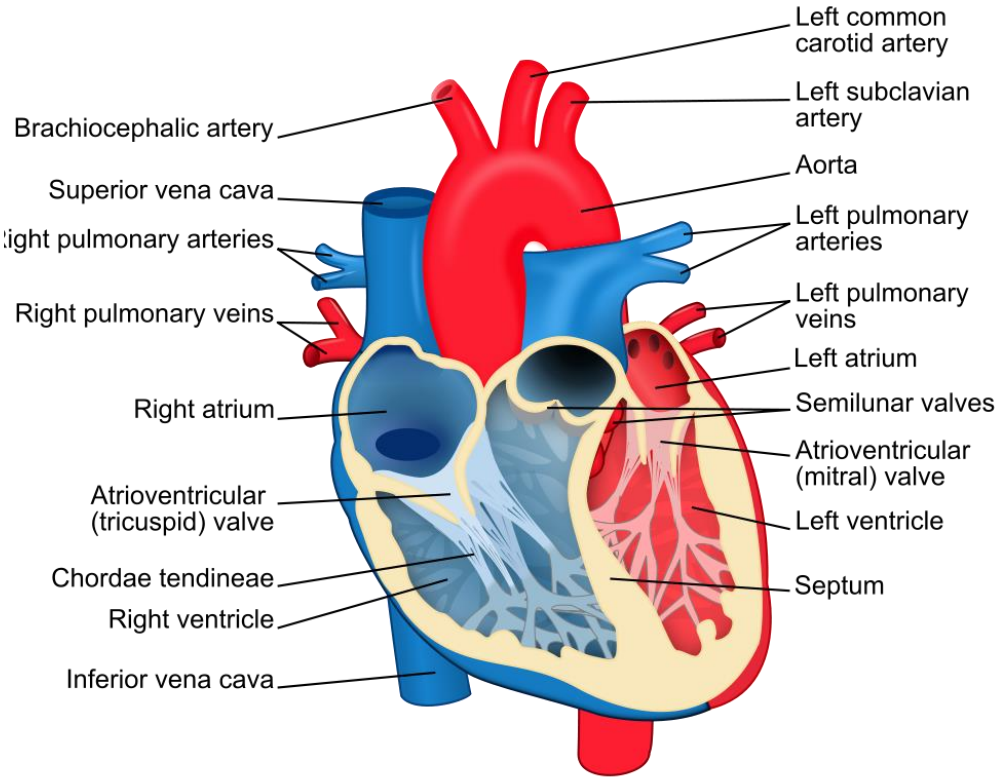
2 The water and minerals move from cell to cell through **plasmodesmata** toward the **stele cylinder**.

3 Because these minerals and water are already in the symplast (and therefore already filtered by a membrane), they get to bypass the Casparian strip. Endodermal cells and living stele cells release the water and minerals out into the stele **apoplast**.

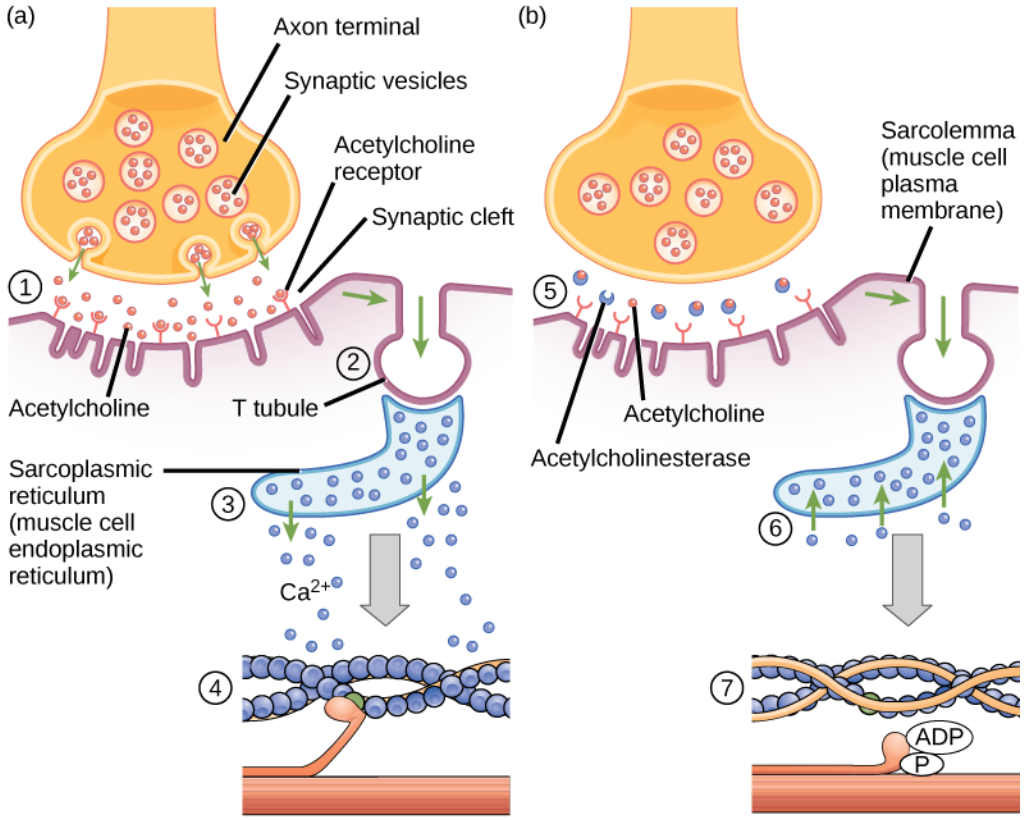
Organ Systems cooperate to accomplish life processes.

Ex. Respiratory & Circulatory Systems



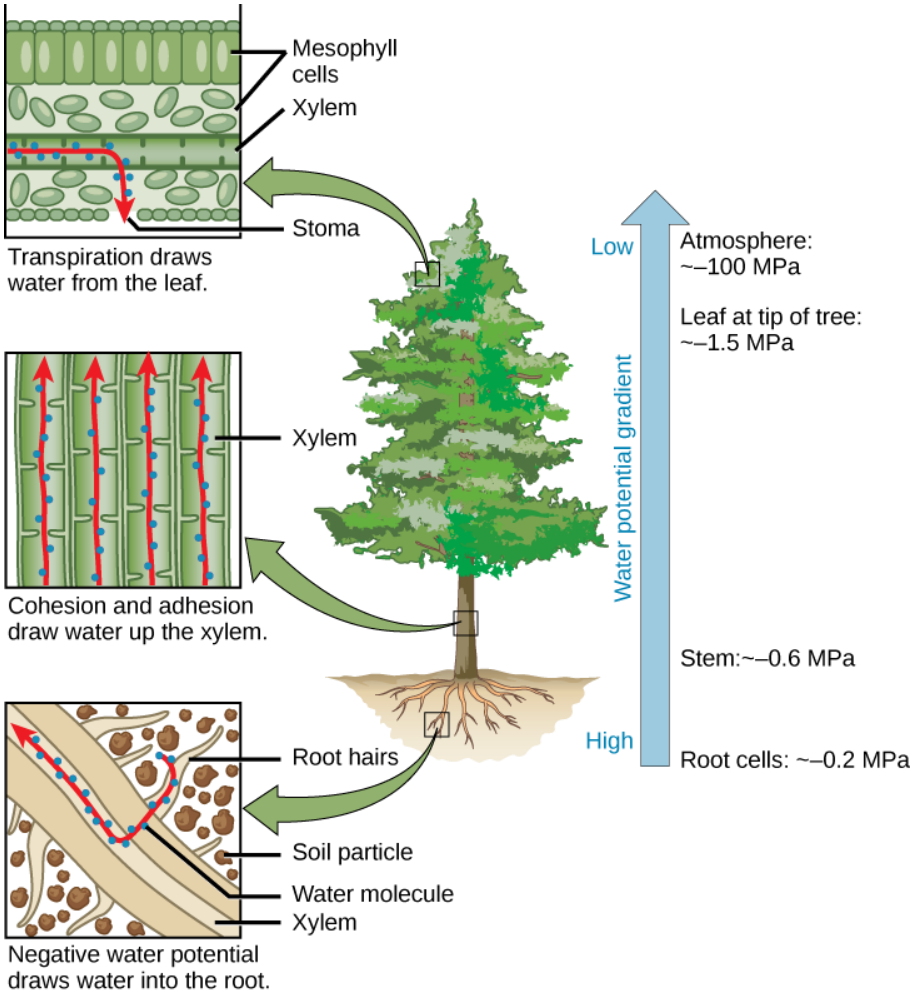


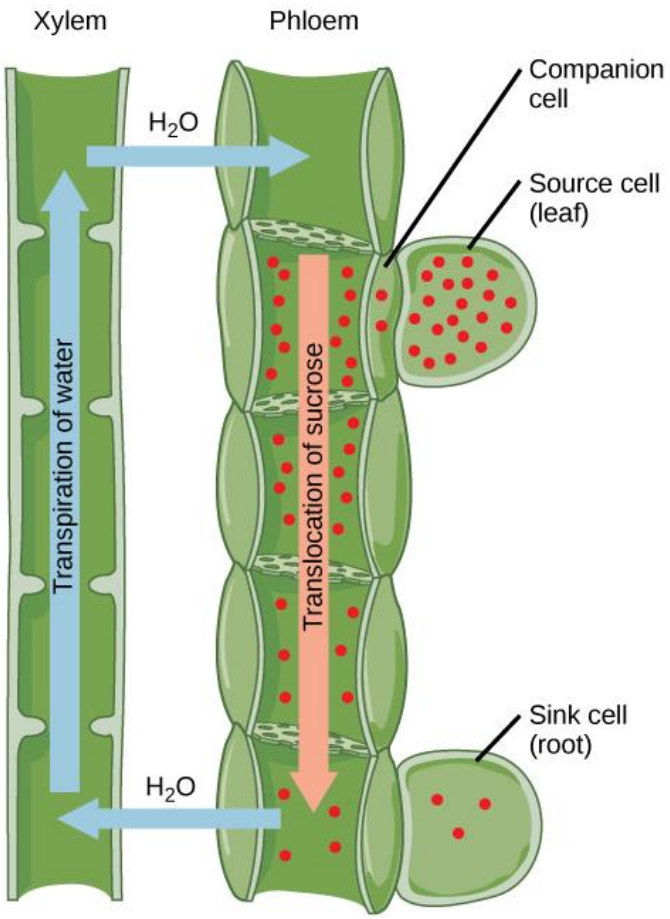
Ex. Nervous & Muscular Systems



1. Acetylcholine released from the axon terminal binds to receptors on the sarcolemma.
2. An action potential is generated and travels down the T tubule.
3. Ca^{2+} is released from the sarcoplasmic reticulum in response to the change in voltage.
4. Ca^{2+} binds troponin; Cross-bridges form between actin and myosin.
5. Acetylcholinesterase removes acetylcholine from the synaptic cleft.
6. Ca^{2+} is transported back into the sarcoplasmic reticulum.
7. Tropomyosin binds active sites on actin causing the cross-bridge to detach.

Ex. Shoot System & Root System





7.2: Organisms respond to changes in their external environments.

1. RESPONSES TO THE ENVIRONMENT

Organisms Respond

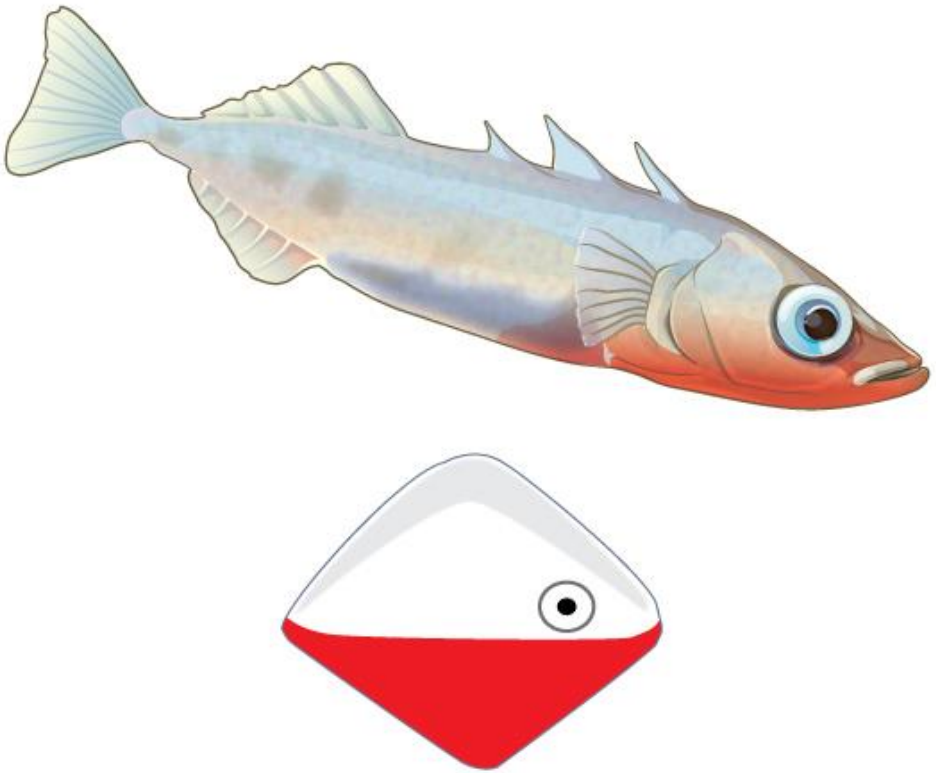
As the environment changes, organisms change.

Two major mechanisms:

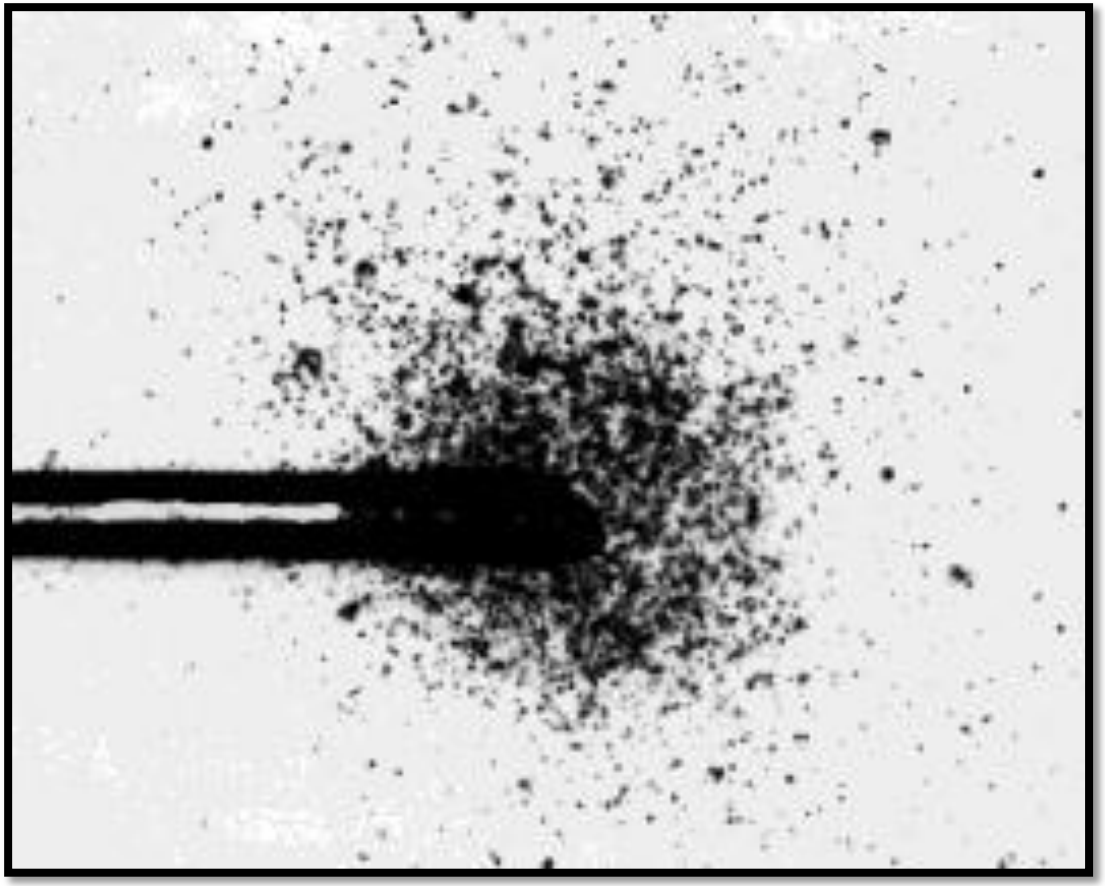
- Changing **Behavior**
- Changing **Physiology**

There is not a clear line between the two.

Ex. **Fixed Action Patterns** in Sticklebacks

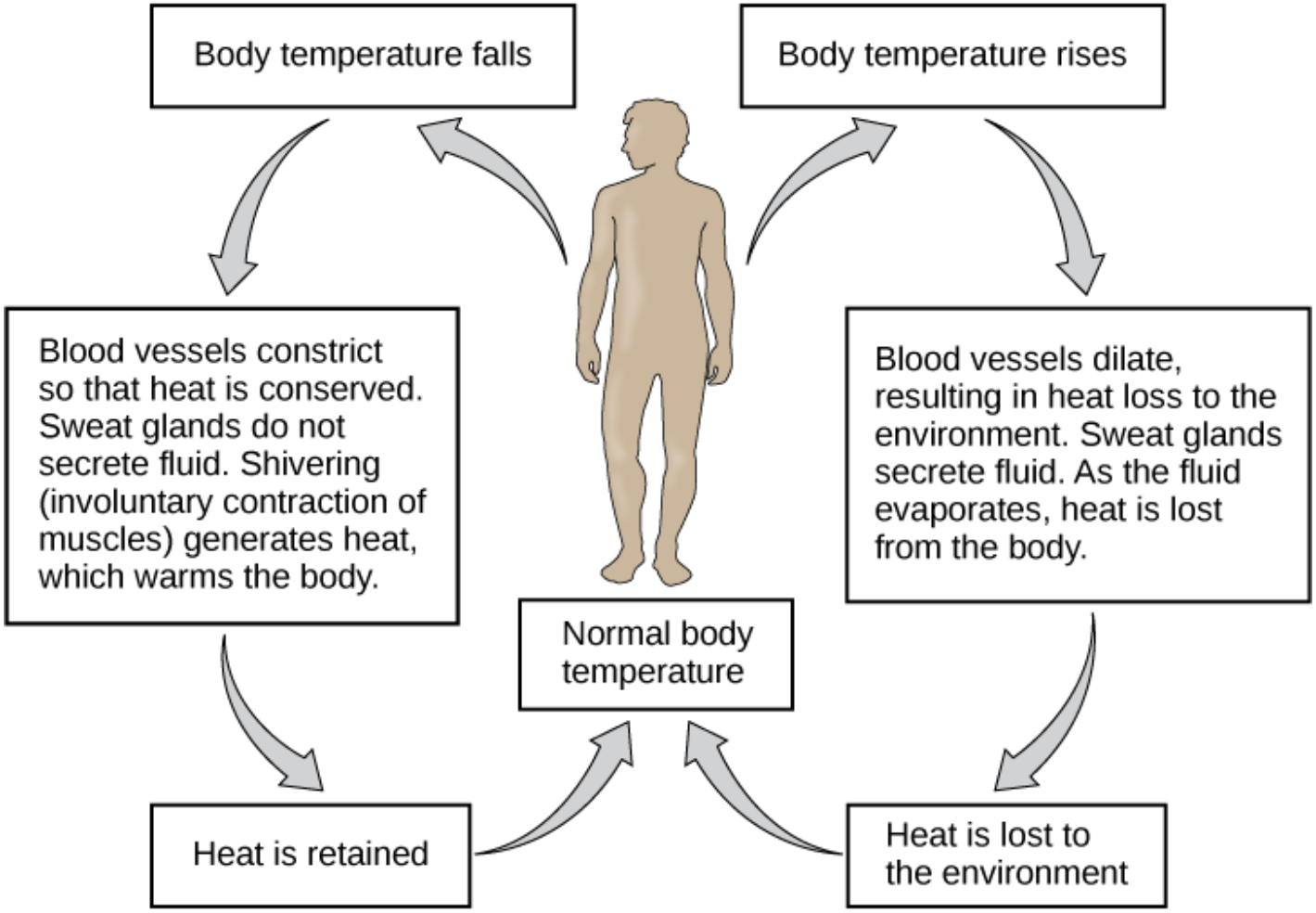


Ex. **Chemotaxis** in *E. coli*



Ex. Phototropism

Ex. Shivering & Sweating



Proximate vs. Ultimate Explanations

Proximate Explanations: Address how an organism is accomplishing a particular response.

Ultimate Explanations: Address the evolutionary reasoning for the response.

Ex. Imprinting

Proximate Explanation: Immediately after birth, the organism has a "critical period" wherein it will imprint on any moving object near it.

Ultimate Explanation: Organisms who imprint are more likely to survive, since the object they are most likely to see is a parent.

7.3: Interactions among living systems and with their environment result in the movement of matter and energy.

1. ENERGY AND MATTER ACQUISITION

Energy Flows, Matter Cycles

Organisms need matter and energy in order to remain alive.

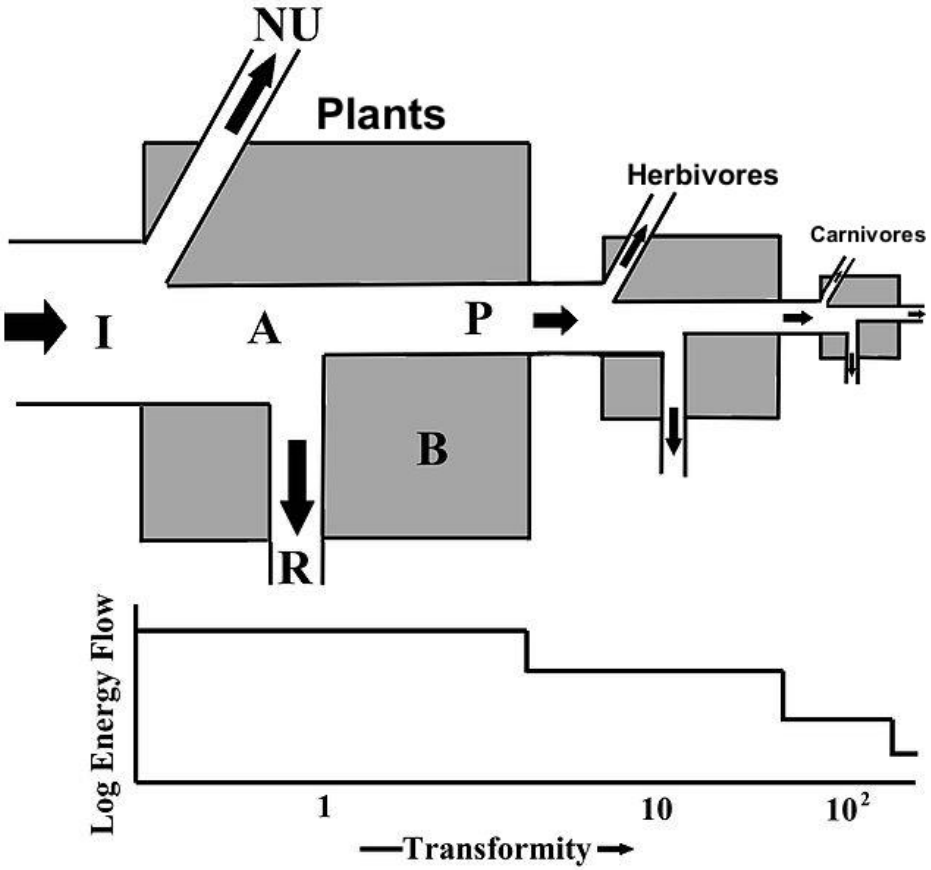
Organisms are highly adapted to acquire matter and energy from the environment.

Adaptations can be physiological or behavioral.

Adaptations in one environment may be maladaptive in another.

Energy Flow

Energy is incorporated in to a community by the producers in that community. Producers will usually occupy the greatest **biomass** in the ecosystem.

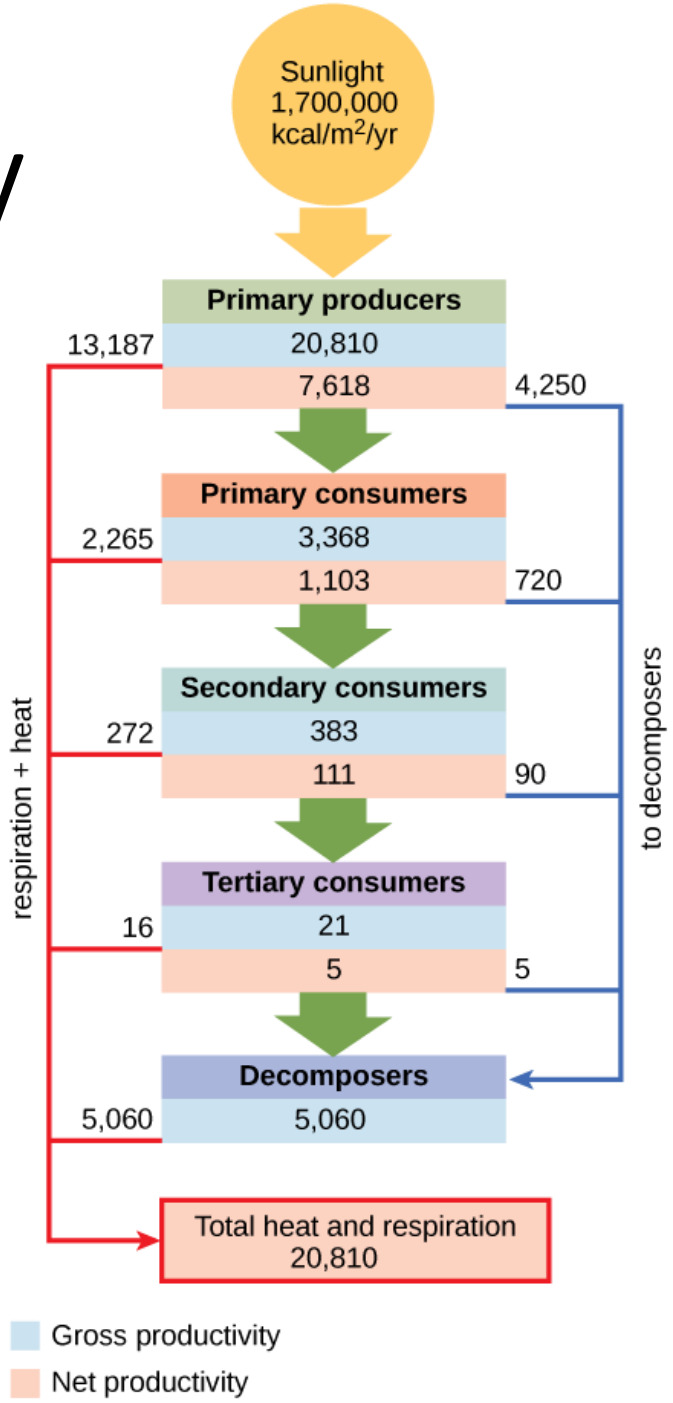


Productivity

Primary productivity: the total amount of energy converted into biologically useful forms by producers.

Gross primary productivity is different from net primary productivity

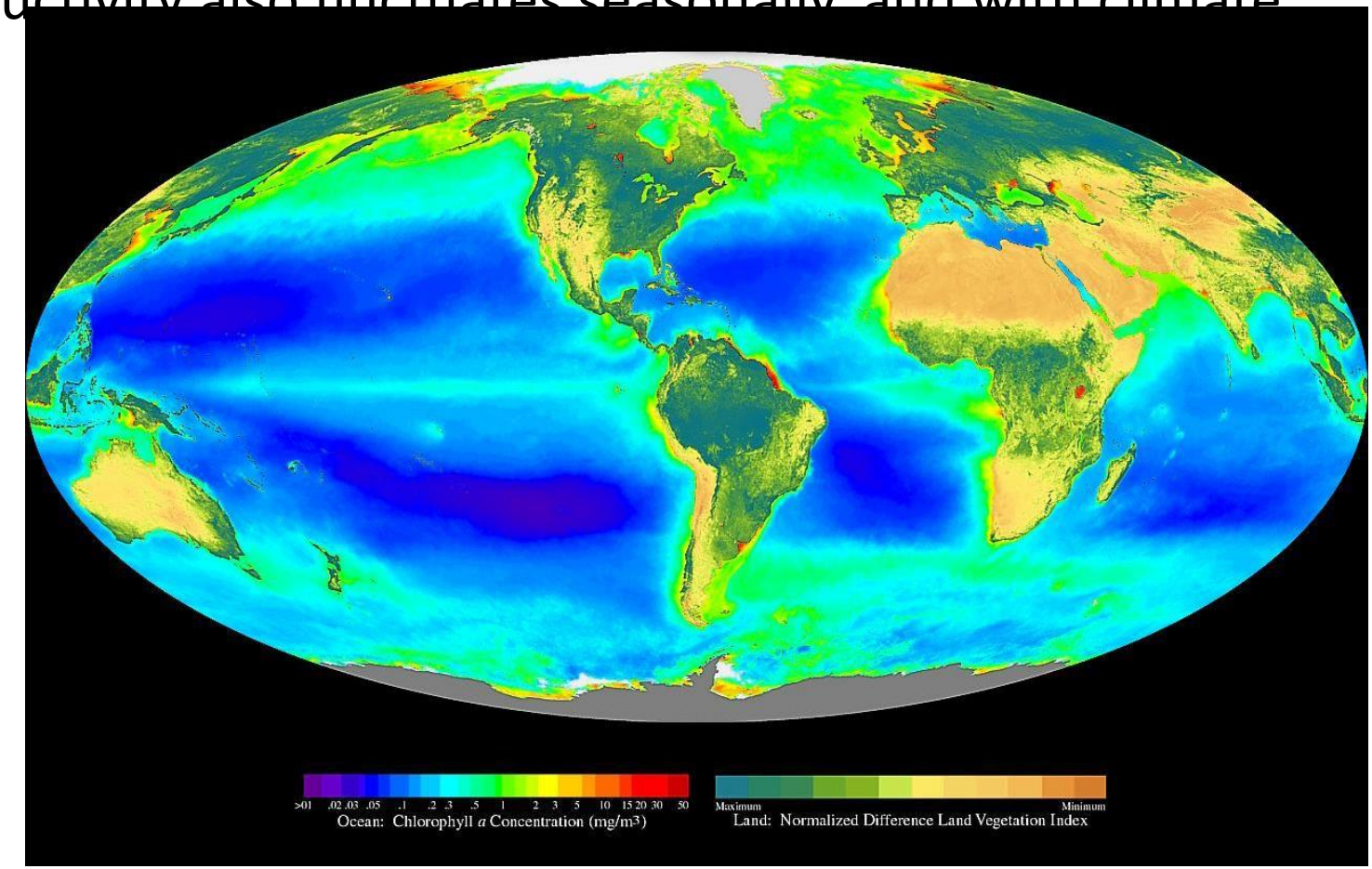
NPP = GPP – (metabolism + lost energy)



Energy Flow

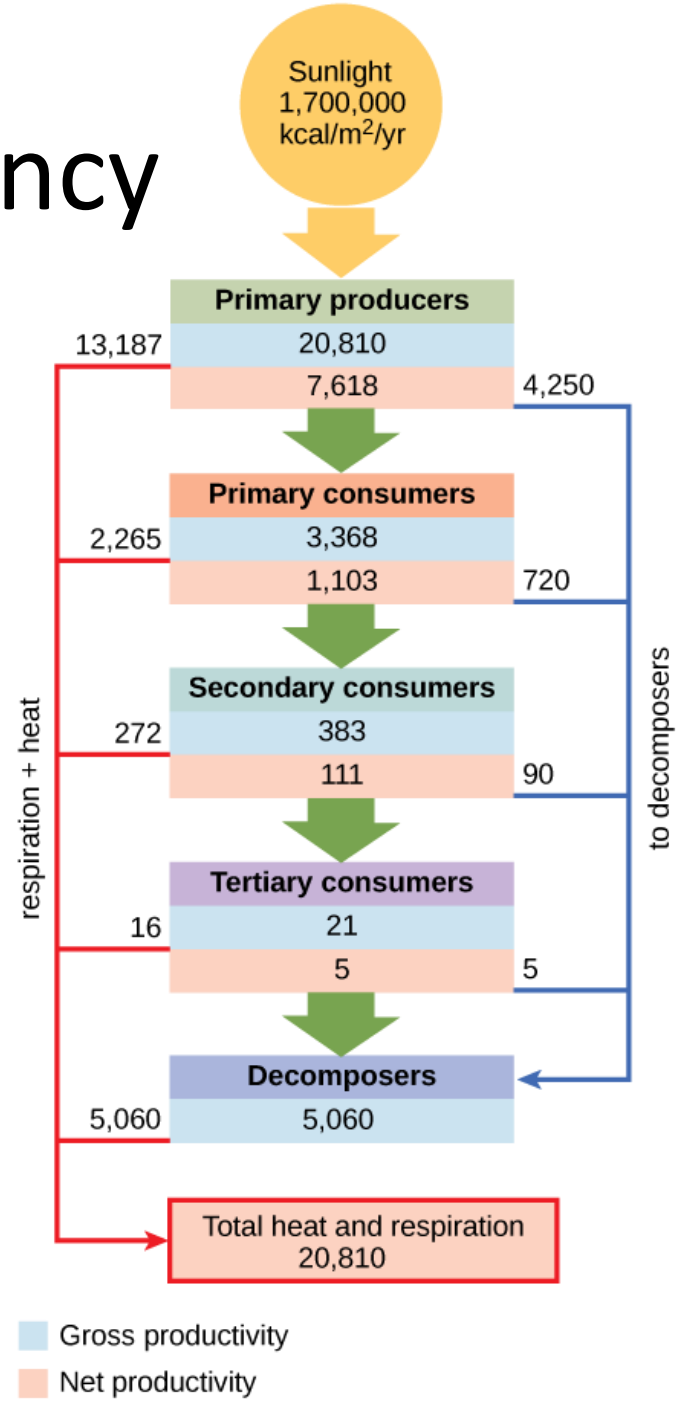
Not all ecosystems are equally productive. Locations where there is the most direct sunlight (tropics) and enough nutrients (temperate and cooler bodies of water) are most productive.

Productivity also fluctuates seasonally, and with climate



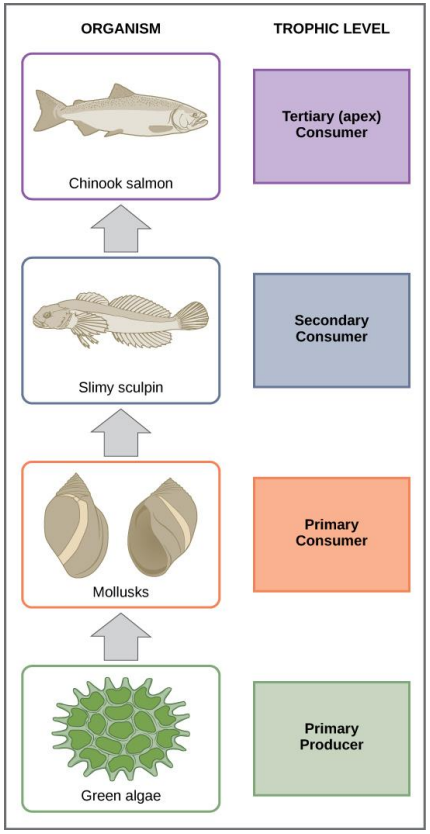
Trophic Efficiency

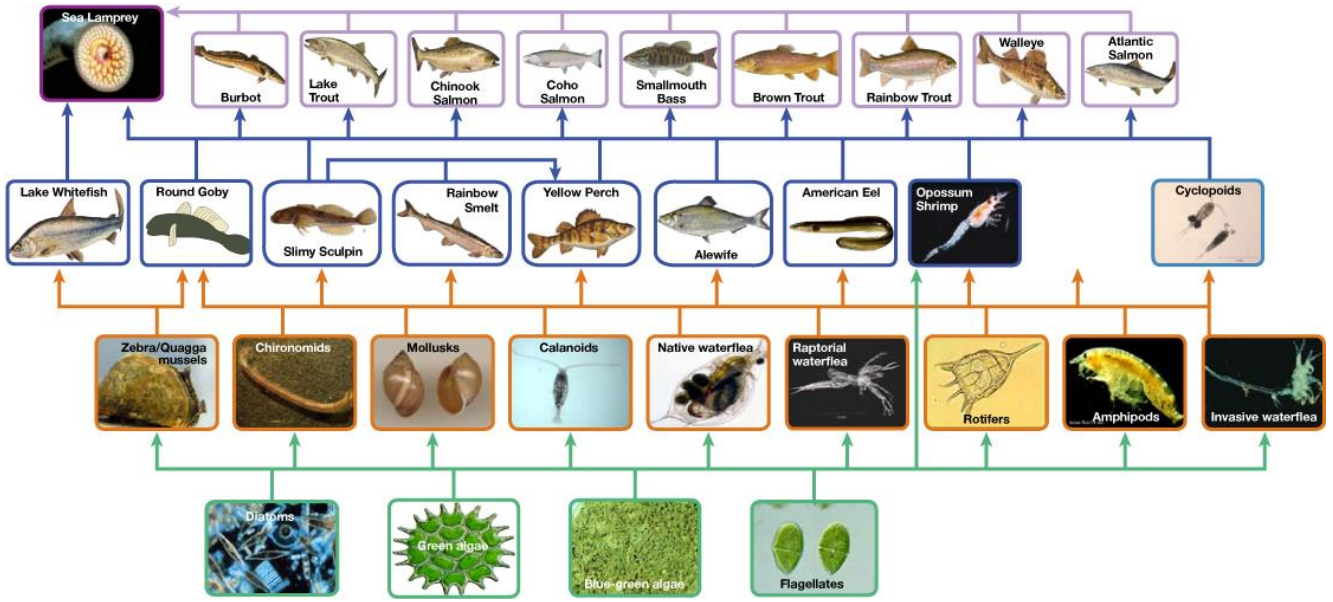
Within a food chain, only **~10%** of energy at any trophic level will be passed on to the next trophic level.



Food Chains and Food Webs

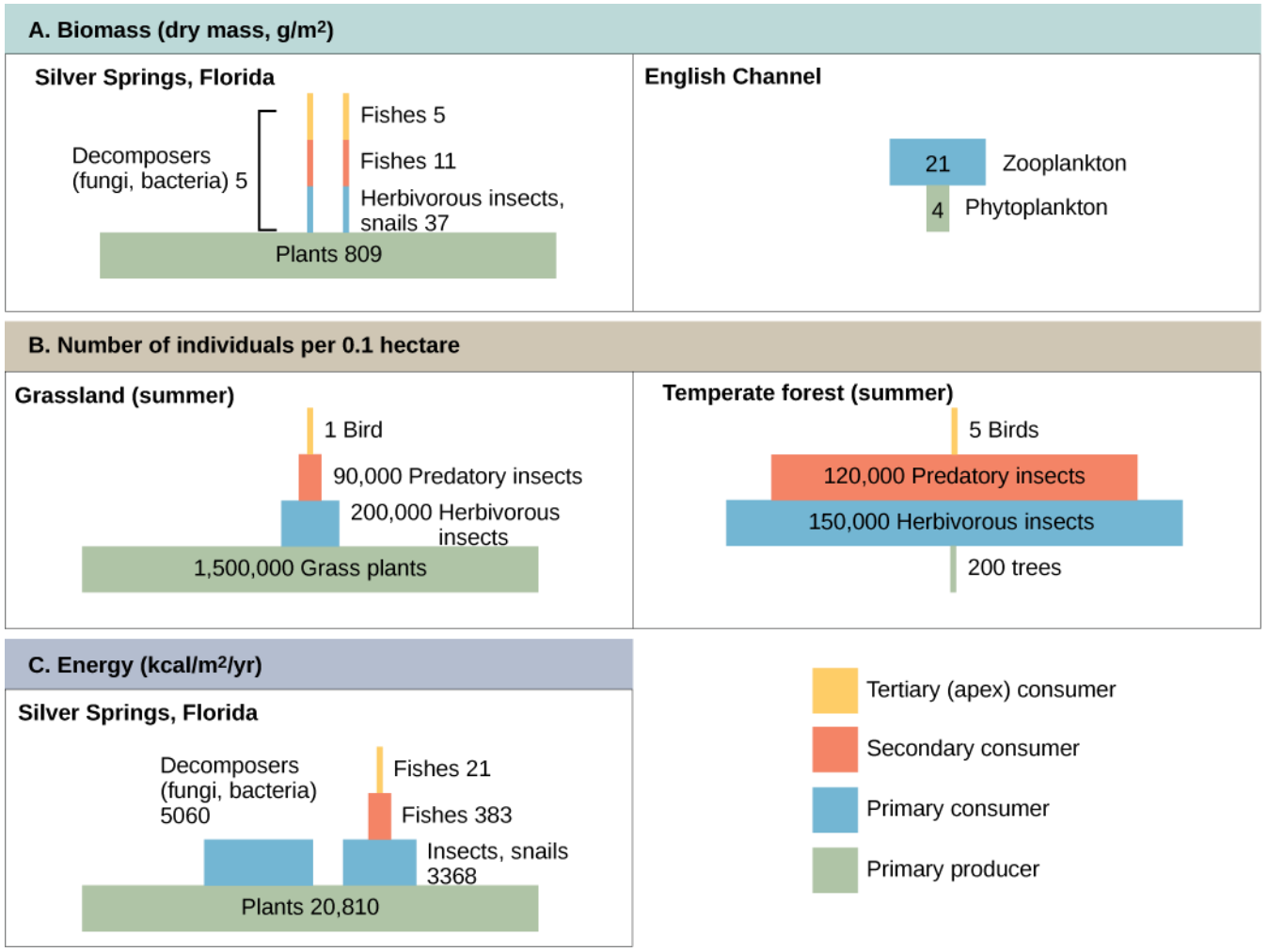
Trophic interactions are represented as food chains and food webs.





Pyramids

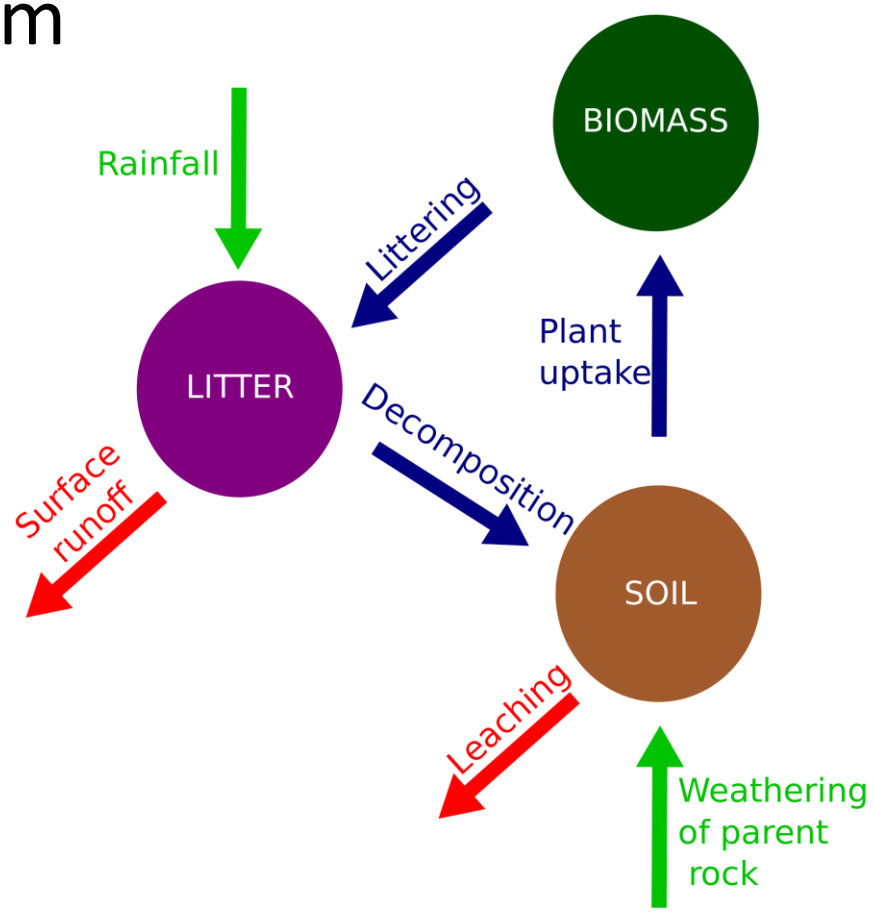
Trophic structure can also be represented as pyramid diagrams



Matter Cycles

Matter cycles between **abiotic** and **biotic** reservoirs in an ecosystem

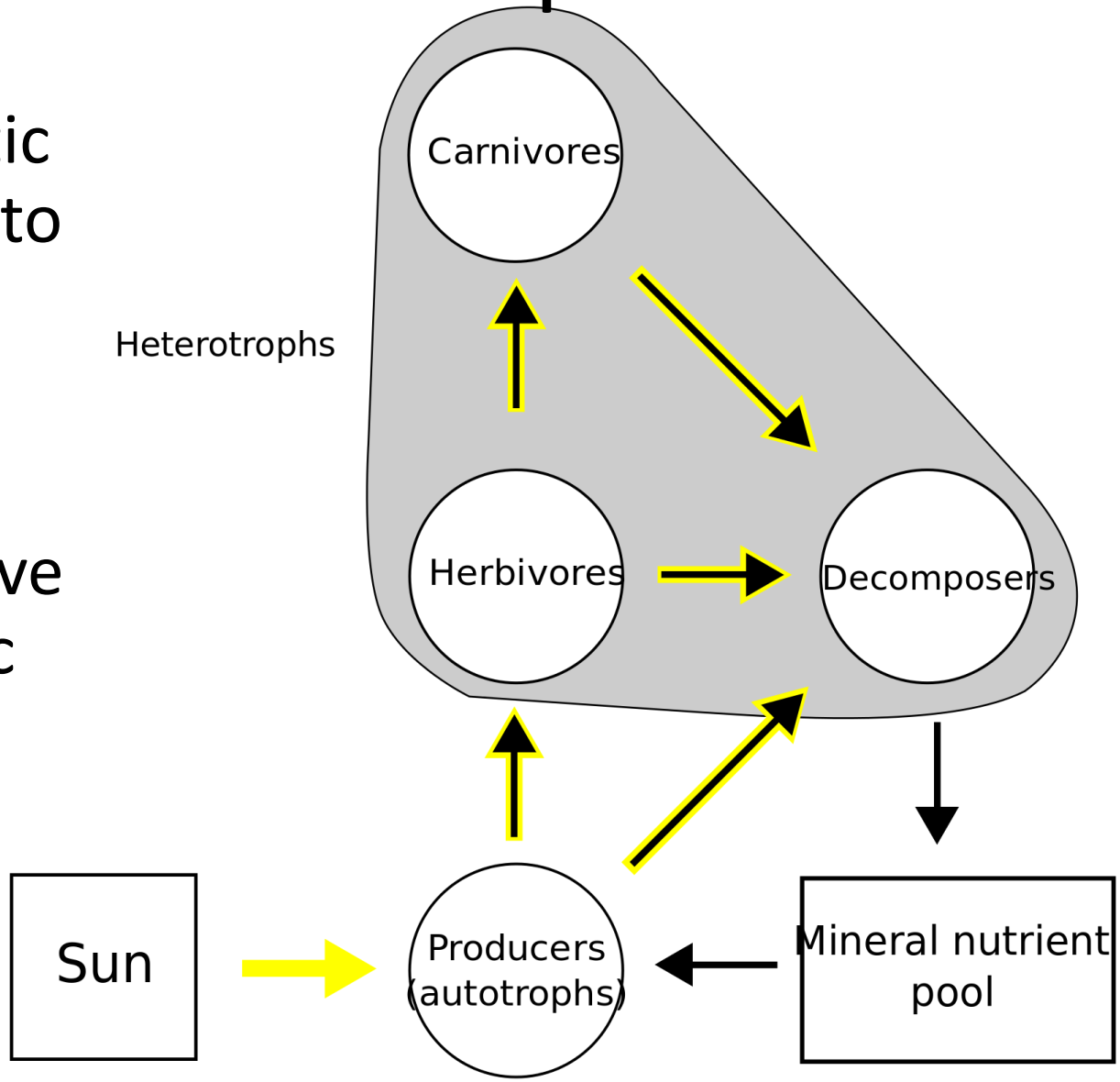
Average Residence Time for Water Molecules
Biospheric (in living organisms) 1 week
Atmospheric 1.5 weeks
Rivers 2 weeks
Soil moisture 2 weeks–1 year
Swamps 1–10 years
Lakes & reservoirs 10 years
Oceans & seas 4,000 years
Groundwater 2 weeks to 10,000 years
Glaciers and permafrost 1,000–10,000 years



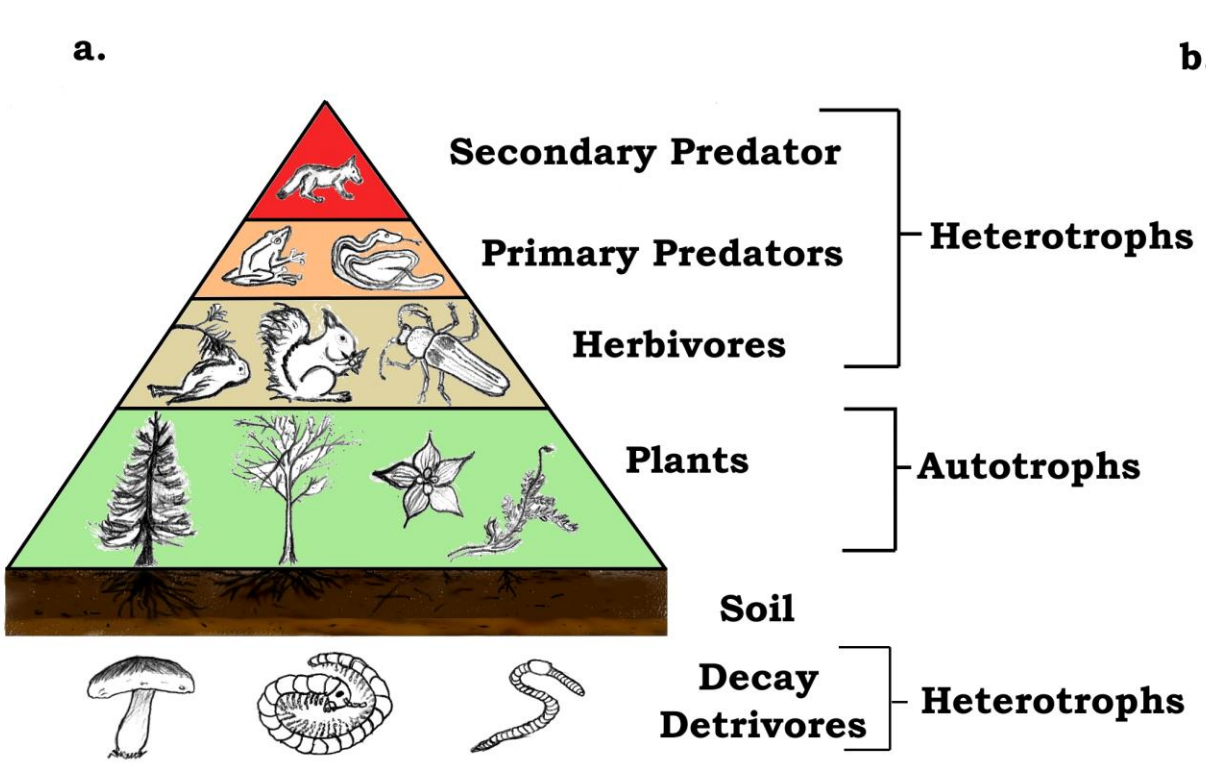
Producers & Decomposers

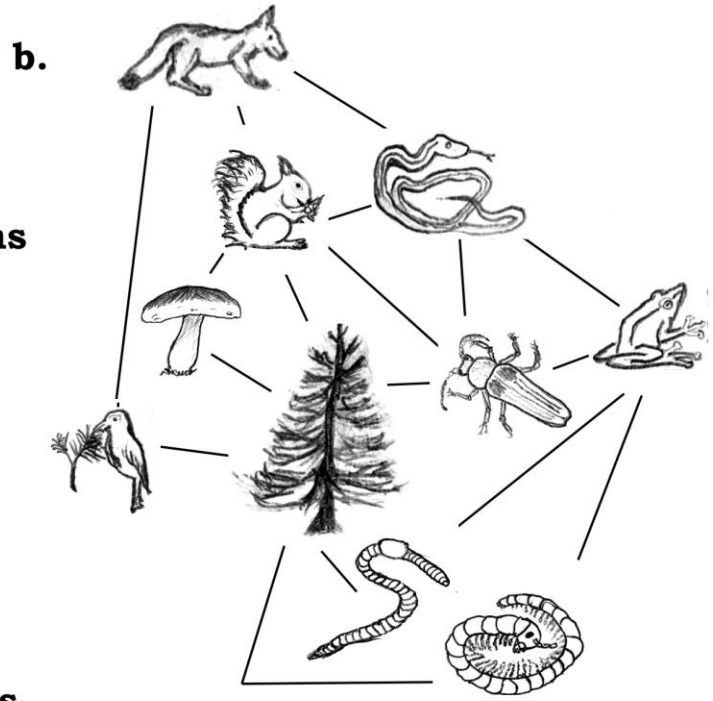
Producers move matter from abiotic sources (e.g. soil) to biotic source (the food web).

Decomposers move matter from biotic sources to abiotic sources.



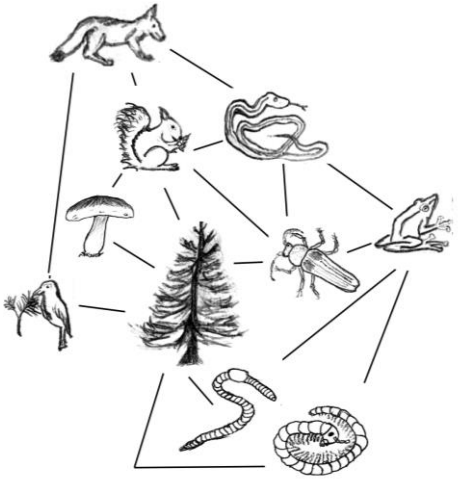
Within a community, matter moves through the food chain.

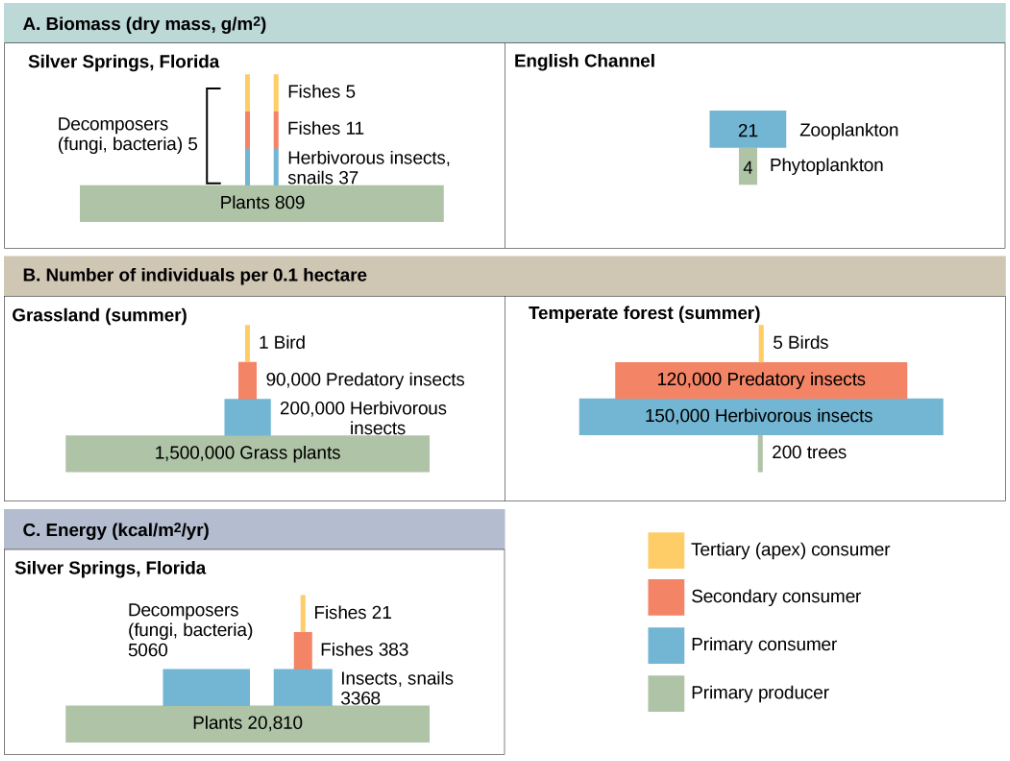


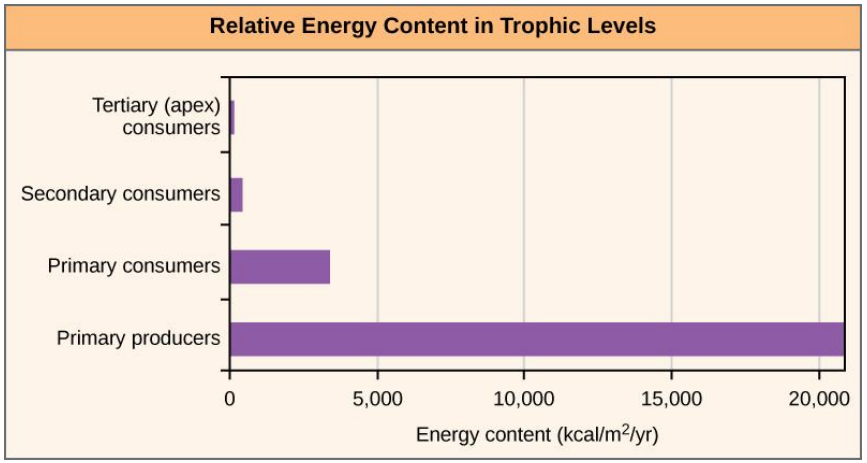


Community Interactions

The influence of community interactions on the movement of matter and energy can be modeled.

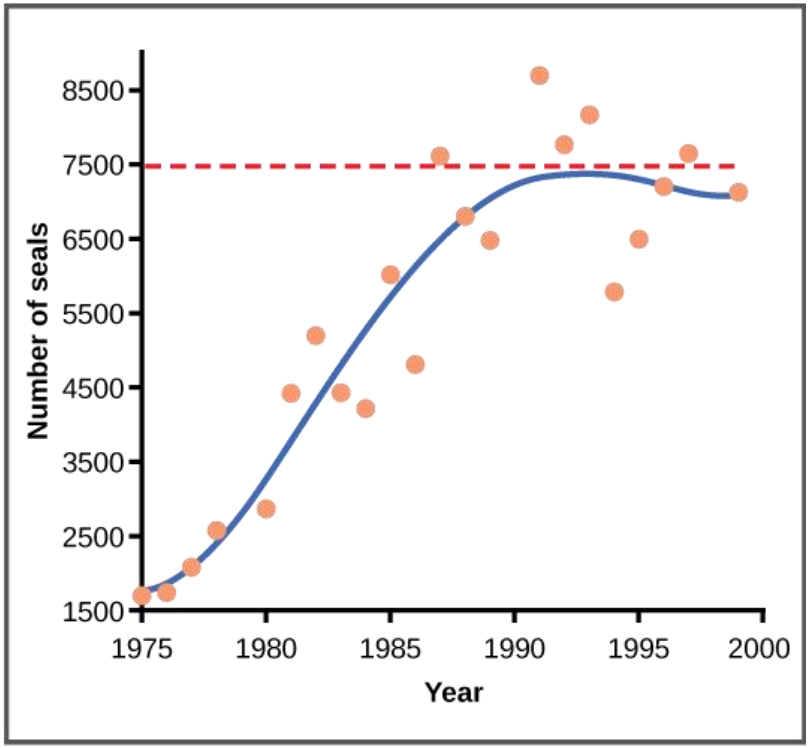






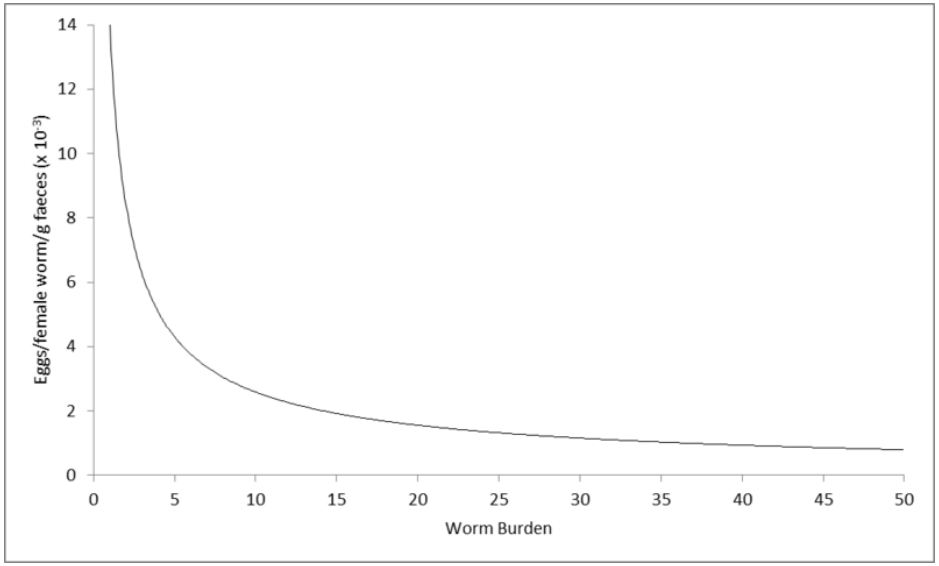
Limiting Factors

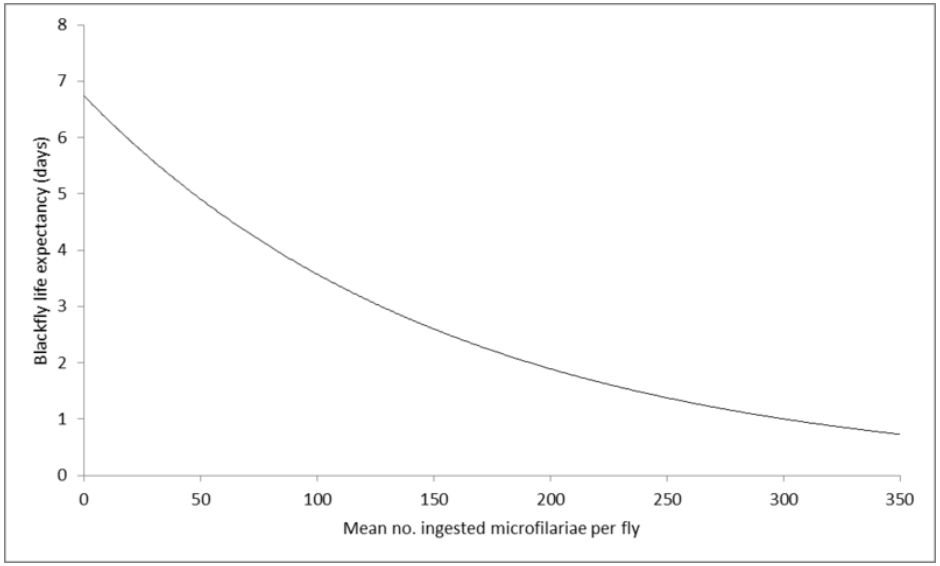
Competition for resources limits population growth. As competition for resources increases, population growth approaches zero.



Density Dependent Factors

As **population density** increases, many limiting factors have larger effects on population growth.

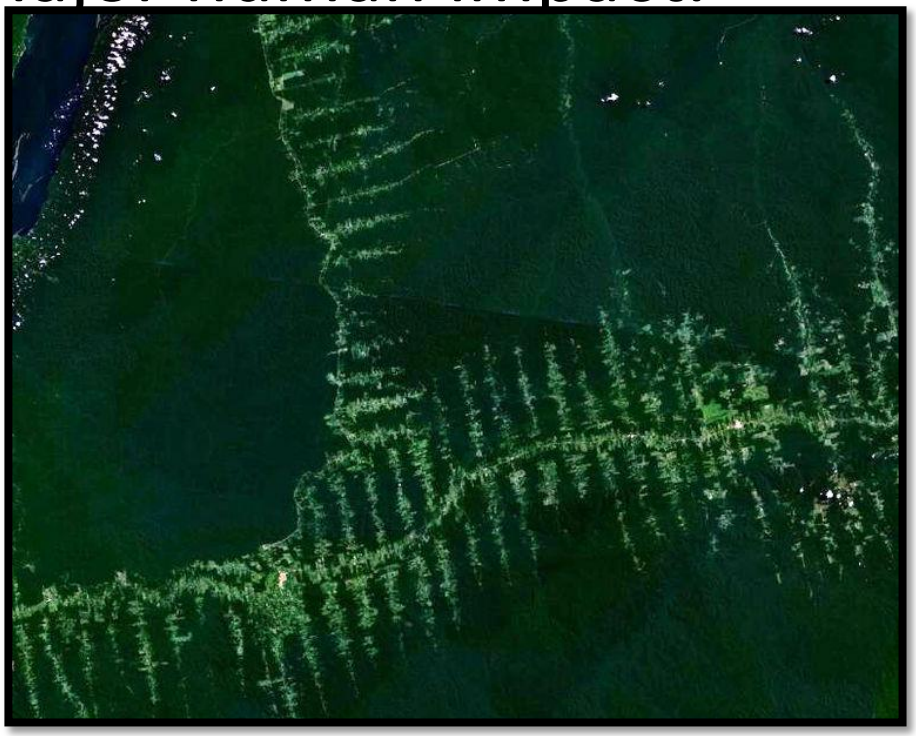




Human Impact

Human activity impacts ecosystems locally, regionally, and globally.

Habitat Destruction is a major human impact.



Human Impacts have contributed to the extinction of many species.

7.3: Interactions among living systems and with their environment result in the movement of matter and energy.

2. MATH SKILLS: PRODUCTIVITY

What You Need To Be Able To Do:

Use your understanding of the laws of conservation of matter and energy to do some basic accounting and determine different aspects of energy and matter usage in a community.

Remember: Inputs have to equal outputs.

Sample Problem

A caterpillar consumes 100 kilocalories of energy. It uses 35 kilocalories for cellular respiration, and loses 50 kilocalories as waste (heat and in waste products). Determine the trophic efficiency for its creation of new biomass.

Conversion Factors

The formula sheet provides two conversion factors to help with productivity calculations relating oxygen production to carbon fixation in photosynthesis:

$$\text{mg } O_2/L \times 0.698 = \text{mL } O_2/L$$

$$\text{mL } O_2/L \times 0.536 = \text{mg carbon fixed/L}$$

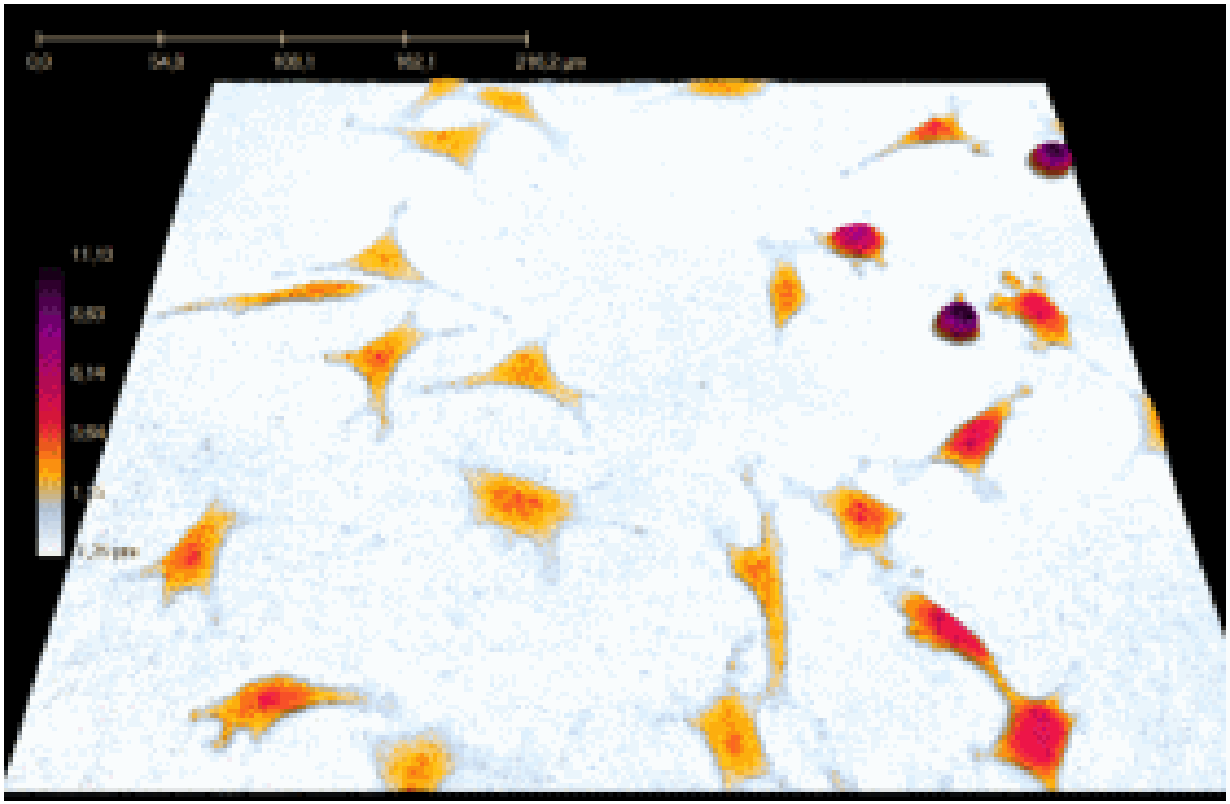
7.4: All biological systems from cells and organisms to populations, communities and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy.

1. LIMITING FACTORS

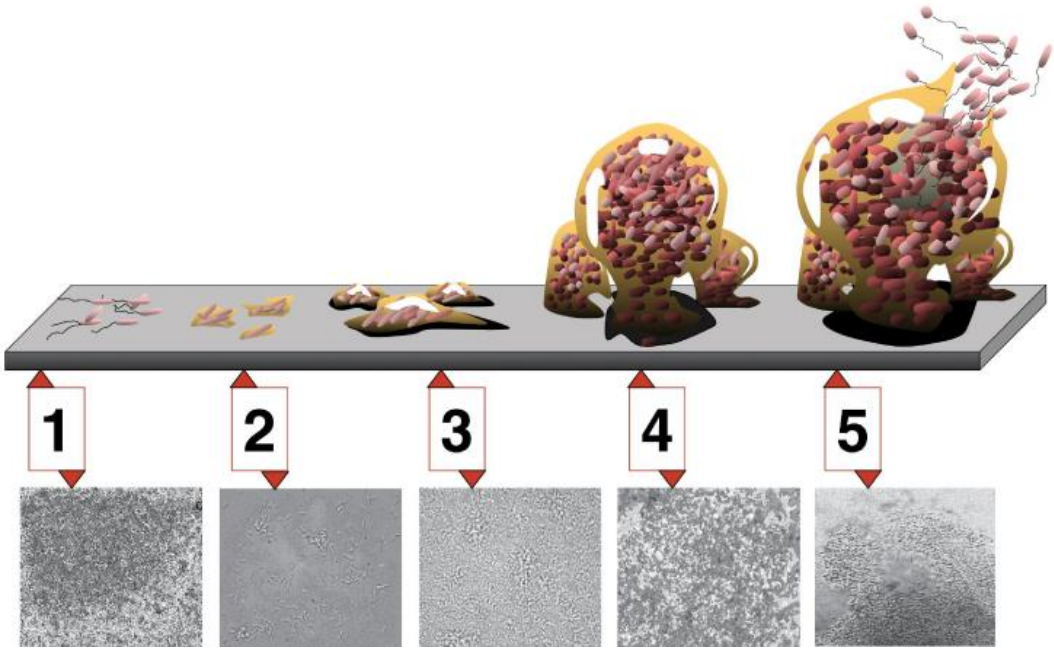
Biotic and Abiotic Factors

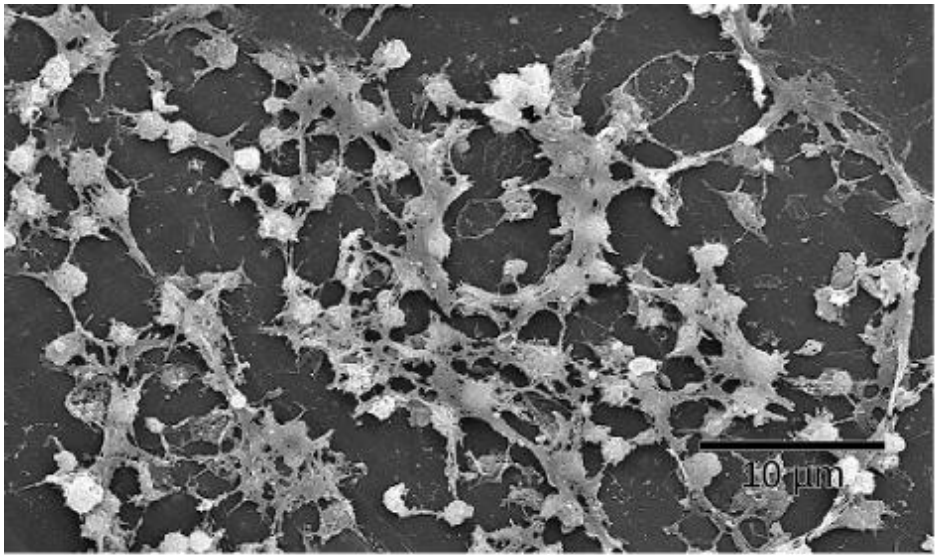
Cellular activities, organism activities and the structure of populations, communities, and ecosystems will all be affected by interactions with biotic and abiotic factors in the environment.

Ex. Density-Dependent Regulation of Cell Division

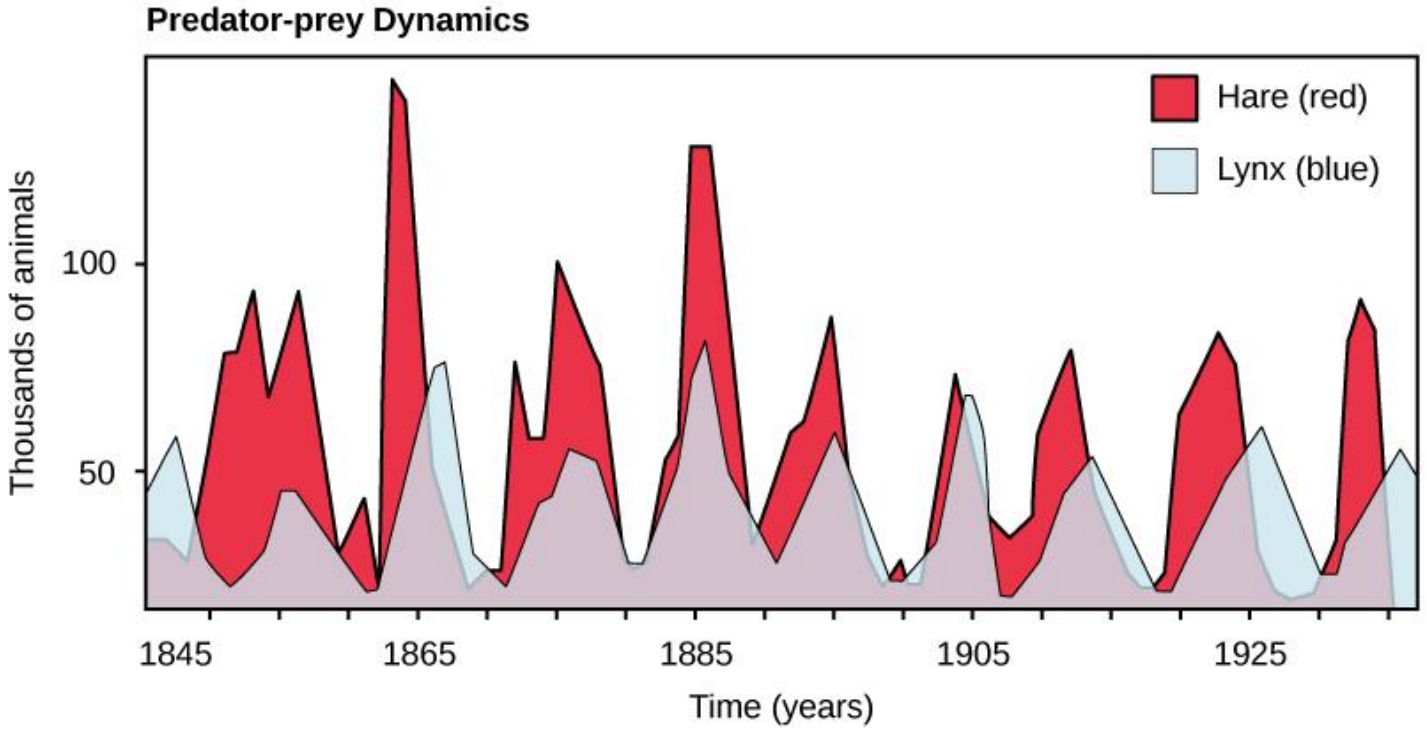


Ex. Biofilm Generation in Prokaryotes





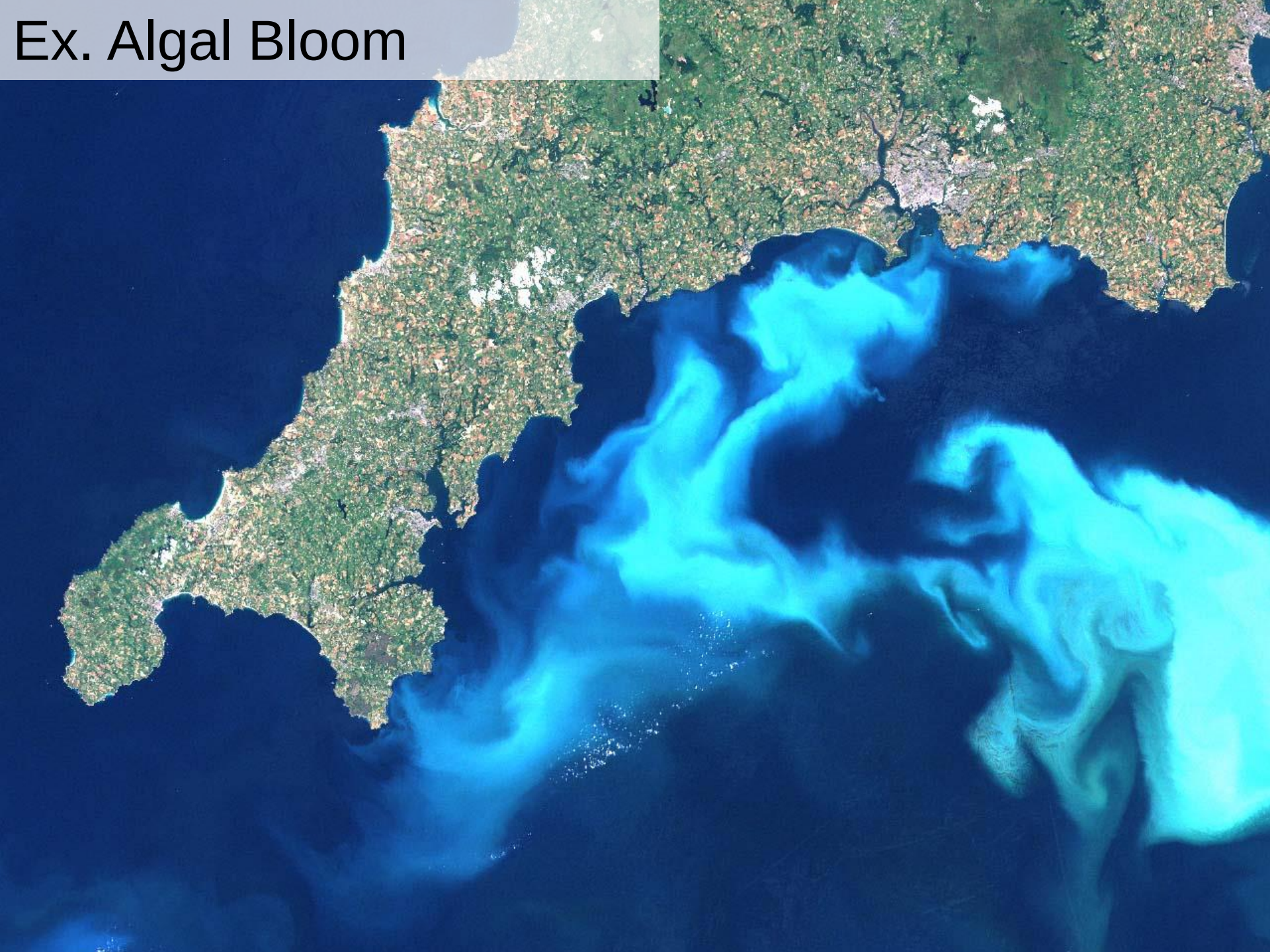
Ex. Predator-Prey Relationships



Ex. Resource Availability

Ex. Community Structure

Ex. Algal Bloom



In All Cases

Biotic and abiotic interactions both play roles in affecting biological systems at all levels of organization.

These affects can be beneficial, detrimental, or variable in their effects on the system and its state at the time of the interaction.

7.5: The level of variation in a population affects population dynamics.

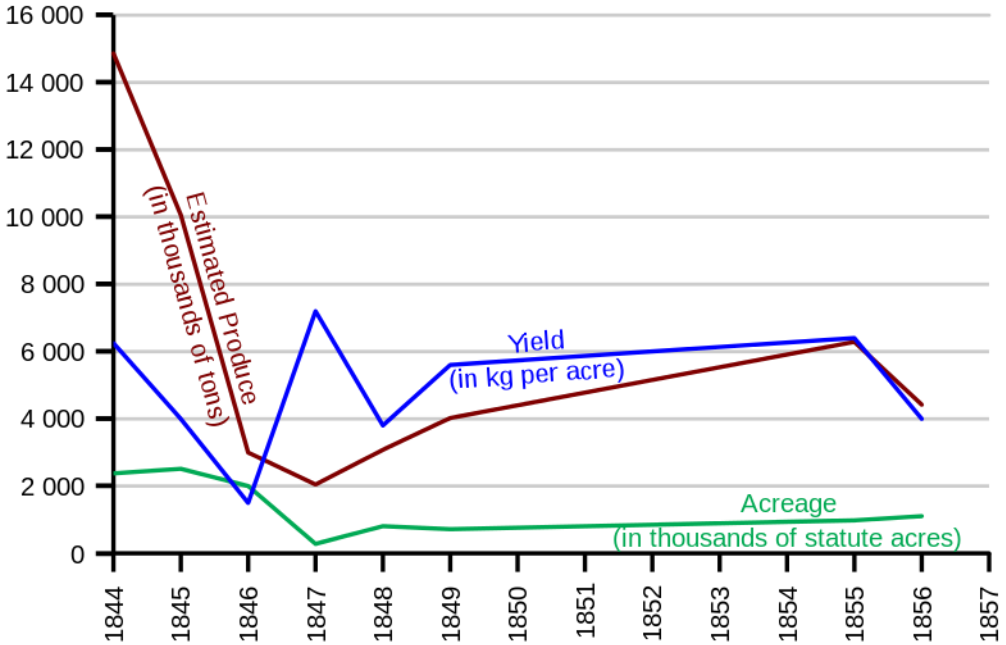
1. POPULATION DIVERSITY

Genetic Diversity & Resilience

The ability of a population to respond to changes in its environment (its "**resilience**") is directly related to its genetic diversity.

Populations with the least genetic diversity are most at risk for extinction in an ecosystem.

Ex. Potato Blight

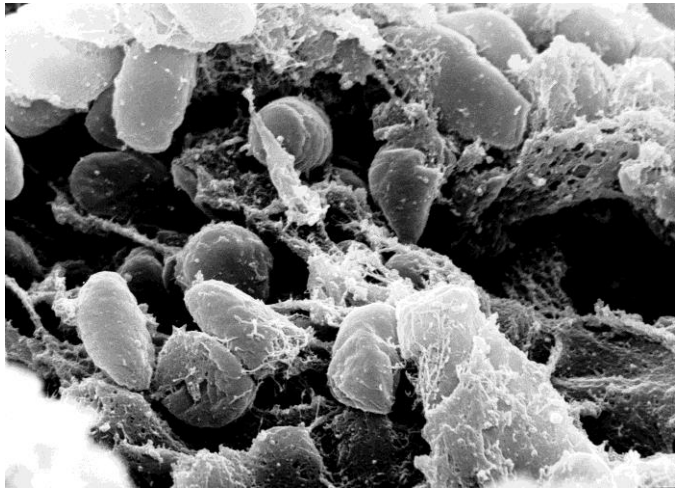


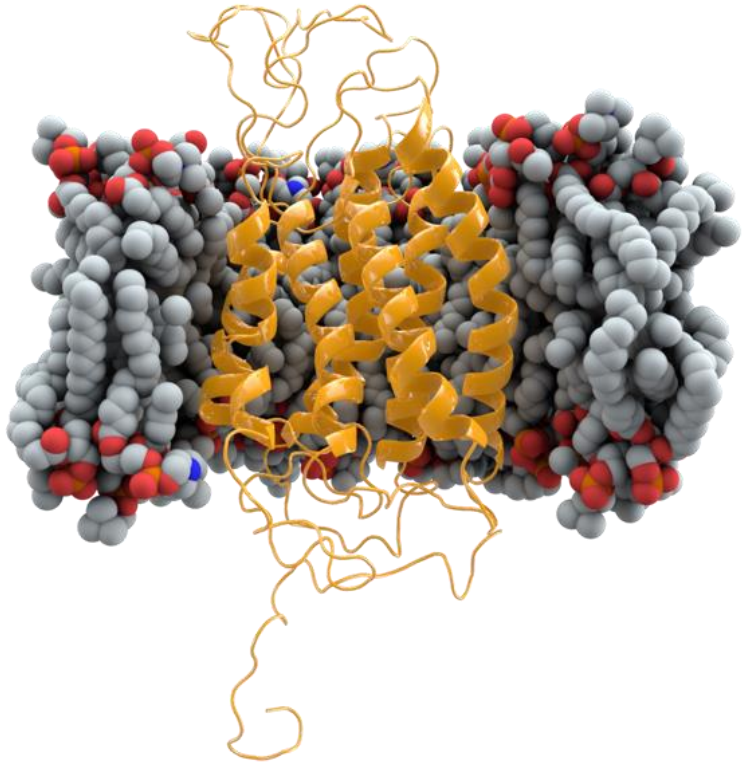
Genetic Diversity & Responses

Genetic diversity leads to a diversity of responses among individuals in a population to the same environmental changes.

This diversity can be physiological or behavioral.

Ex. Black Plague Survival



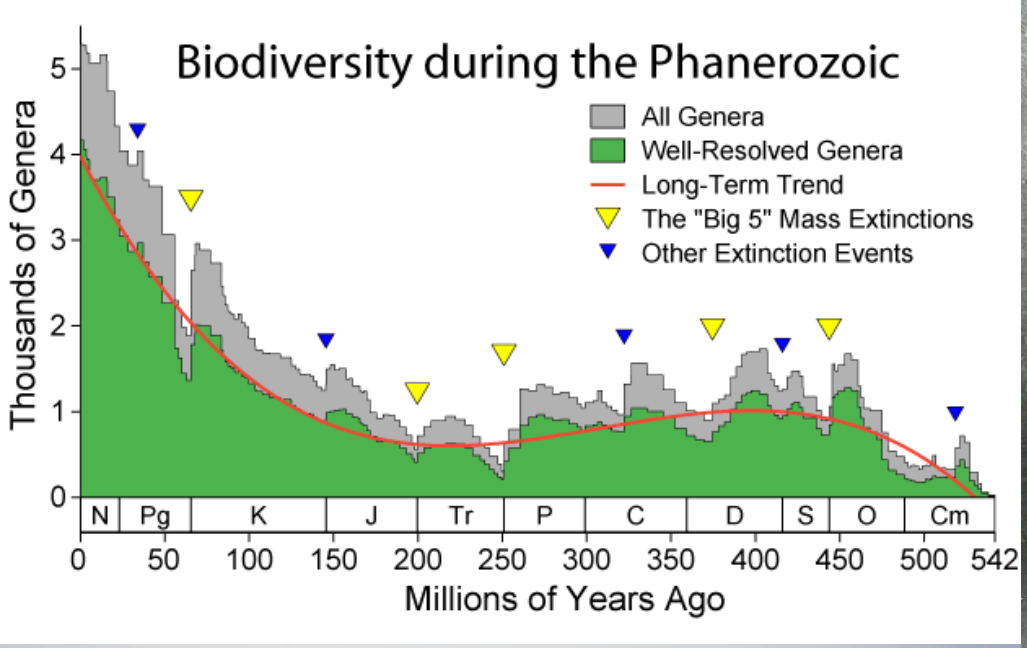


Ex. Stampede Behavior

Modeling Diversity

Various models can be used to estimate the genetic diversity in a population:

- Hardy-Weinberg Equilibrium
- Direct Genetic Sampling
- Direct Phenotype Sampling
- Fossil Record Analysis


Biodiversity during the Phanerozoic
All Genera
Well-Resolved Genera
Long-Term Trend
The "Big 5" Mass Extinctions
Other Extinction Events
Thousands of Genera
0
1
2
3
4
5
N
Pg
K
J
Tr
P
C
D
S
O
Cm
0
50
100
150
200
250
300
350
400
450
500
542
Millions of Years Ago


3dham.com
Split ammonite

7.6: Interactions between and within populations influence patterns of species distribution and abundance.

1. COMMUNITY INTERACTIONS

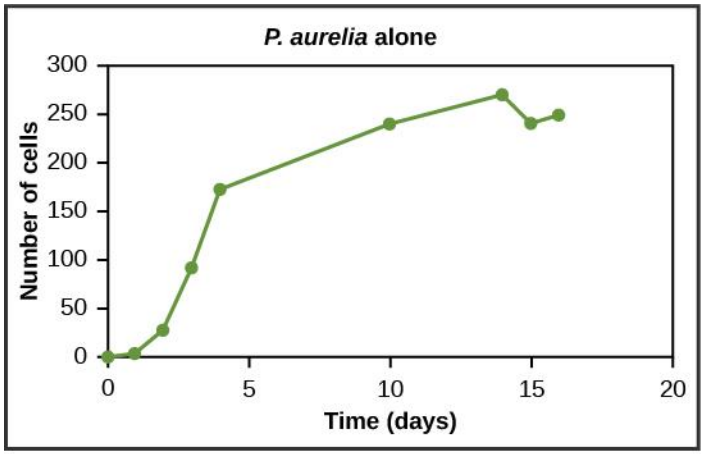
Populations Interact

Interactions between populations affects the **distribution** and **abundance** of organisms.

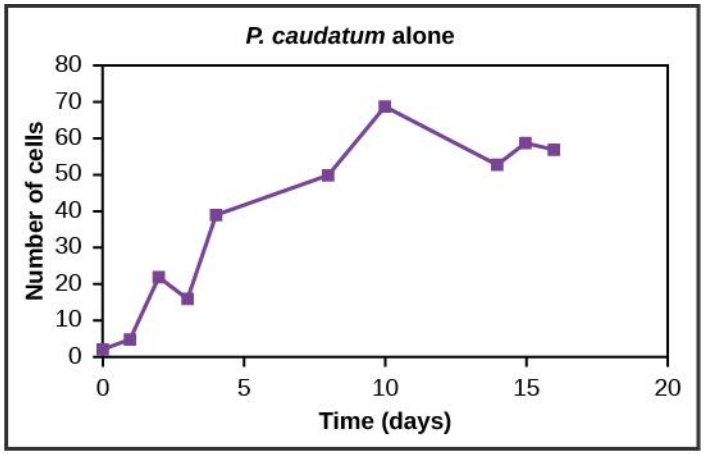
Niche: the total interactions of an organism with its environment.

Competition, and **predation** can limit the distribution and abundance of a population.

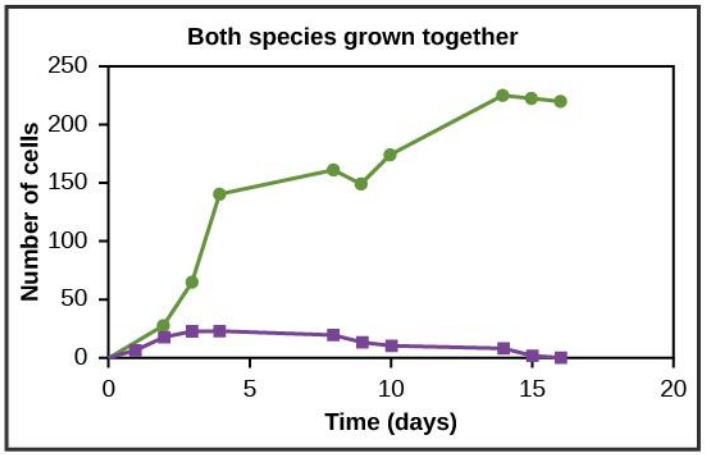
Competitive exclusion principle: When two species have overlapping requirements in the same ecosystem, one species will outcompete the other for those overlapping resources.



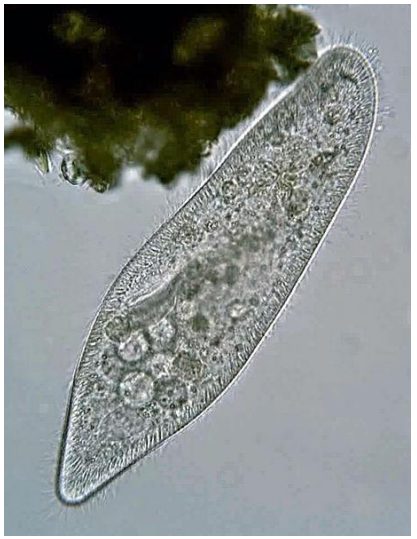
(a)



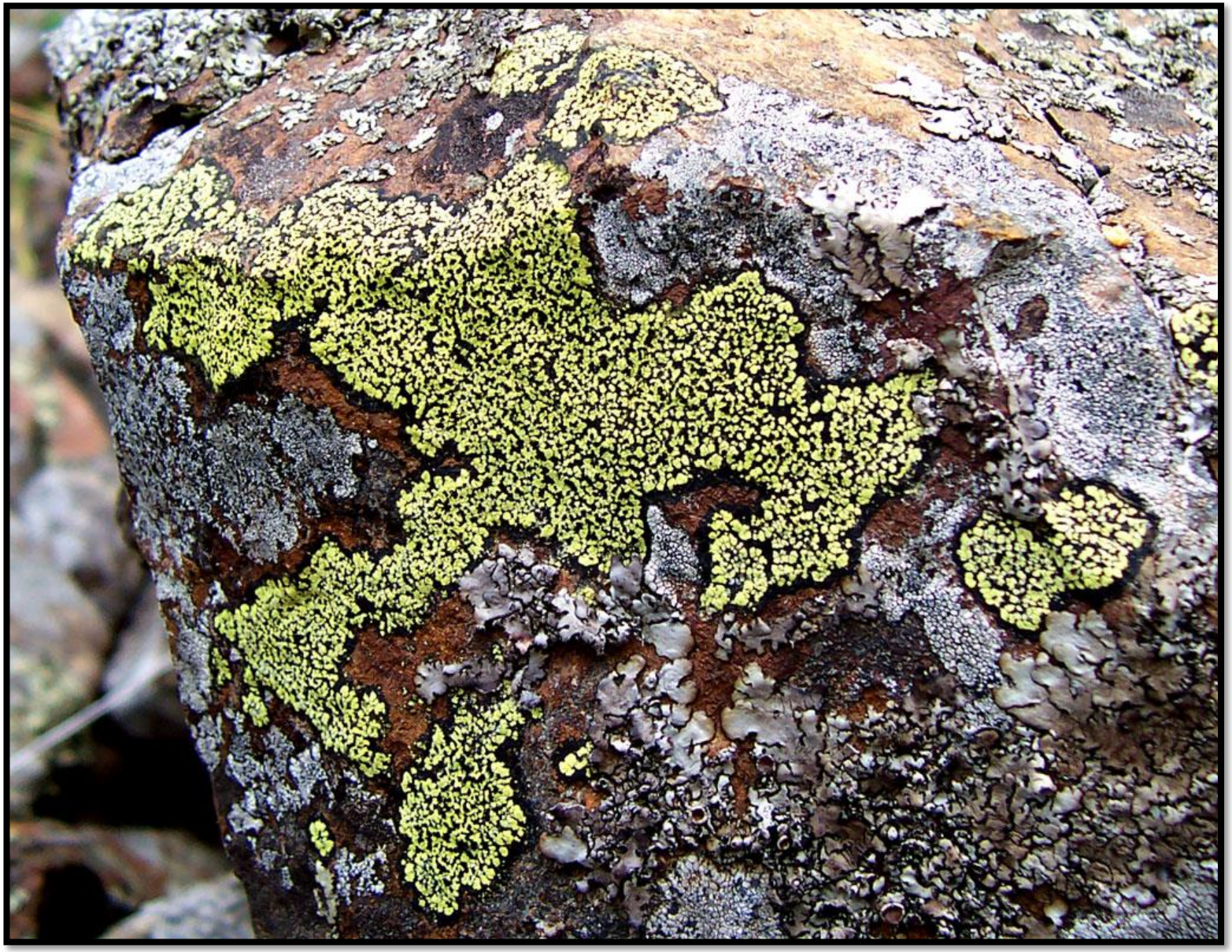
(b)



(c)



Symbiosis can limit or expand the distribution of a population.



Mutualism: +/+

Commensalism: +/0

Parasitism: +/-

Population Level Emergence

A population has properties unique to its level of organization. These properties emerge from the interactions among the individuals who comprise the population with each other and the ecosystem.

The interactions between populations can be analyzed at the individual level and at the population level.

Distribution and Abundance

Two major population properties.

Distribution and abundance of organisms are affected by community interactions and environmental changes.