Chapter 54 (Campbell)
Community Ecology

(54) Community Ecology

I.

Main Idea: Species living in close proximity will inevitably interact with each

Main Idea: These interactions can be positive, negative or have little to no effect.

COMMUNITY INTERACTIONS

- A ***community*** is a group of species living close together and interacting
- Some of these interactions affect the survival and reproduction of the two species interacting
- These interspecific interactions include:

A. Competition (-/-)

- Limited resources cause species to compete for them and this lowers the fitness of both species

1. Competitive Exclusion

- In 1934, Russian Ecologist G.F. Gause concluded that two competing species could not coexist permanently in the same place
- One species will inevitably have a slight reproductive advantage and eventually eliminate the inferior competitor...***competitive exclusion principle***

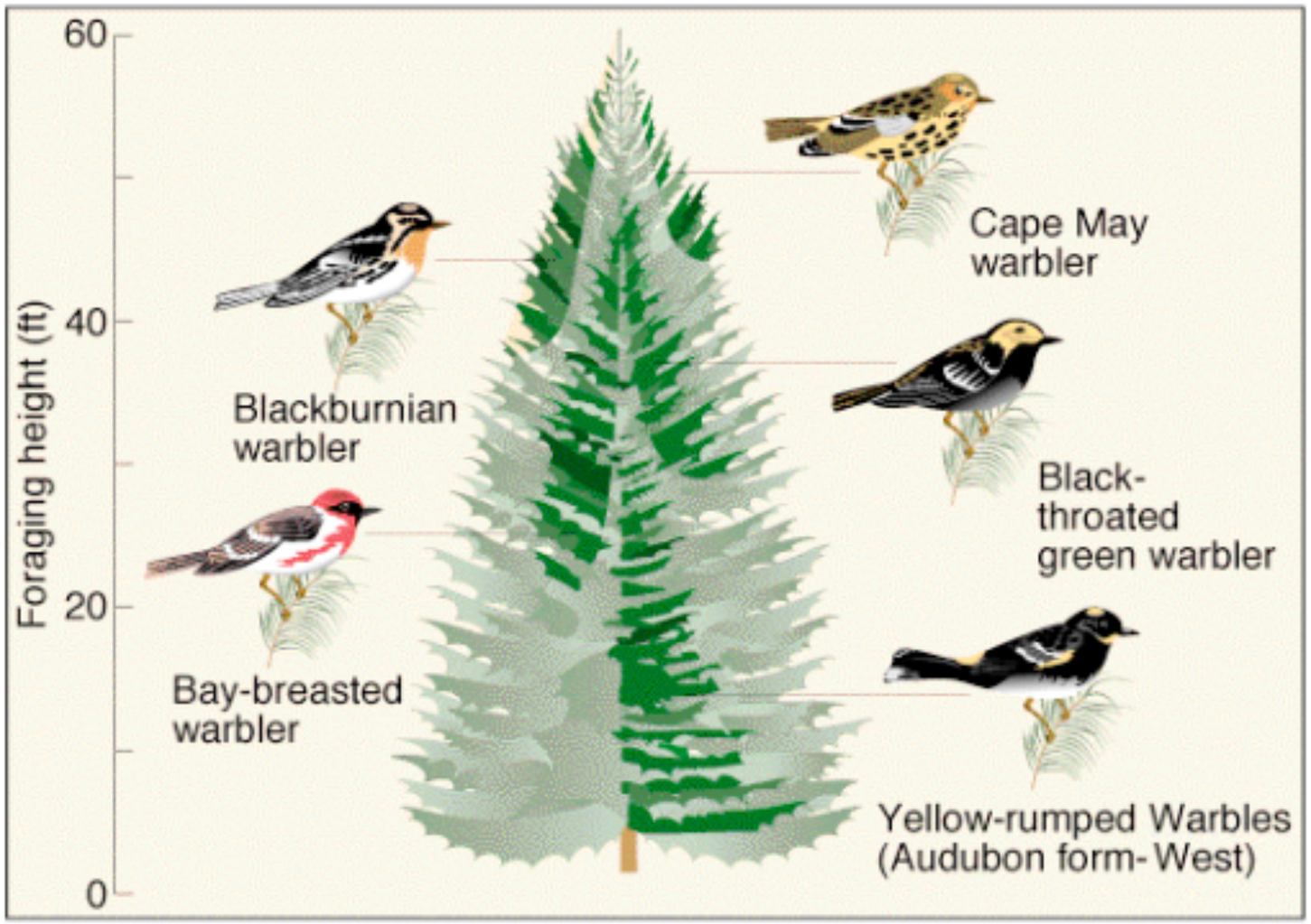
2. Ecological Niches & Evolution

- Sum use a species resources both abiotic and biotic in their environment...***niche***
- *Competitive exclusion principle* rephrased...no two species can occupy the same niche

2. Ecological Niches & Evolution

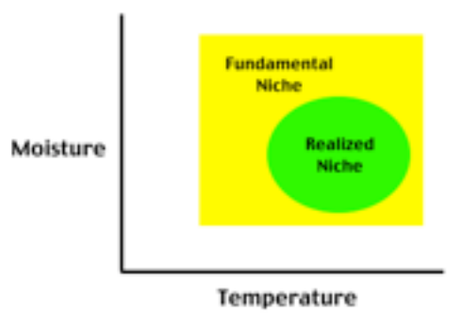
- Since the two species can not occupy same niche one will use slightly different resources their by differentiating or partitioning the niche
- This resource partitioning allows two species to live in very similar niches
- Evolution by natural selection provides the mechanism for this partitioning.
- Species use their small and unique variations to use these to carve out a specific smaller niche from a larger one

Resource Partitioning



Note: species can partition their niches by *space* seen here or by *time*...think diurnal vs nocturnal

- As a result of competition a species occupies a ***realized niche*** (niche it actually lives in) which is smaller than its ***fundamental niche*** (niche it could occupy)

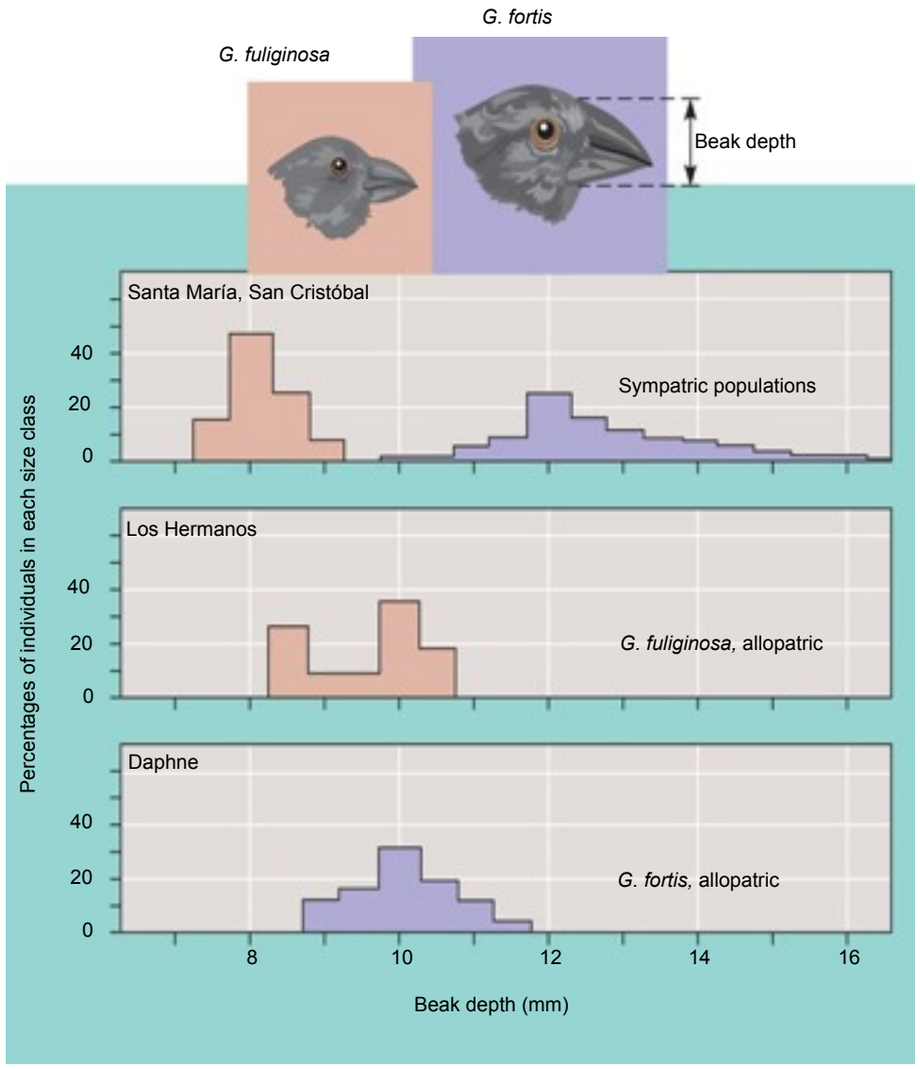


3. Character Displacement

- Geographically separate (*allopatric*) species who use the similar resources or who face similar challenges are often morphologically similar

- Species who not geographically separate (*sympatric*) are morphologically different due to competition within the same niche

- The tendency for sympatric species to diverge from one another more so than allopatric species is called ***character displacement***.

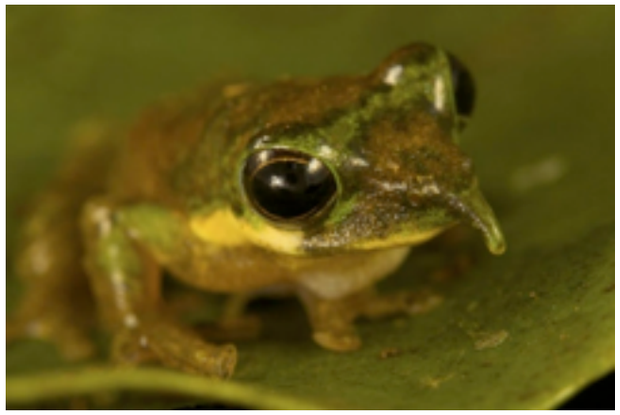


B. Predation (+/-)

- Natural selection has fine tuned both predator and prey with remarkable adaptations.
  - **Predators**:
    - acute senses, speed, agility, claws, teeth, fangs, stingers and venoms
  - **Prey**:
    - behavioral defenses; hiding, fleeing, forming herds or schools, alarm calls
    - morphological & physiological defenses; camouflage (cryptic coloration), warning colors (aposematic colorations), spines, poisons, toxins, chemicals, mimicry

Can you think of an example of each?

Smell

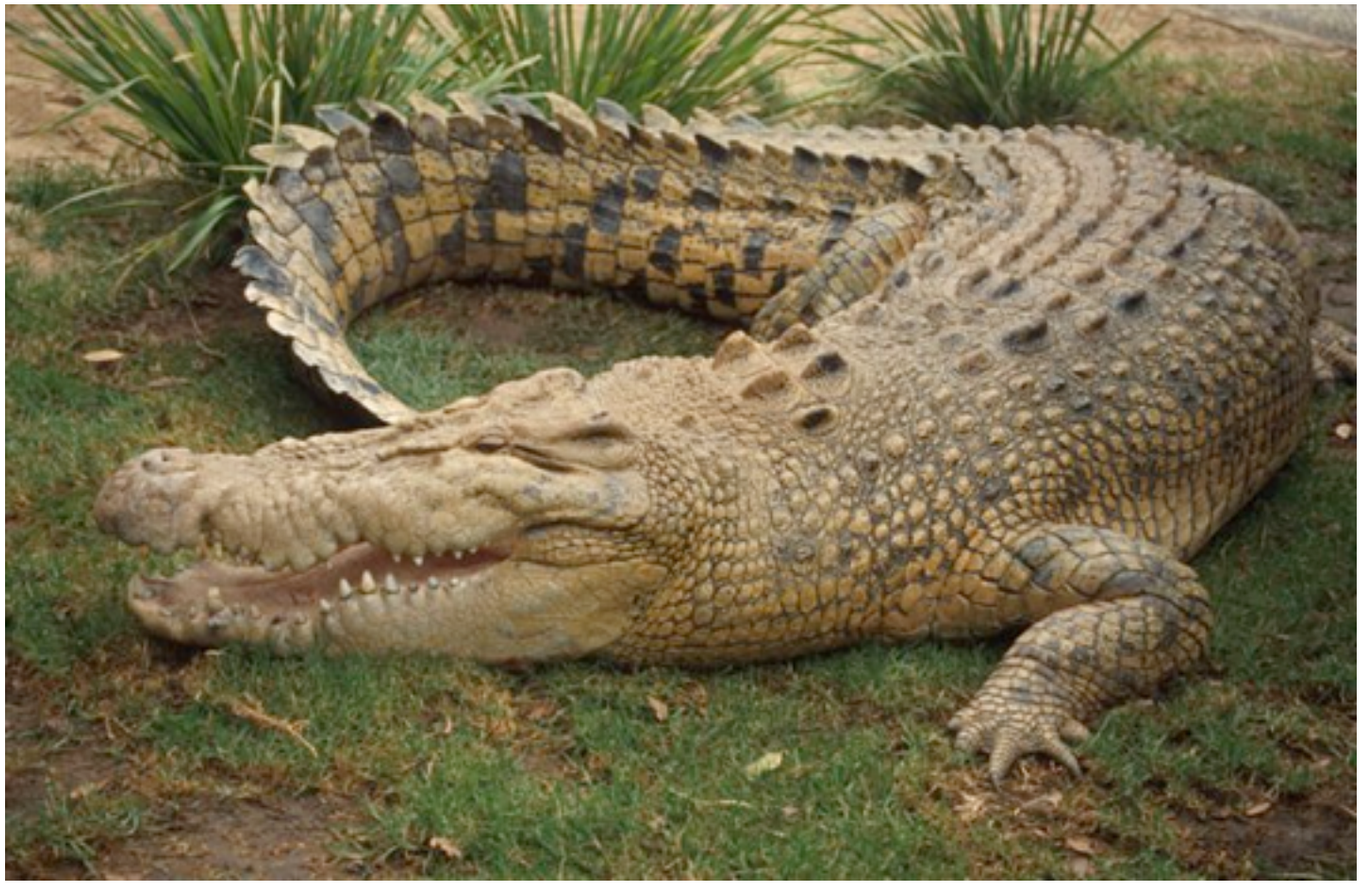


Hearing

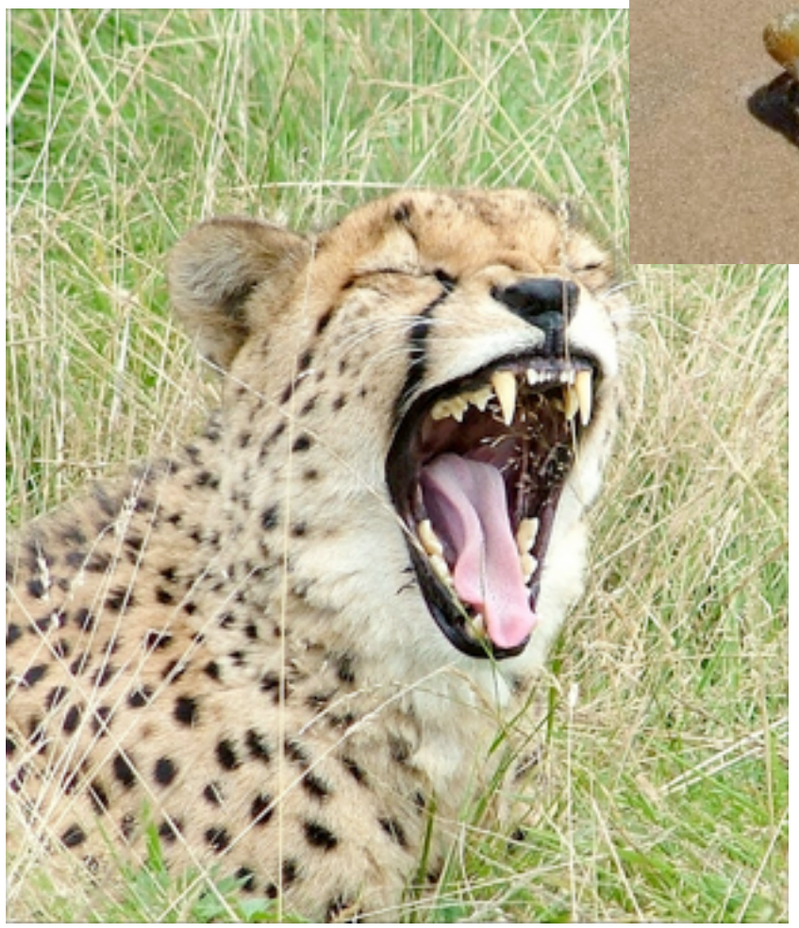
Vision

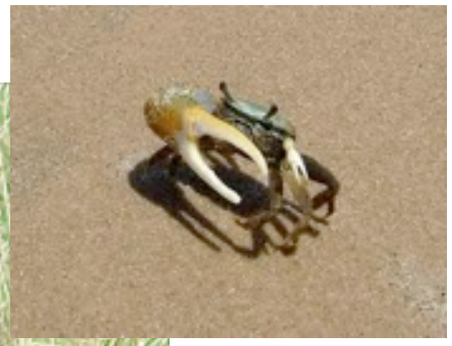
Taste

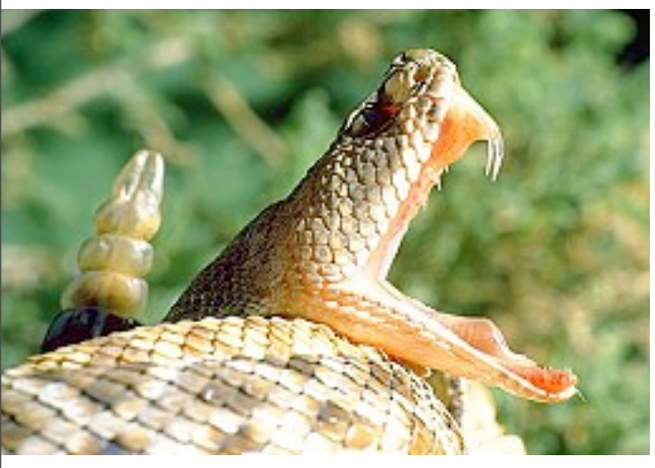
Touch



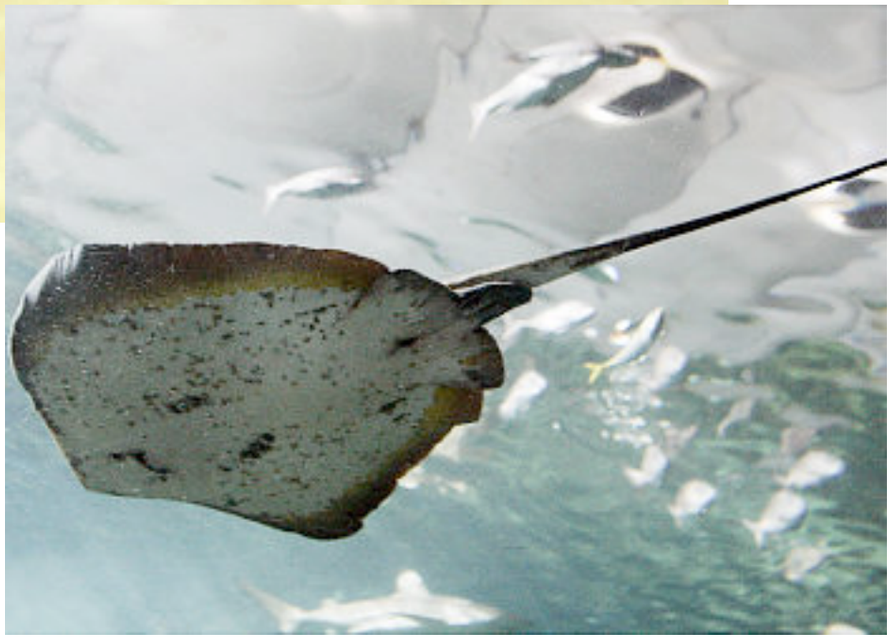
Claws, Teeth & Fangs



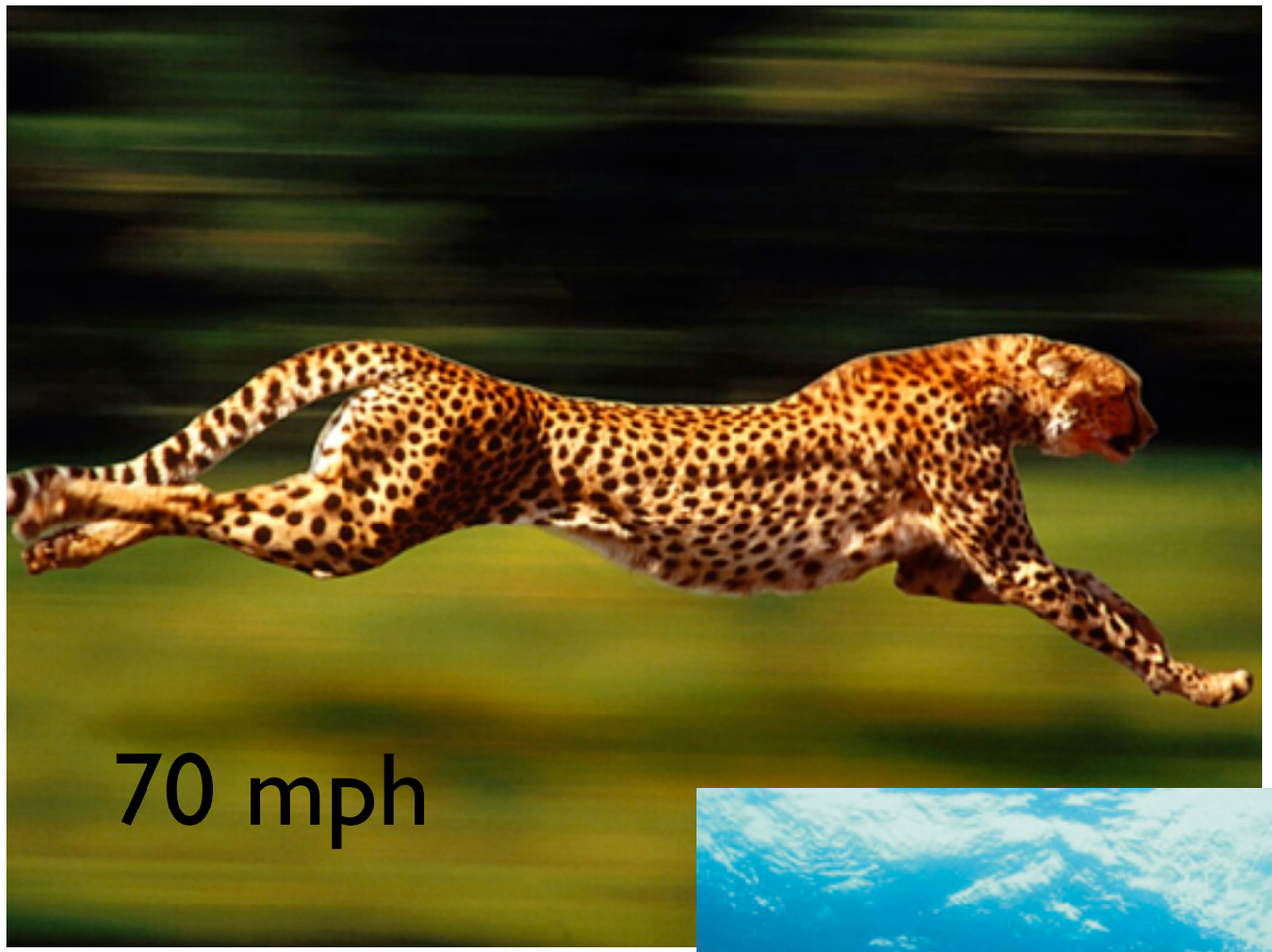


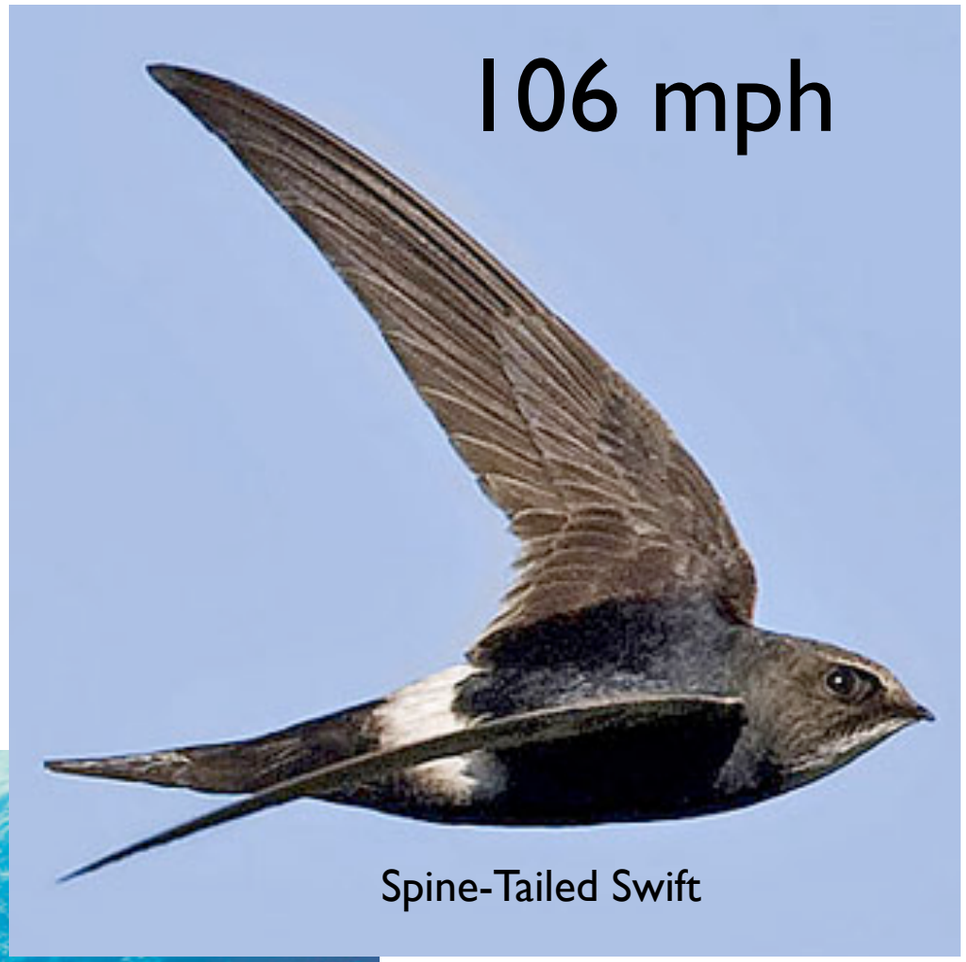


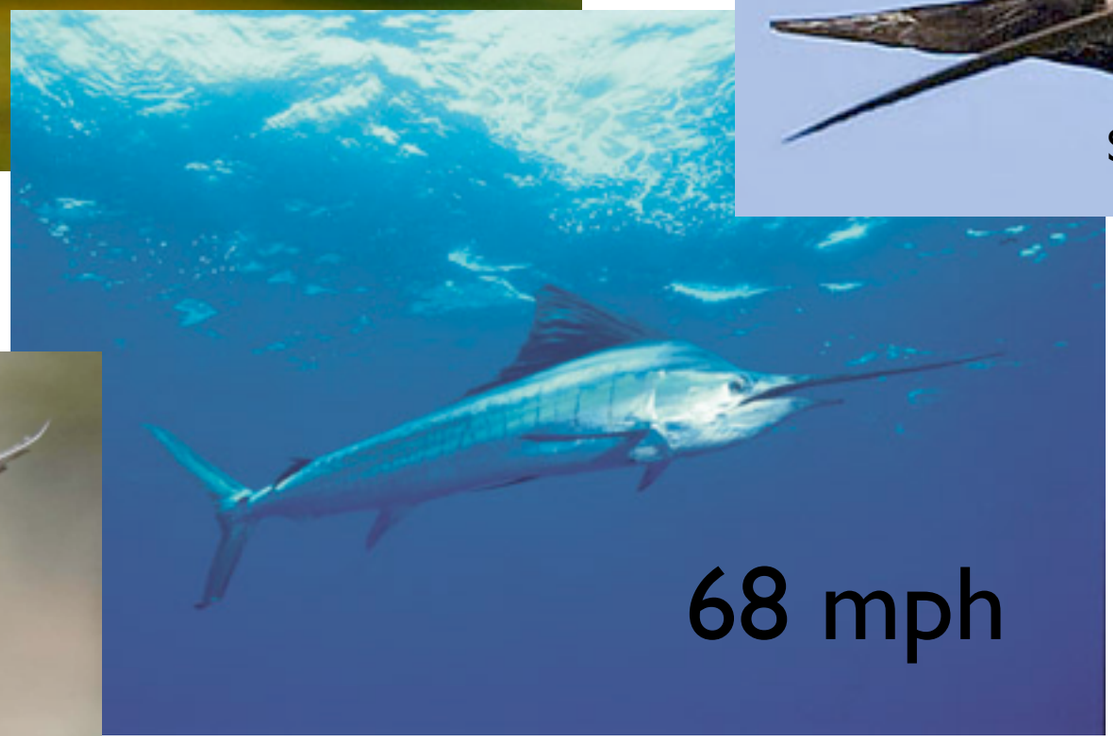
Stingers



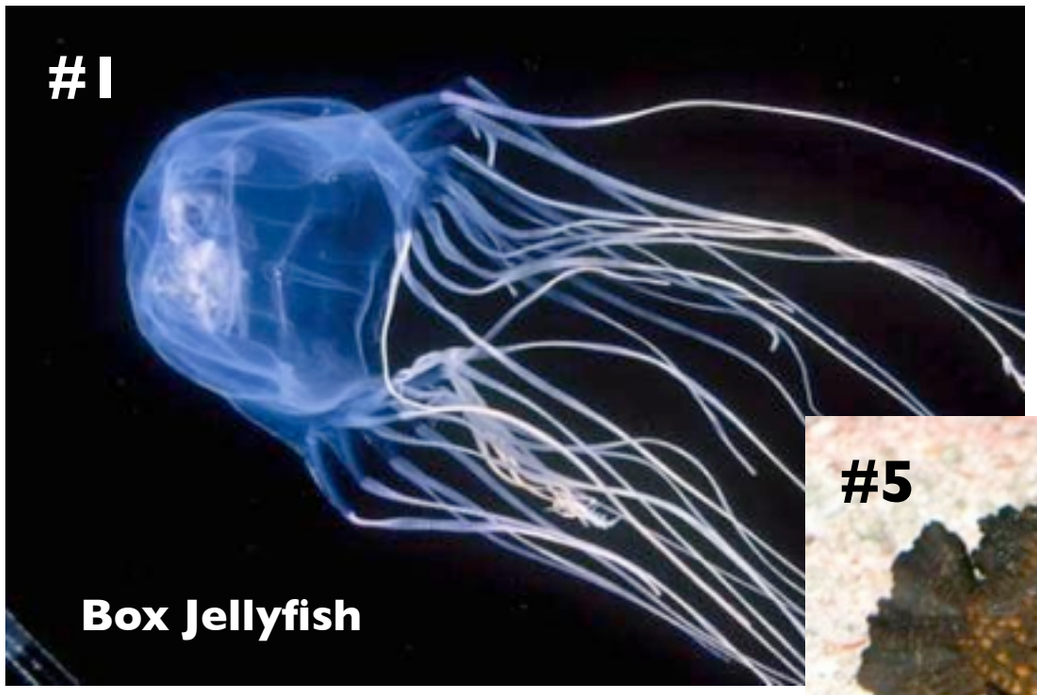
Speed & Agility







Venoms (Top 5?)


#1
Box Jellyfish


#3
Taipan


#5
Stonefish


#2
Brazilian Wandering Spider


#4
Blue Ringed Octopi

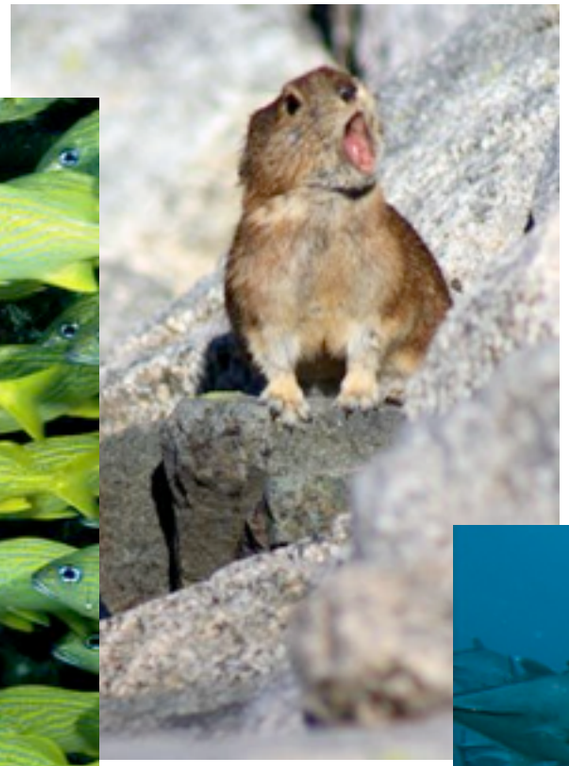
Should have made the list?

Most Poisonous Plants

Spines

Thorns

Alarm Calls, Herds & Schools



- **Batesian Mimicry:** a harmless/palatable species copying a harmful/unpalatable species

- **Mullerian Mimicry:** two or more harmful/unpalatable species resembling each other

C. Herbivory (+/-)

- Natural selection has fine tuned herbivores (and the plants) with remarkable adaptations.
  - **Herbivores**:
    - insects can detect toxic chemicals with their feet
    - mammals
      - use smell to assess plants,
      - mammals also have specialized teeth (molars) for grinding plant matter,
      - mammals have specialized digestive tracts to breakdown cellulose
  - **Plants**:
    - Spines and Thorns
    - Toxins: strychnine, nicotine, selenium, peppermint, cloves,

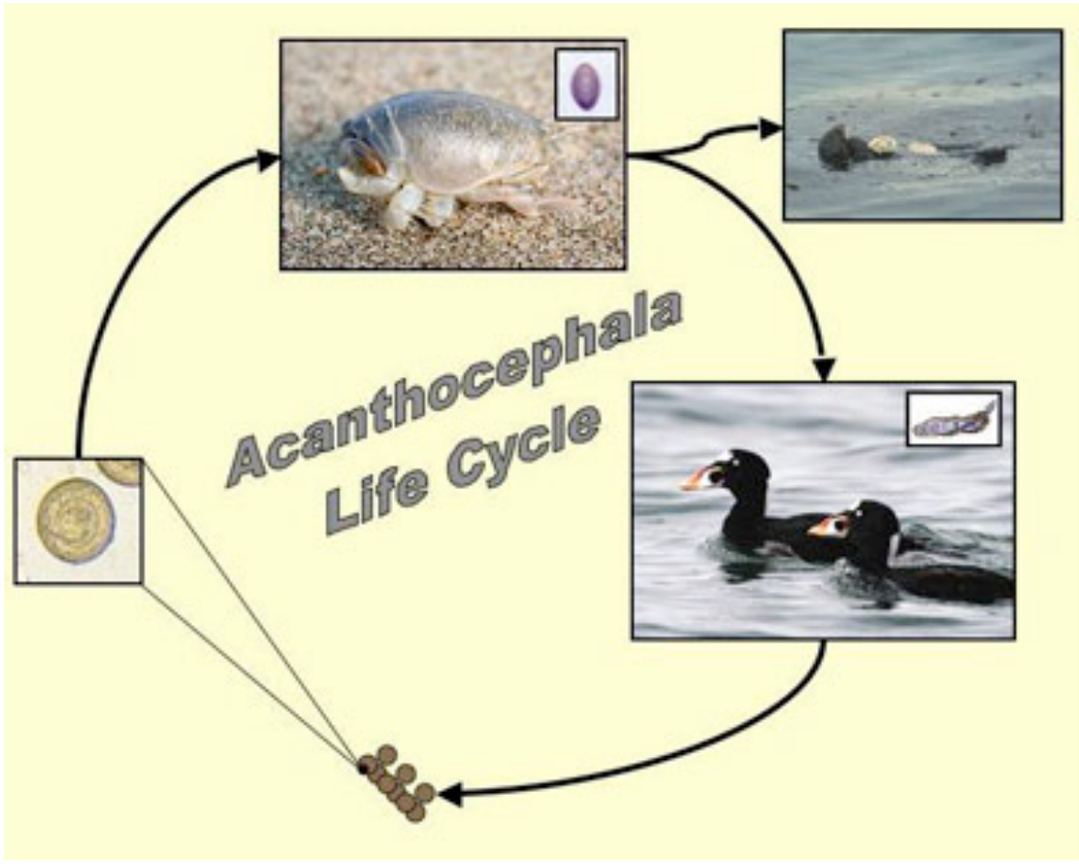
Can you match the toxins on the last slide with their respective plants?

D. Symbiosis

Note: Some define symbiosis narrowly as mutualism however the authors of your text use a broader definition to include *all* direct interactions between species, those that we covered already and those to come.

1. Parasitism (+/-)

- *Parasites* are organisms that derive nourishment from a host, the *host* is the organism that is harmed in the process.
- Endoparasites feed/live within their host (tapeworms)
- Ectoparasites feed/live on their host (ticks)



Most parasites have complex life cycles. This parasite requires two hosts and the parasite actually alters the behavior of the first (crustacean) to make it more susceptible to predation by its second host (birds).

2. Mutualism (+/+)

- These interactions benefit both species involved.
- Many important mutualistic relationships exist in nature. *(As a result many of these are relevant on the AP exam...know them well!)*
  - *#1. Nitrogen Fixation (bacteria and plants-legumes)*
  - *#2. Cellulose Digestion in Ruminants (herbivores and bacteria)*
  - *#3. Mycorrhizae (fungi and plants)*
  - *#4. Coral Reefs (algae and animals-corals)*
- Coevolution is often times the mechanism that generating these relationships.
- *Obligate mutualism*: at least one species has lost the ability to live with out its partner
- *Facultative mutualism*: both species can survive with out its partner

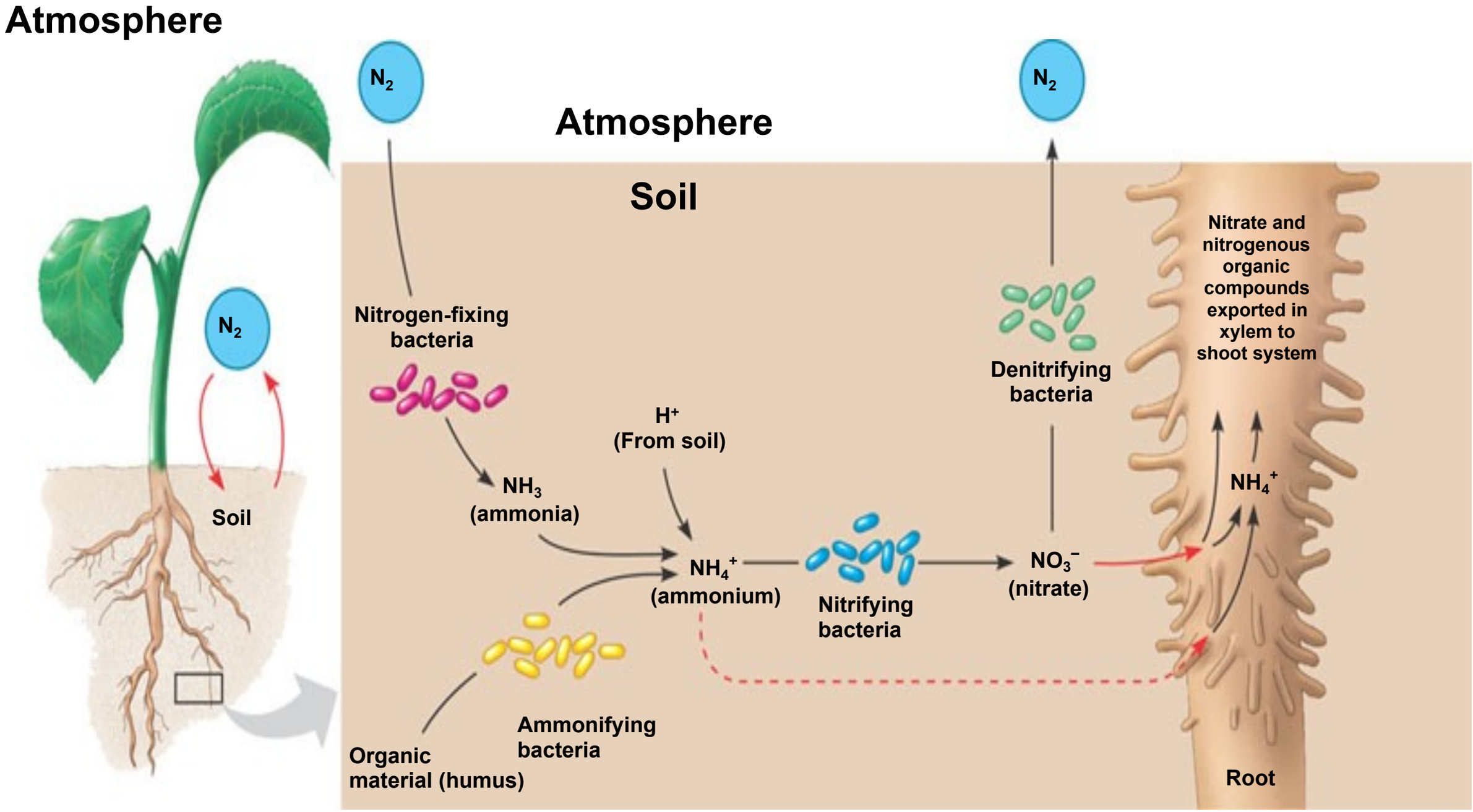
#1. Nitrogen Fixation (bacteria and plants-legumes)

An Introduction

- Atmospheric nitrogen is abundant however it is biologically unavailable. Most organisms are unable to break the triple covalent bonds between nitrogen atoms.
- It is imperative that these bonds are broken because **"life" needs nitrogen atoms** to build amino acids and nucleotides.
- Nitrogen fixation is the conversion of atmospheric nitrogen (N_2) gas to ammonia (NH_3)...$\mathbf{N_2 + 8\ H^+ + 8\ e^- \rightarrow 2\ NH_3 + H_2}$
- This reaction requires ***nitrogenase*** the enzyme cable of fixing nitrogen gas.
- This reaction is **energetically costly**.
- The microorganisms capable of nitrogen fixation are called ***diazotrophs***
  - Cyanobacteria (blue-green algae), Azotobacteraceae, *Rhizobia, *Frankia
    - The latter two form mutualistic relationships with other species

#1. Nitrogen Fixation (bacteria and plants-legumes)

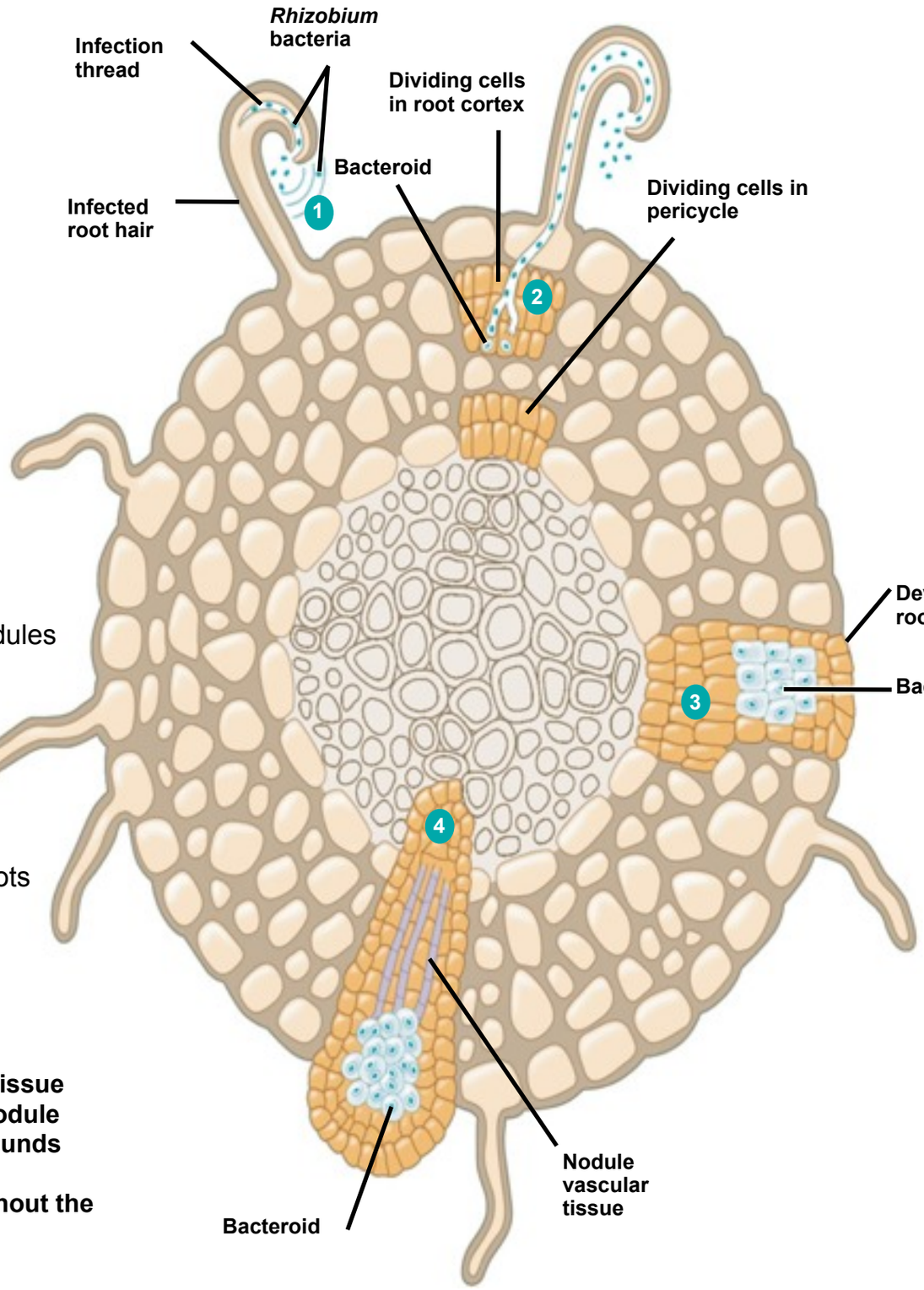
Overview



#1. Nitrogen Fixation (bacteria and plants-legumes)

Mutualism: Rhizobium & Legumes

1 Roots emit chemical signals that attract *Rhizobium* bacteria. The bacteria then emit signals that stimulate root hairs to elongate and to form an infection thread by an invagination of the plasma membrane.



2 The bacteria penetrate the cortex within the Infection thread. Cells of the cortex and pericycle begin dividing, and vesicles containing the bacteria bud into cortical cells from the branching infection thread. This process results in the formation of bacteroids.

3 Growth continues in the affected regions of the cortex and pericycle, and these two masses of dividing cells fuse, forming the nodule.

4 The nodule develops vascular tissue that supplies nutrients to the nodule and carries nitrogenous compounds into the vascular cylinder for distribution throughout the plant.

#2. Cellulose Digestion in Ruminants (herbivores and bacteria)

Overview

- **Herbivores** have an established mutualistic relationship with **anaerobic bacteria** (some yeast and fungi as well) that lives in its digestive tract. These anaerobic bacteria possess the enzyme *celulase* necessary to chemically digest cellulose

- **Termites** have an established mutualistic relationship with a **protist** (some yeast and fungi as well) that lives in its digestive tract. These protists possess the enzyme *cellulase* necessary to chemically digest cellulose.

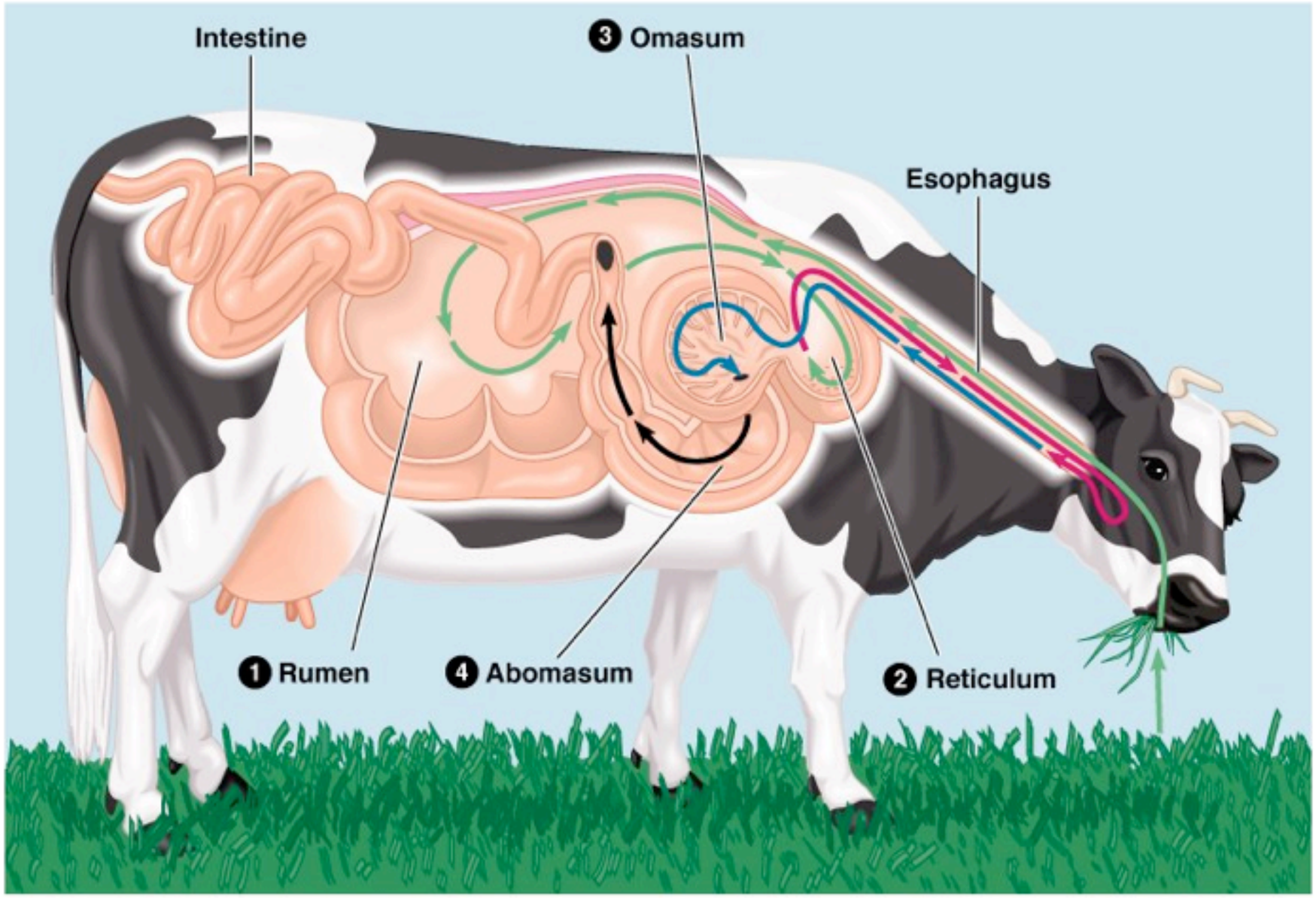
- Many animals, like humans can not digest cellulose which will as a result simply pass through our digestive tracts. This is what we call fiber and diets high in fiber may reduce the risk of colon cancers.

- In Abrahamic religions, a distinction between clean and unclean animals approximately falls according to whether the animal ruminates. The Law of Moses in the Bible allowed only the eating of animals that had cloven hooves and "that chew the cud", a stipulation preserved to this day in the Jewish laws of Kashrut. (source wikipedia)

- **The verb *to ruminate* has been extended metaphorically to mean *to ponder thoughtfully* or *to meditate* on some topic. Similarly, ideas may be *chewed on* or *digested*. *Chew the (one's) cud* is to reflect or meditate. (wikipedia)**

- **Methane has 23 times the warming potential of carbon dioxide and its production by ruminants may contribute to a greenhouse effect or climate change. Methane production by animals, principally ruminants, is estimated 15-20% global production of methane. The rumen is the major site of methane production in ruminants. (wikipedia)**

What do the microorganisms get from this relationship?



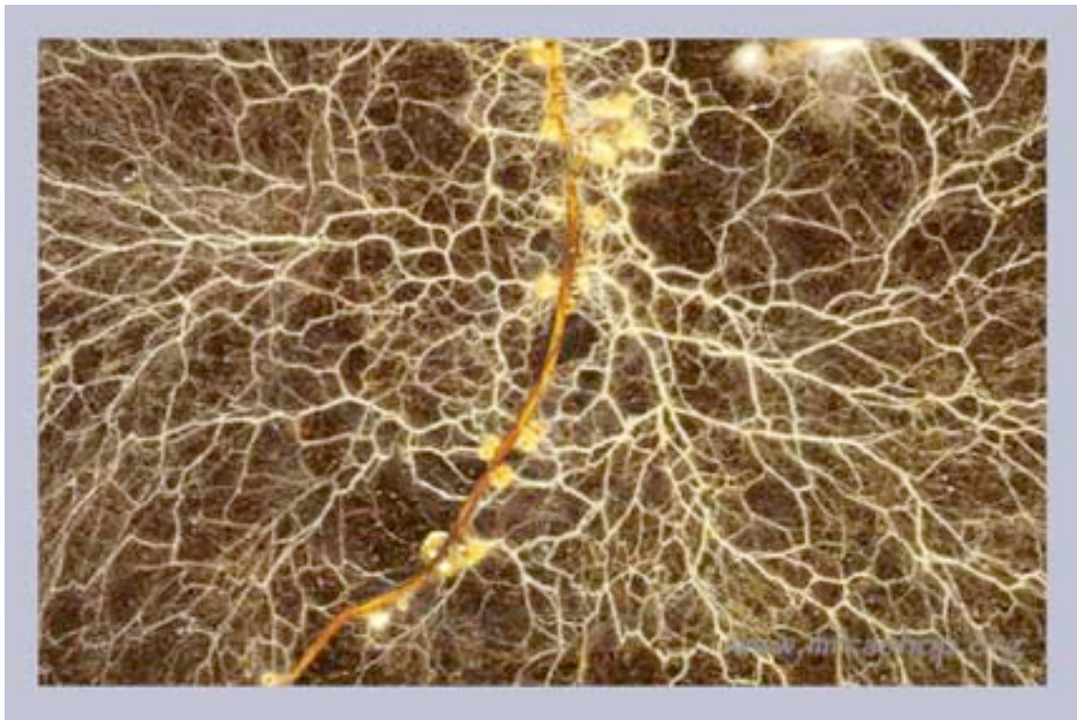
#3. *Mycorrhizae (fungi and plants)*

Overview

- This relationship is both *ancient* and *extensive*. Fossil evidence suggests that this relationship is over 400 million old and may have contributed to plants colonizing land. Furthermore this relationship is found in roughly 80% of all plant species.

- Plants (through photosynthesis) provide fungi a constant supply of sugar (food) while the fungi provides plants with increased water and mineral absorption (through their vast surface area and unique cell chemistry).

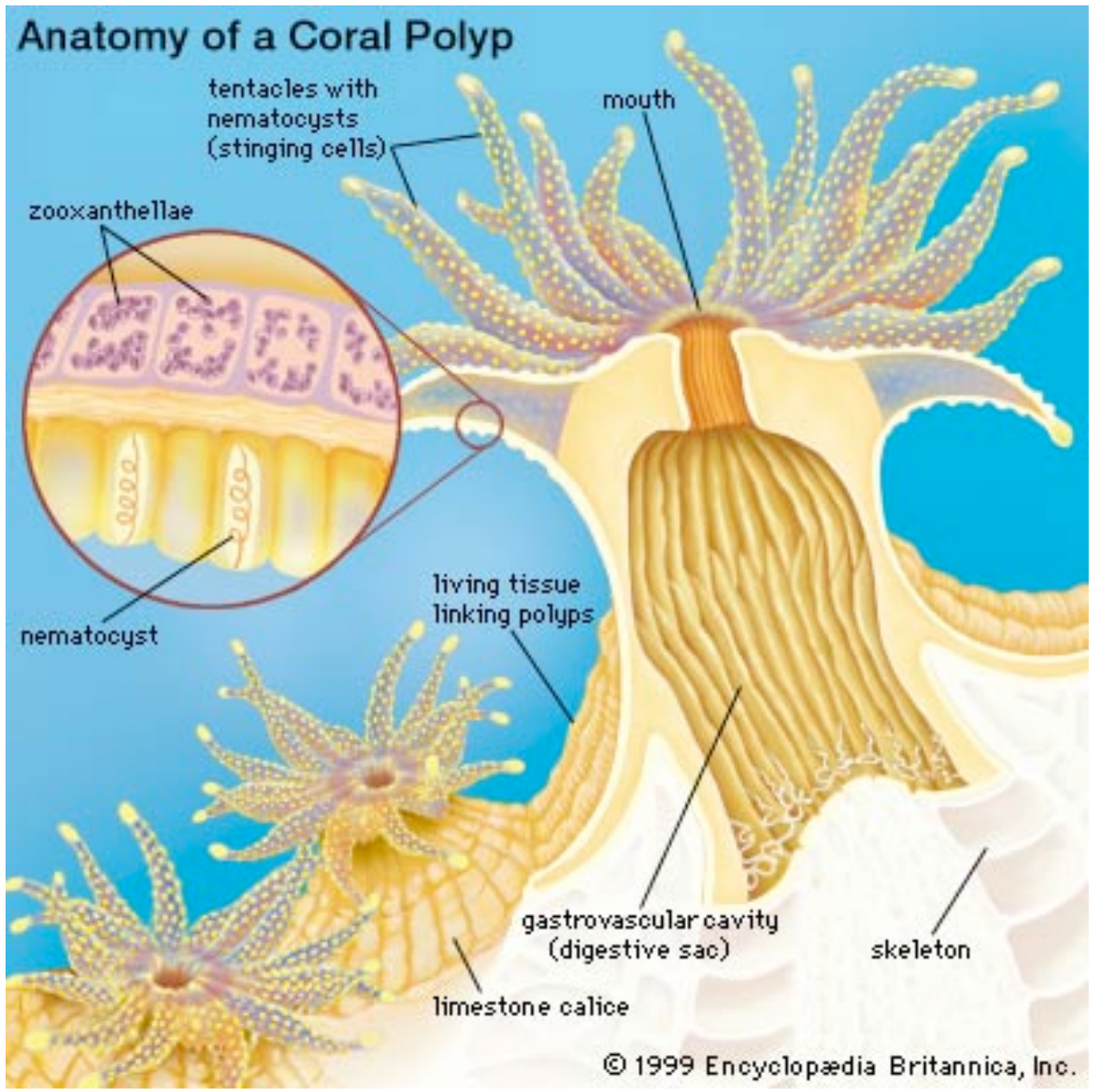
- Mycorrhizal plants are more resistant to disease, toxins and drought.

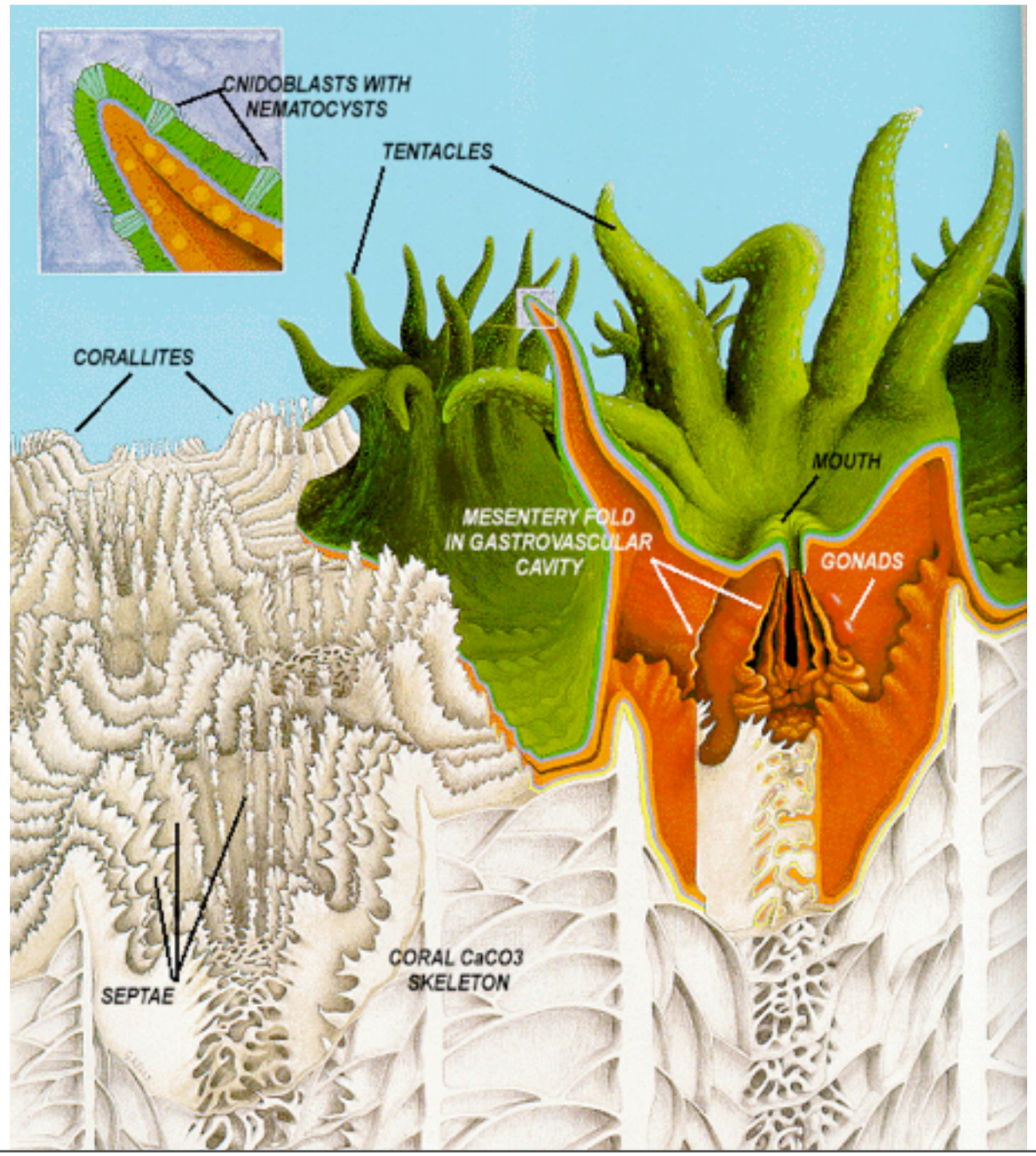


#4. Coral Reefs (algae and animals-corals)

Overview

- **Coral** (a coelenterate = a hollow bodied animal) provides shelter and inorganic nutrients to the **Algae (zooxanthellae)** provides sugars through photosynthesis.





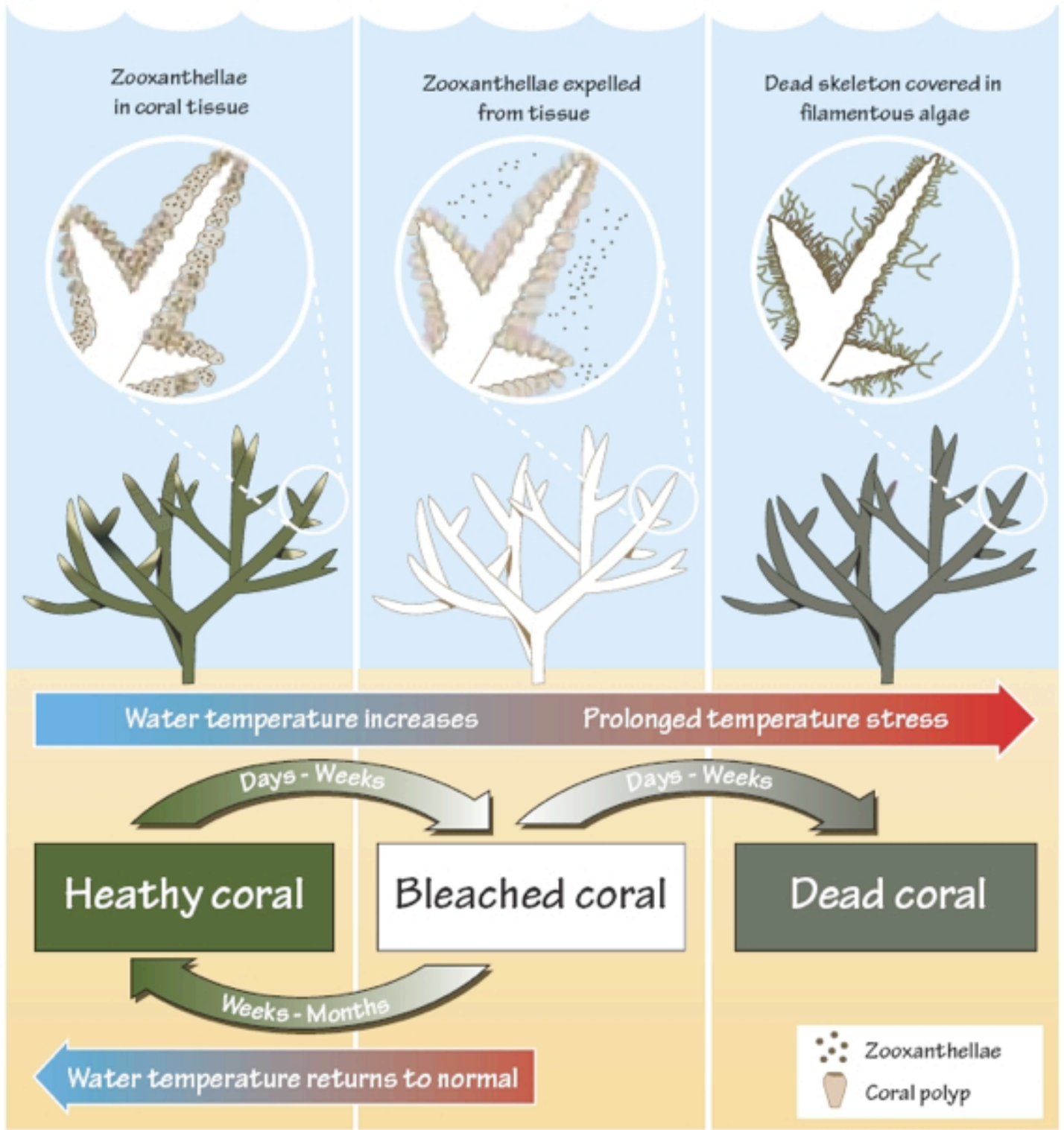
- **Coral bleaching** occurs when the coral expels the algae as a result of environmental stress.

- The algae's photosynthetic pigments (or protozoan) give coral reefs their color when they are expelled all that remains is the light colored inorganic compounds.

Healthy coral

Bleached coral

Dead coral



3. Commensalism (0/+)

- These interactions benefit one species and the other is effected no way positive or negative. Some argue that this can not exist, that all interactions have some effect no matter how small.

  - ex. barnacles on whales, algae on turtle shells

What do you think? Can argue both ways?

On your own checkout the story of the Honey Badgers & Honey Guides. As well as the relationship between the Acacia and Ants

E. Facilitation (+/+) or (0/+)

- Occurs where the survival and reproduction of one species is dependent on another even though they are not in direct contact of a symbiosis.

- *common in plant ecology, where one species alters the soil composition thereby effecting what other species can or can not live in those conditions.*

(54) Community Ecology

II.

Main Idea: Diversity is important for healthy communities.

Main Idea: Each community has unique feeding relationships.

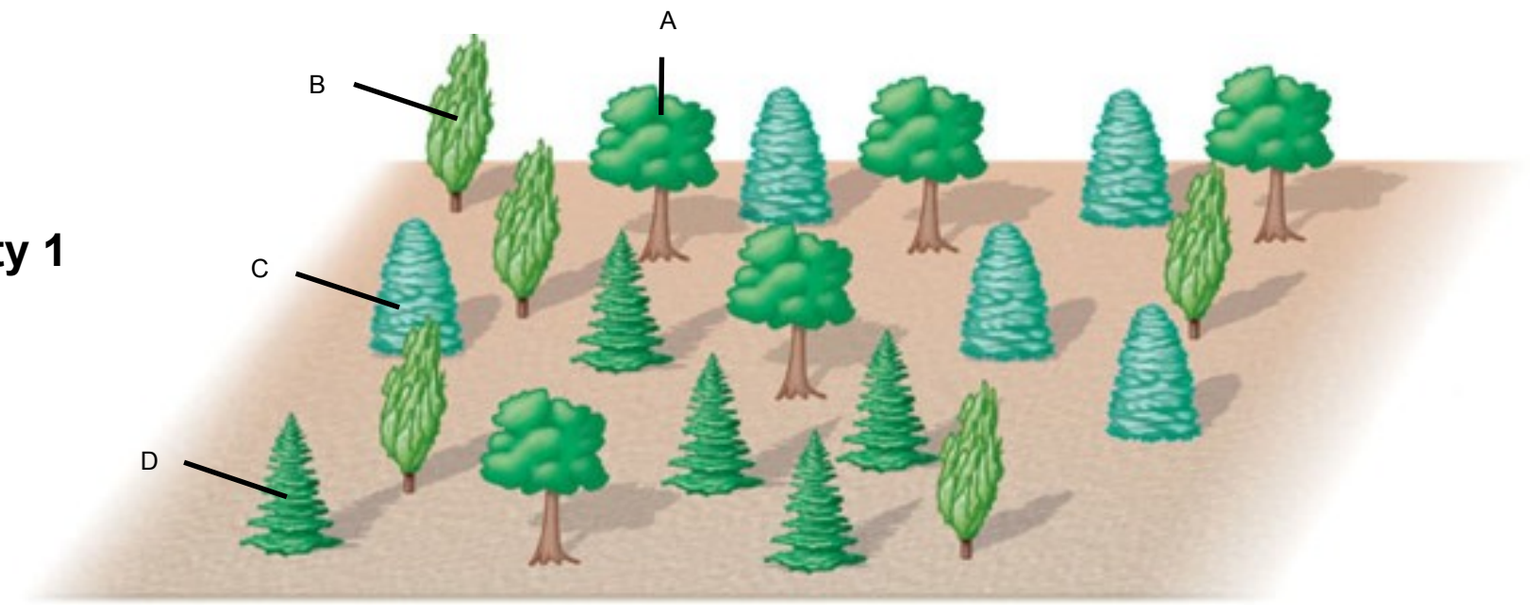
DIVERSITY & TROPHIC STRUCTURE

A. Species Diversity

- Diversity has two components
  - 1. **Richness** = number of different species
  - 2. **Relative Abundance** = the proportion that each species represents of all individuals in the community
- *Shannon Diversity (H)* is a widely used index used to calculate both richness and abundance
  - $H = -(p\text{A} \ln p\text{A} + p\text{B} \ln p\text{B} + p\text{C} \ln p\text{C} + ...)$
  - where: A,B,C are species, *p* is abundance, ln is natural logarithm
  - The higher the "H" the more diverse the community
  - Often times finding number and abundance can be difficult.

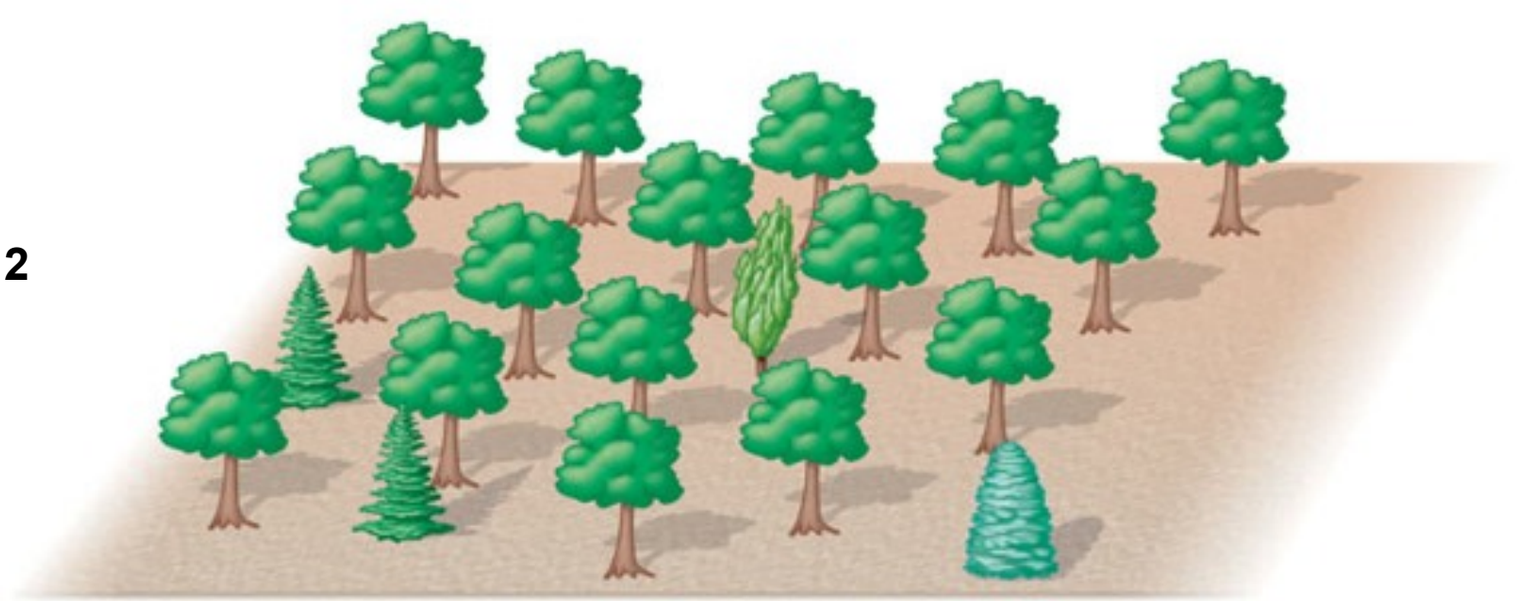
Which community below is more diverse? Use your gut.

Community 1



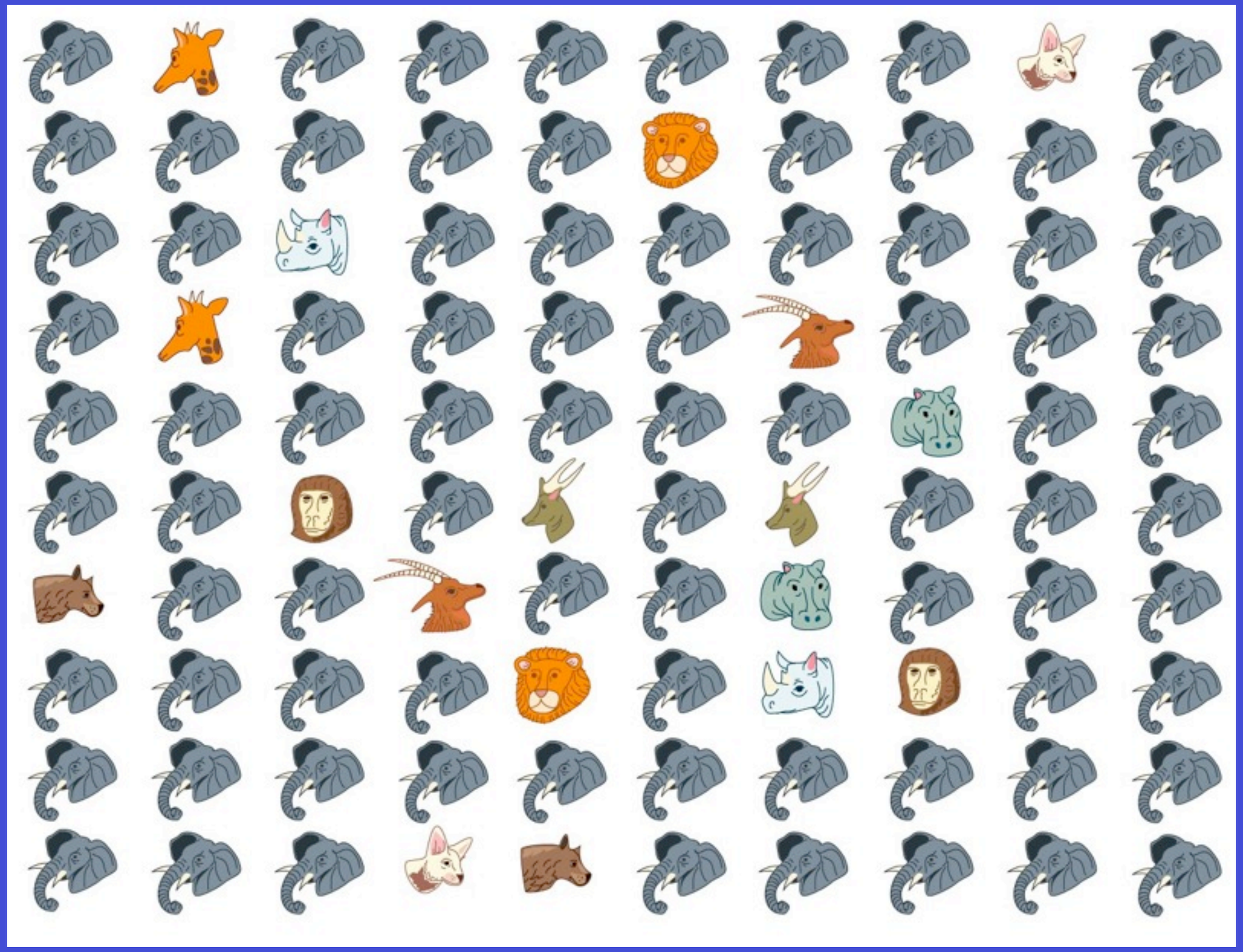
A: 25% B: 25% C: 25% D: 25%

Community 2



A: 80% B: 5% C: 5% D: 10%

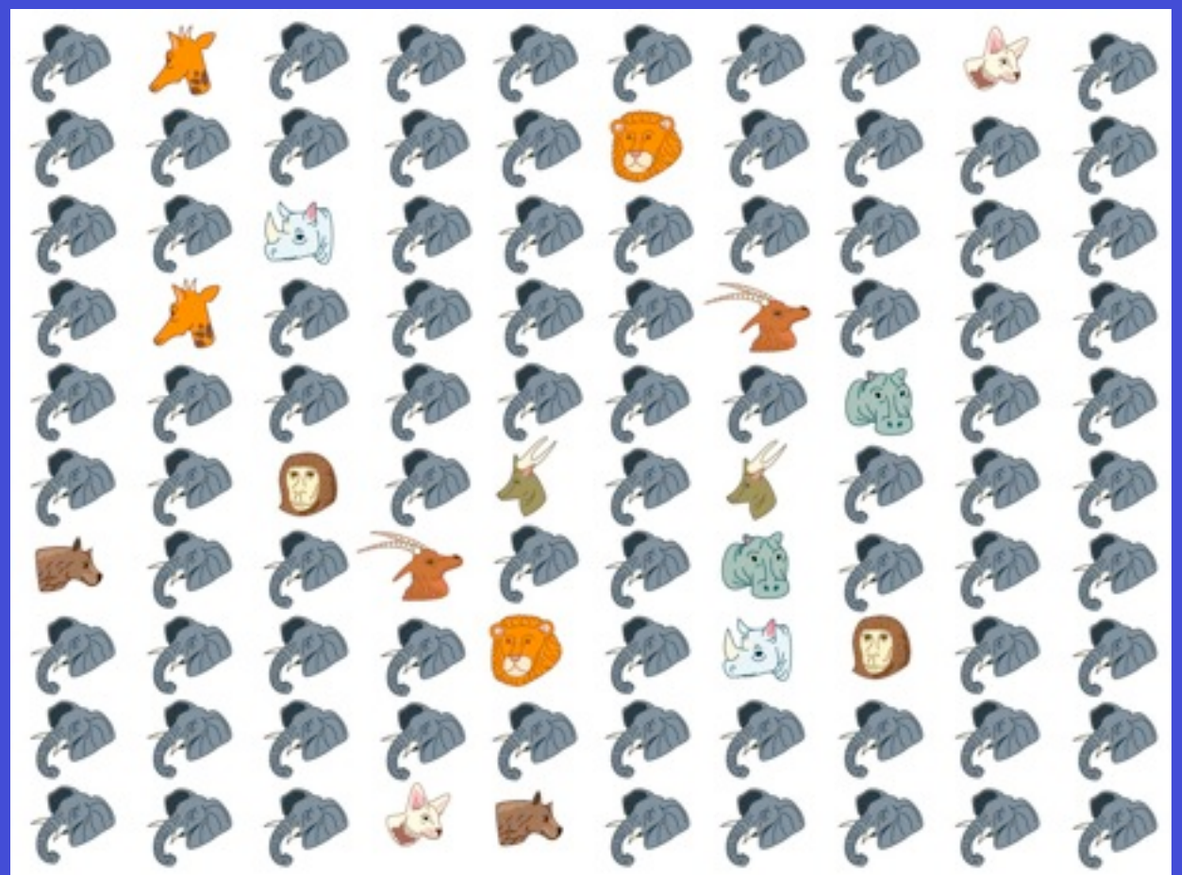
Now check your gut... Calculate the Shannon diversity.



10 species; 100 ind, 87 elephants, 9 sp w/ 2 ind each

10 species; 100 ind, 10 ind each species

Species Diversity



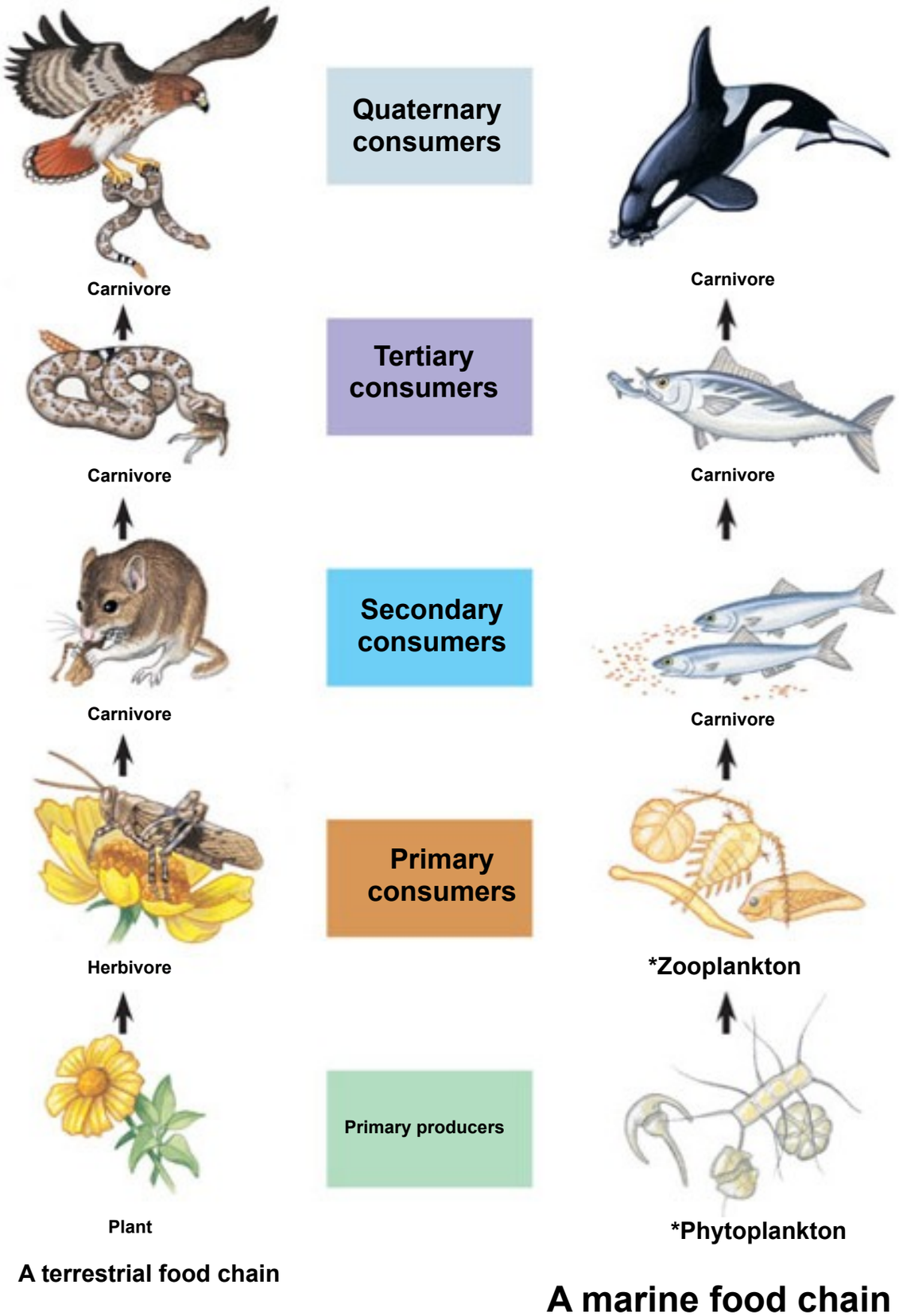
Merely counting the number of species is not enough to describe biological diversity.

B. Diversity & Stability

- Diversity has its benefits
  - 1. **Productive**, higher diversity communities are more productive
  - 2. **Resilient**, higher diversity communities are more stable during times of environmental stress
  - 3. **Stable**, higher diversity communities are more stable (consistent) year to year in their productivity
  - 4. **Resistant**, higher diversity communities are more resistant against *invasive species*.

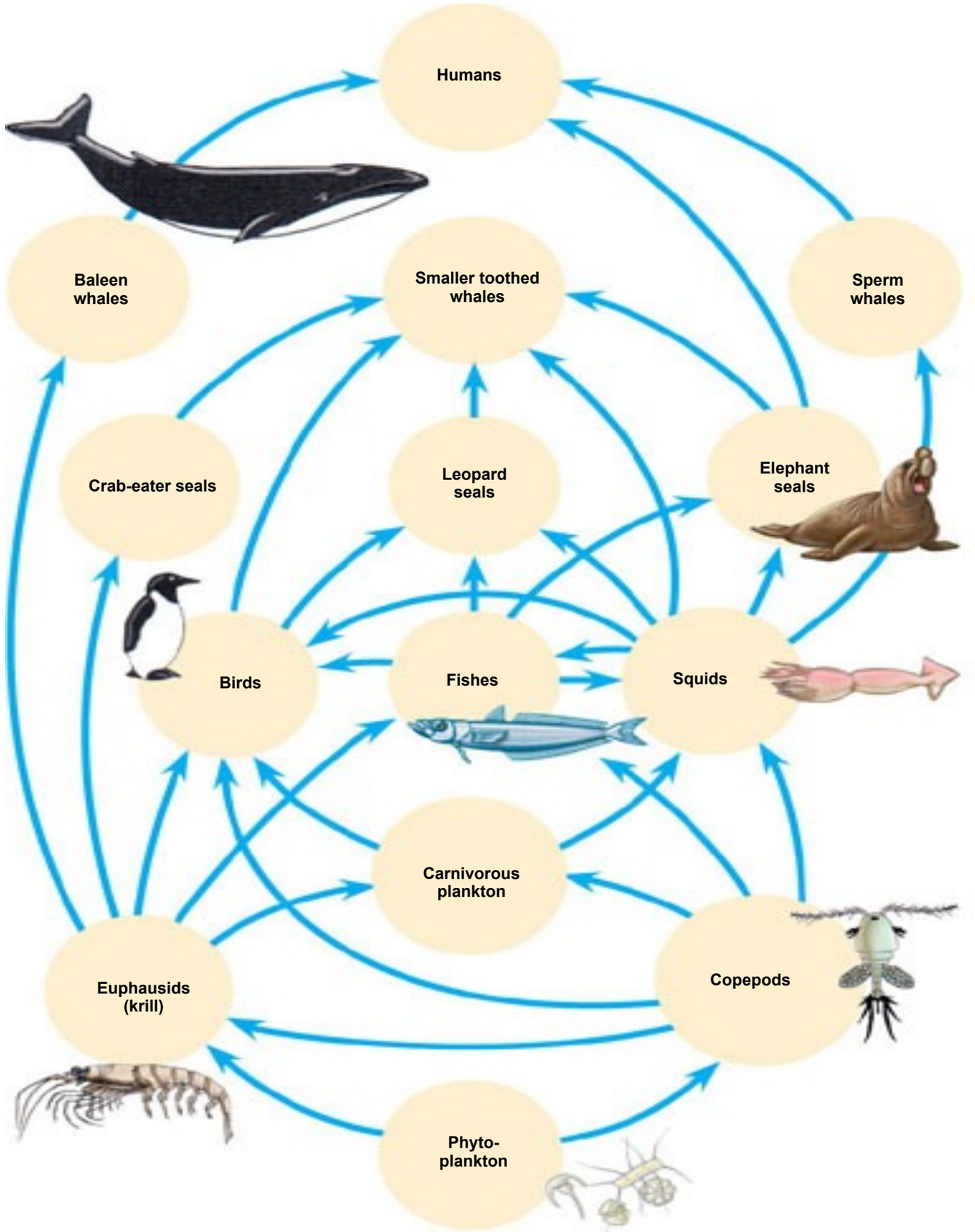
C. Trophic Structure

- **Trophic Structure**...feeding relationships within the community.
- The movement of food energy from autotrophs through and up to the largest consumers...**food chains**.



1. Food Webs

- Interconnected and linked food chains make up **food webs**.
- The arrow points in the direction of foods movement. In other words A ⟶ B indicates that B is eating A. Many students reverse this so be careful



Could you interpret these feeding relationships IF...

1. the pics were removed?
2. the pics and names were removed?
3. What if I removed all pics, names and turned in upside down?

1. Food Chain Lengths

- Food chains are limited in their lengths.
- The two common hypotheses..
  - The *Energetic Hypothesis* states that the energy transfer one one trophic level to another is inefficient (about 10-20%) and after 3 - 5 transfers there is not enough energy to support another level.
  - The *Stability Hypothesis* states long chains are unstable, that fluctuations in lower trophic levels are magnified in the higher levels.
    - The most current data supports the *energetic hypothesis*.

D. Dominant & Keystone Species

- Certain species have a proportionally larger impact in the community due to their abundance or a key role that they play in community interactions
  - 1. **Dominant Species**; are the most abundant or have the highest biomass.
    - These species often effect the occurrence and distribution of other species.
  - These species are likely dominant for one of two reasons
    - either they are *superior competitors*, that is they capture limited resources better than others
    - they avoid predation and disease better than others

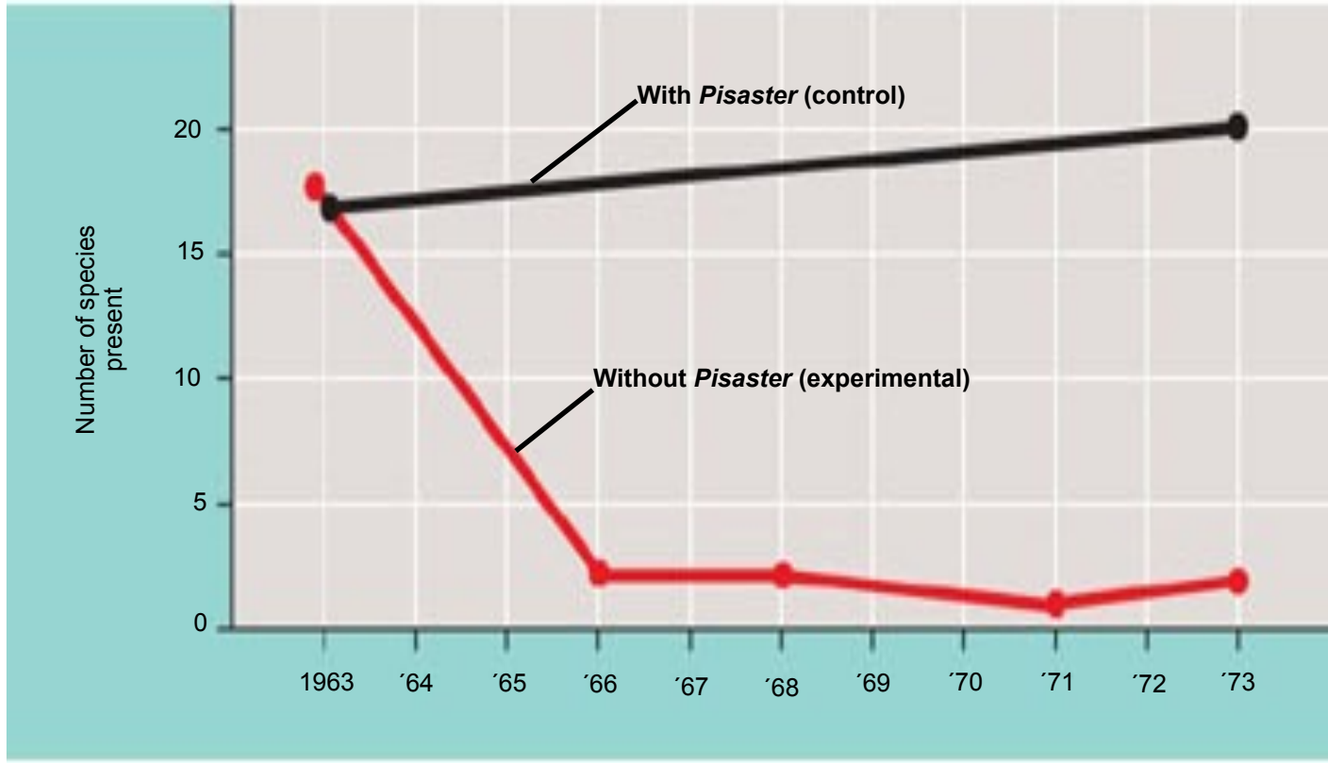
OR...

How could you test the effects of dominant species?

D. Dominant & Keystone Species

- 2. **Keystone Species**; are the most abundant but they exert strong control on community dynamics due their unique role or niche.

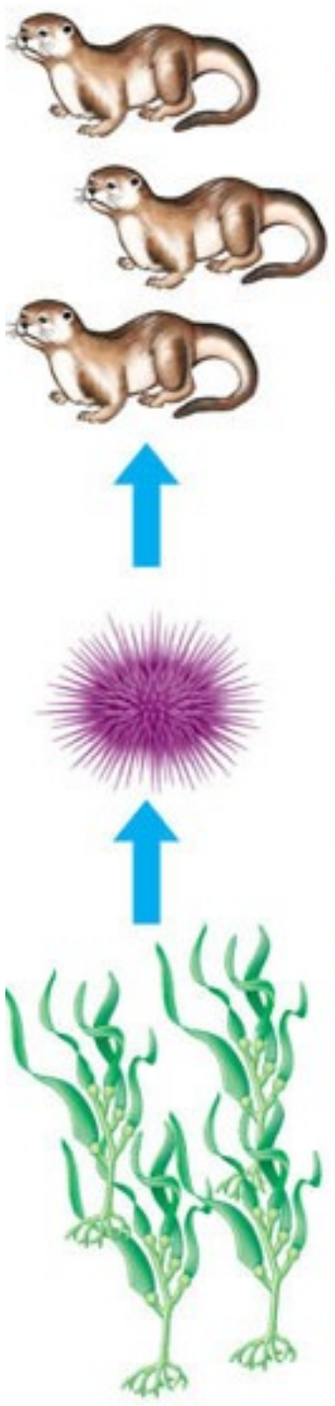
(a) The sea star *Pisaster ochraceous* feeds preferentially on mussels but will consume other invertebrates.

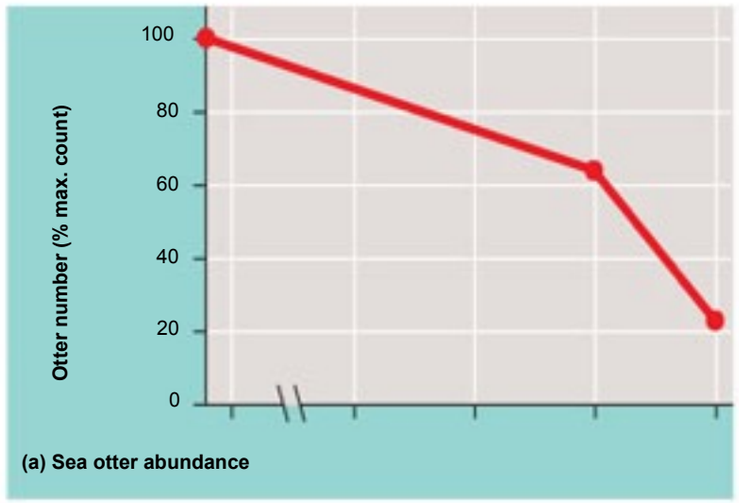


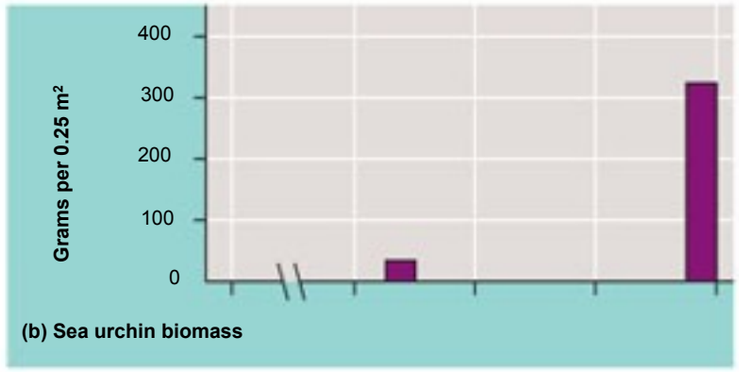
(b) When *Pisaster* was removed from an intertidal zone, mussels eventually took over the rock face and eliminated most other invertebrates and algae. In a control area from which *Pisaster* was not removed, there was little change in species diversity.

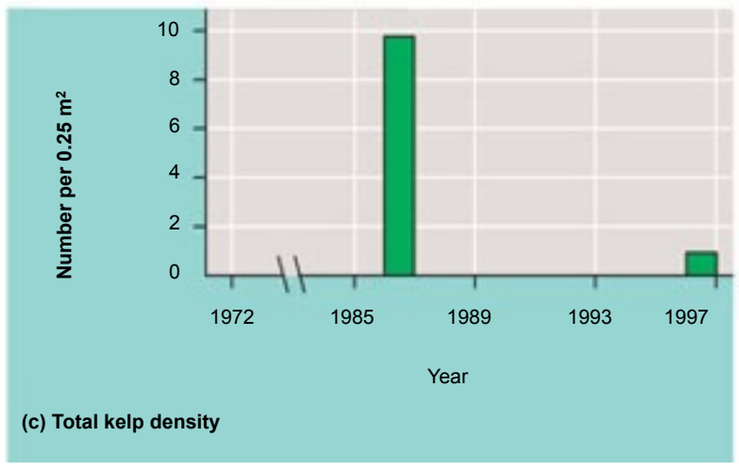
What is a "keystone"?

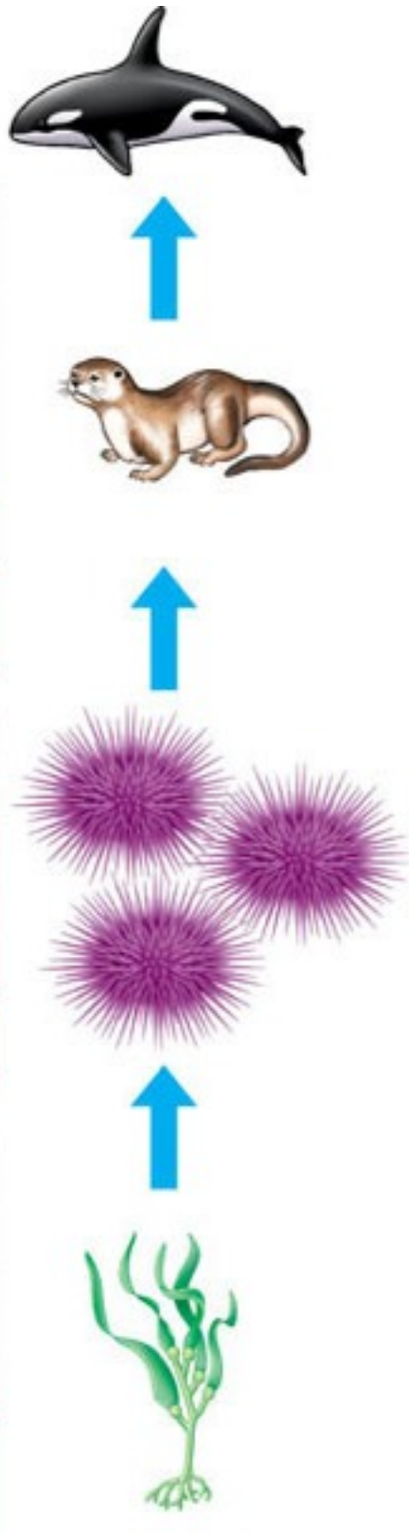
Food chain before killer whale involvement in chain











Food chain after killer whales started preying on otters

Note:

- **Engineer Species**; exert strong control on community by changing the physical environment.

E. Community Organization & Control

- 3 Possible Scenarios:
  - 1. **Bottom-Up Model (V → H)**; available nutrients control vegetation which then controls herbivores abundance which in turn controls predators abundance
  - 2. **Top-Down Model (V ← H)**; predators control herbivores abundance which in turn controls vegetations abundance which in turn controls nutrient uptake
  - 3. **Bi-Directional Model (V ↔ H)**; each trophic level is sensitive to the one above and below itself

How would nutrient levels be effected if you removed the top predator in 4 level trophic community? What if had only 3 trophic levels?

(54) Community Ecology

III.

Main Idea: Disturbances play an important role in communities.

Main Idea: Disturbances influence the diversity of species and the composition of species found in a community.

DISTURBANCES INFLUENCE SPECIES DIVERSITY AND COMPOSITION

- **Disturbance-** an event that changes a community by removing organisms from it or altering resource availability.
  - Ex. storms, fire, floods, droughts, freezing, overgrazing, human activities
- **Nonequilibrium Model-** describes communities as constantly changing after a disturbance

A. Disturbances

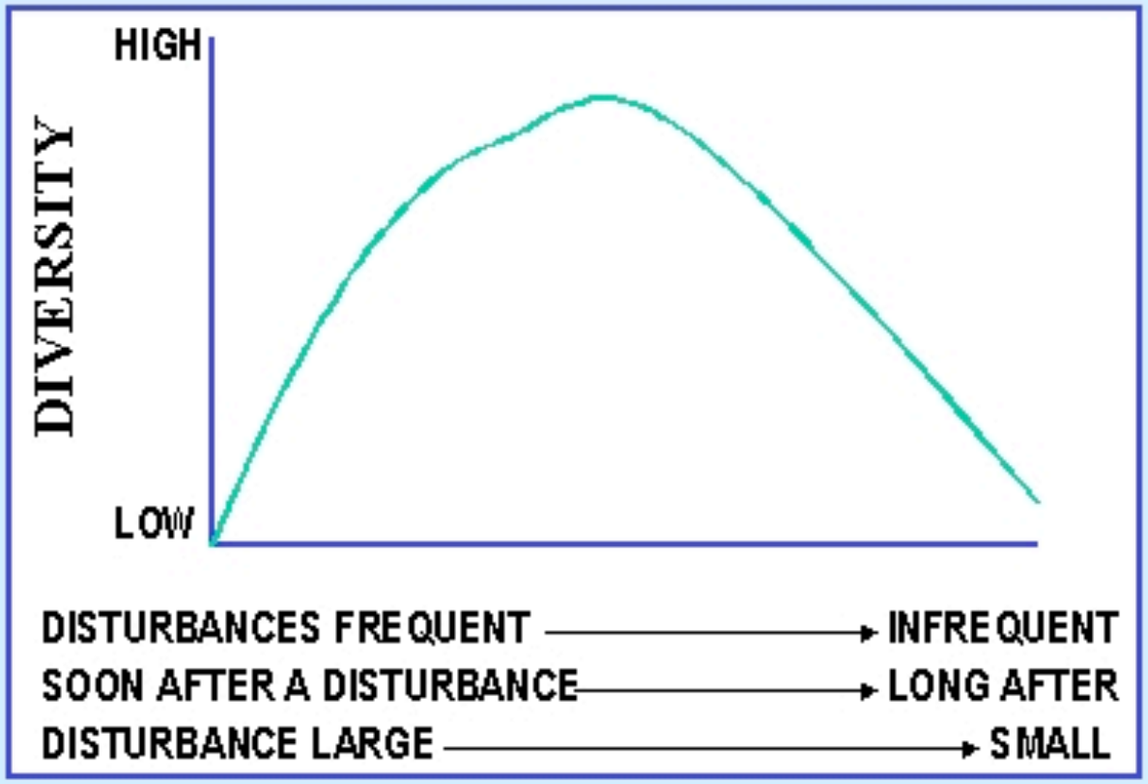
- Vary in frequency and severity in each community.
  - *high level disturbance* results from high intensity & frequency
  - *low level disturbance* result from low intensity or frequency

- **Intermediate Disturbance Hypothesis-** moderate levels of disturbance result in greater biodiversity than either high or low level disturbances.
  - high level disturbances exceed the tolerance of organisms
  - low level disturbances allow more competitive species to dominate
  - moderate level disturbances are rarely exceed the tolerance of organisms but may be great enough to create new niches for less competitive species

Side Note: There are exceptions. Some small scale disturbances can create patchy habitats which can in fact foster biodiversity. Further some communities (Lodgepole Pine in Yellowstone) rely on large scale disturbances for their natural maintenance.

The Intermediate Disturbance Hypothesis (Connell 1978)

- importance of gap formation
- moderate disturbance counteracts competition



FIRE

(a) Before a controlled burn. A prairie that has not burned for several years has a high proportion of detritus (dead grass).

(b) During the burn. The detritus serves as fuel for fires.

(c) After the burn. Approximately one month after the controlled burn, virtually all of the biomass in this prairie is living.

B. Ecological Succession

- *Ecological Succession* occurs when a disturbed area is colonized by a group of species who are later replaced by other species, who are in turn replaced by other species and so on.
  - *Primary succession* begins in a lifeless area where soil has not even formed (exposed bare rock, volcanic islands)
  - This takes a *long time* to complete...on the order of hundreds to thousands of years
    - "First on the scene"... Prokaryotes and Protists
    - Second...Lichens and Moss (important in creating soil)
    - Third...Grasses, Fourth...Shrubs and Last to arrive...Trees

Mt. Hood, Oregon
Soil was washed away during flood exposing bare rock.

Because gravel/sand is loose lichens and moss do not colonize yet. Instead pioneer plants like *lupines* (nitrogen fixers)begin to build soil and retain moisture.

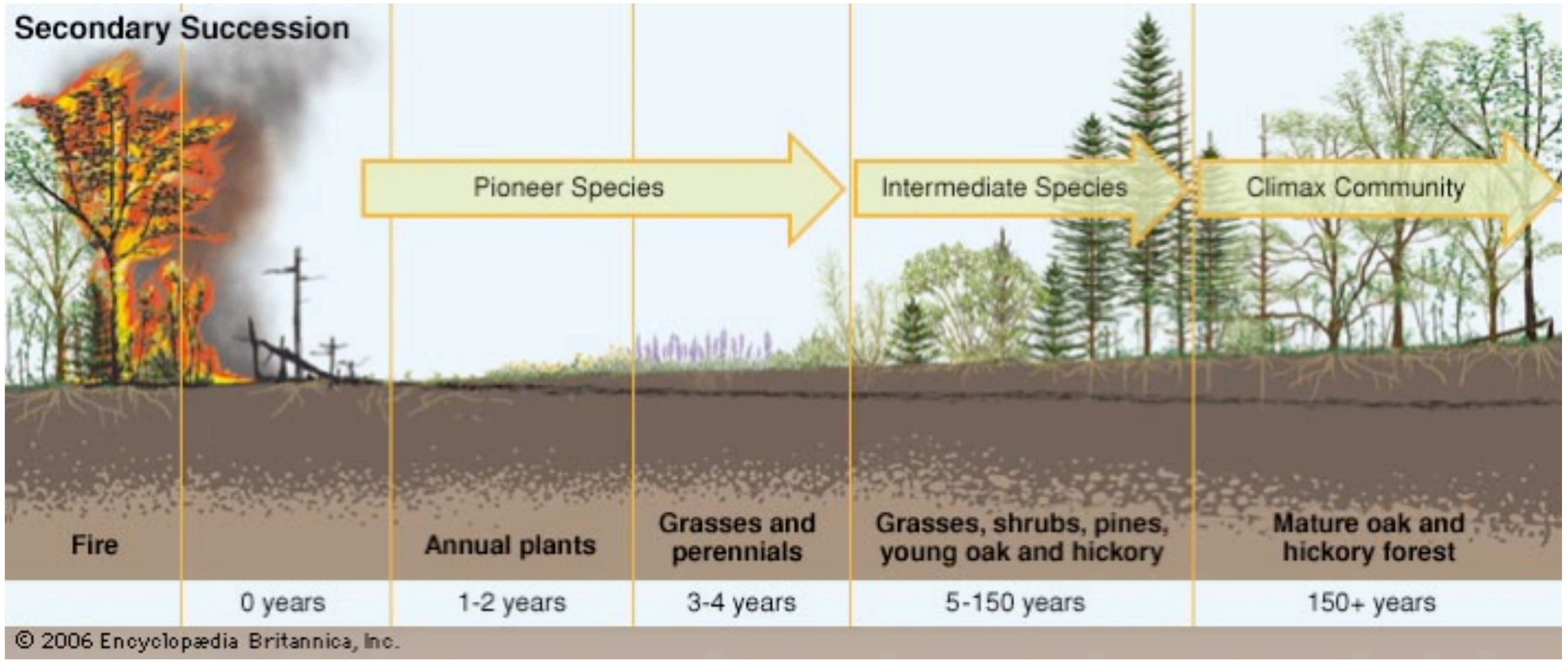
With some soil established and increased shade and moisture the moss and lichens move in and continue create soil.

As soil gets deeper small shrubs begin to appear.

Grasses and larger shrubs begin to appear. On addition saprotrophs (decomposers) continue to decompose dead organic matter and the soil becomes deeper or more nutrient rich.

With enough time the process above continues, soil gets deeper and more nutrient rich until it can one day support a climax community like this one.

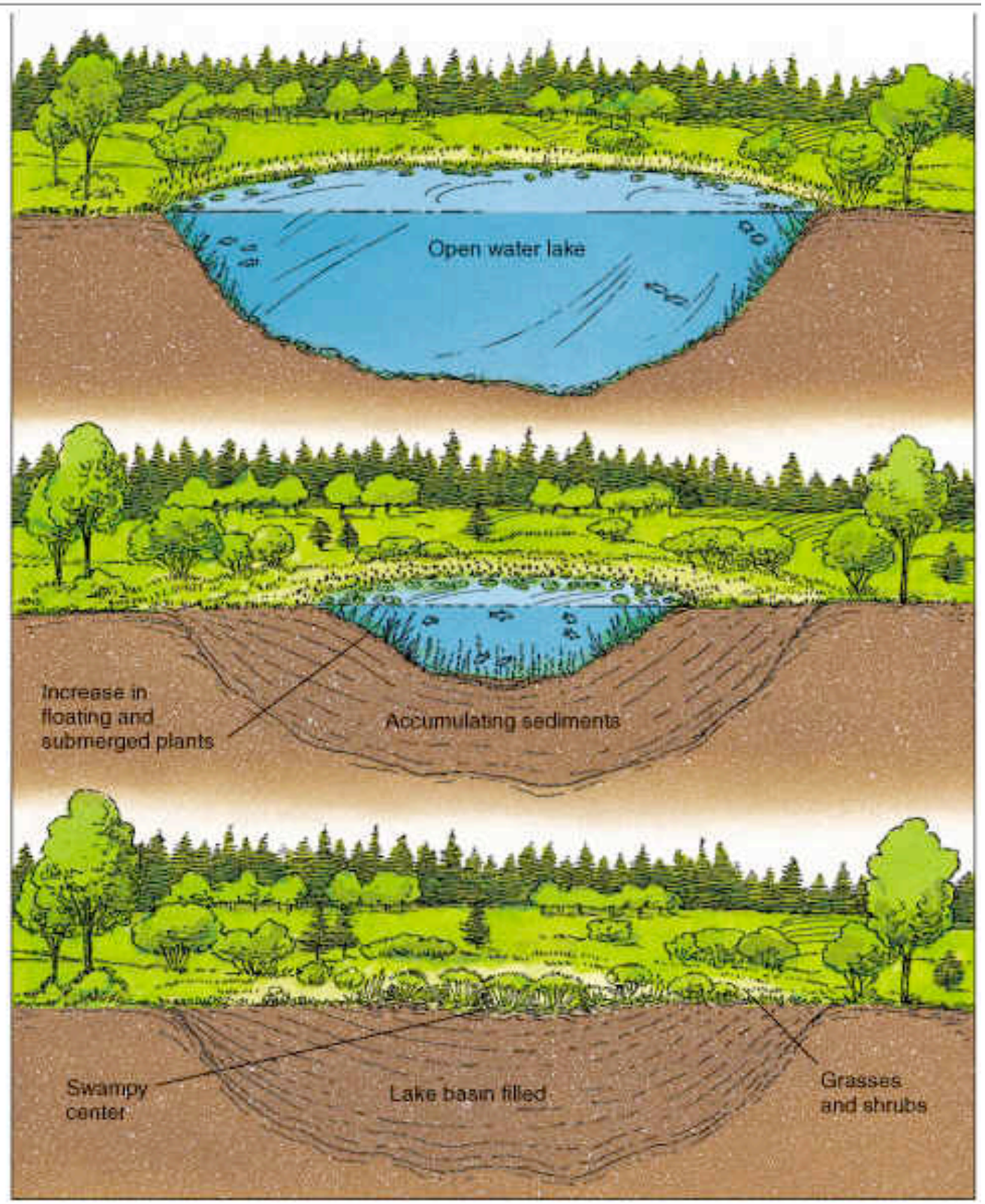
- *Secondary Succession* begins after an existing community (soil is present) has been cleared as a result of some disturbance.
- Time frame here is on the order of months to decades
  - Early and late arrivals can be linked in one of three ways.
    - Early arrivals may *facilitate* later arrivals by making a more favorable environment.
      - *pioneer plant species* alter soil properties in ways that allow other species to colonize the area
    - Early arrivals may *inhibit* later arrivals
    - Early arrivals may be completely *independent* from later



Yellowstone 1988

Yellowstone 2009

Succession also occurs in aquatic communities



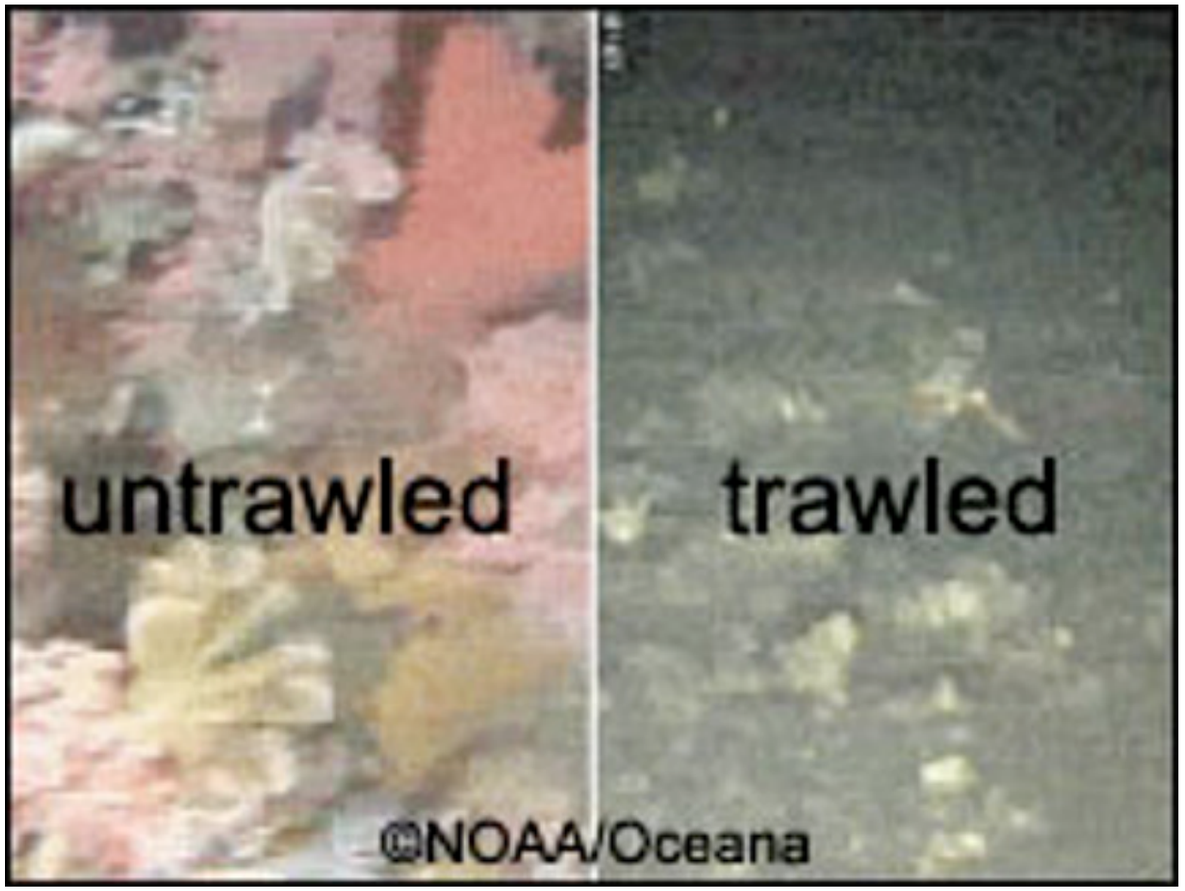
Caption

(a) What begins as a lake gradually fills with organic and inorganic sediments, which successively shrink the area of the pond. A bog forms, then a marshy area, and finally a meadow completes the successional stages. (b) Aquatic succession in a mountain lake. [Photo by Bobbé Christopherson.]

C. Human Disturbances

- The strongest agent of change today is...US.
  - Reasons include: agricultural development, urban development, logging, mining, trawling, and farming.

Case in Point- Ships can trawl over 15 million km^2 of ocean floor (annually). This is roughly the size of South America and 150x more than clear cut forests per year.



(54) Community Ecology

IV.

Main Idea: Latitude and land area effect community diversity.

BIOGEOGRAPHIC FACTORS AFFECT COMMUNITY DIVERSITY

- Here we consider larger scale factors that affect biodiversity.

A. Latitude

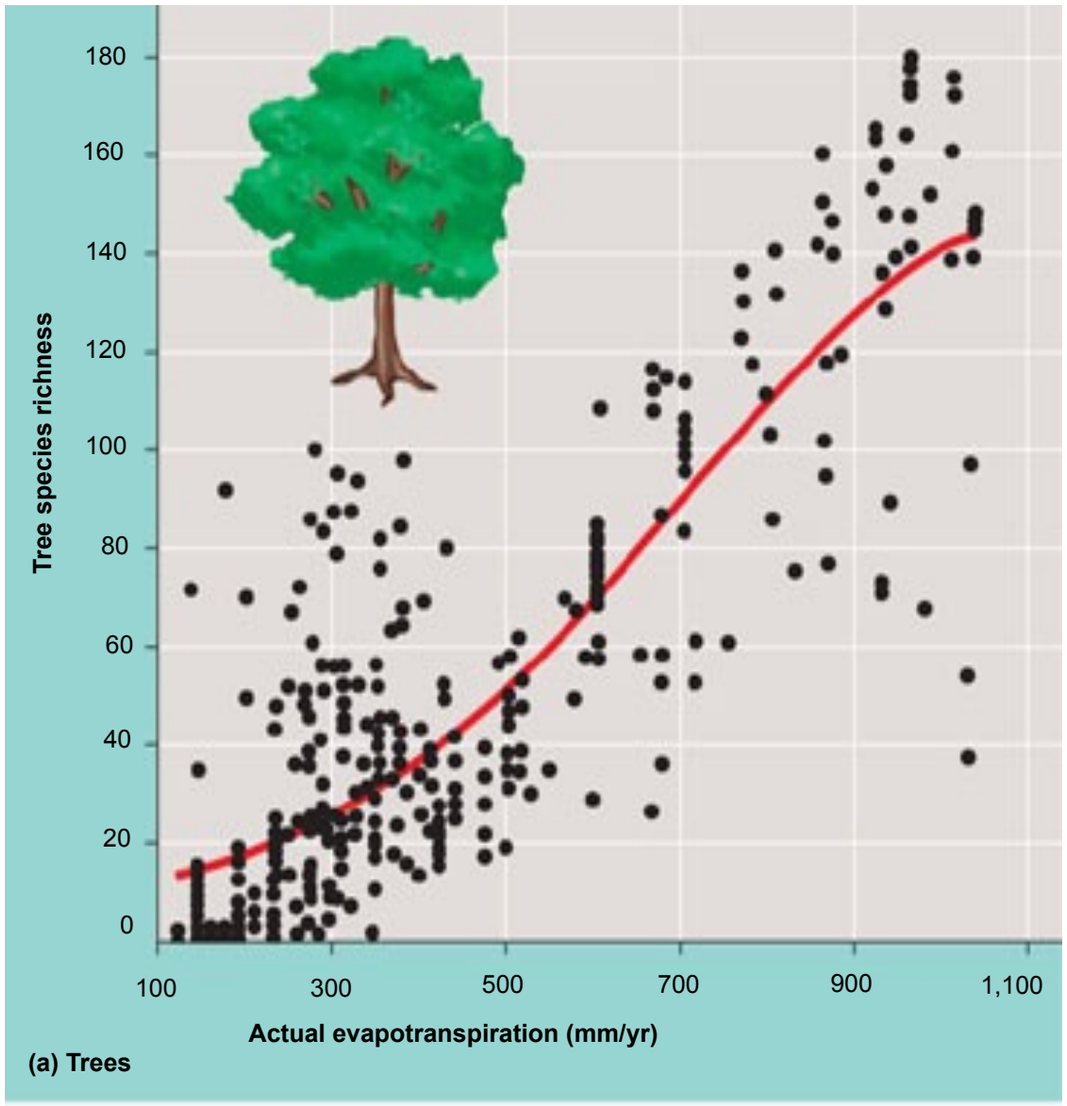
- *Biodiversity is generally greater at the equator and decreases as you move towards the poles.*

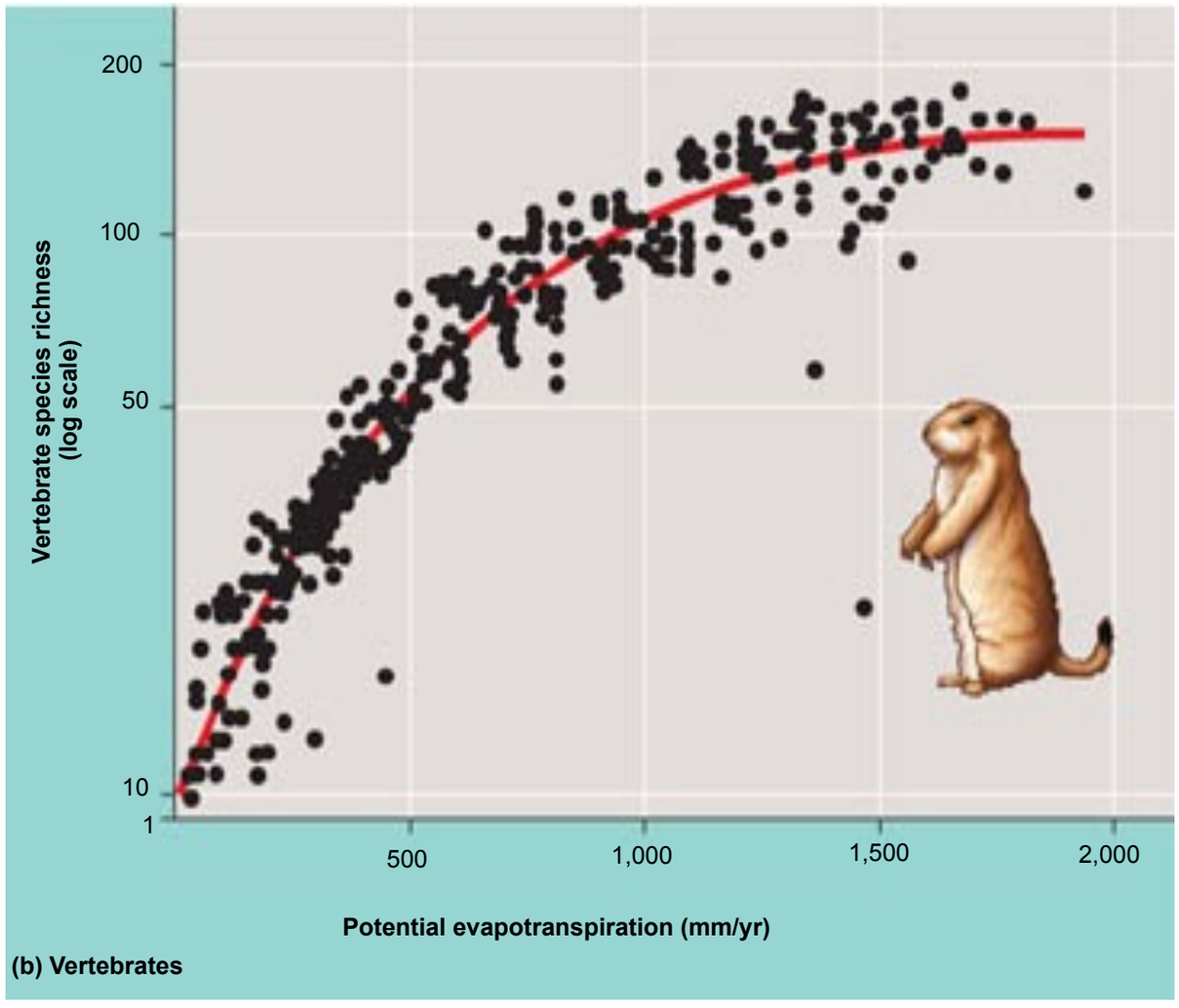
- Two factors contribute to this pattern

  - **Evolutionary History**: Tropical communities are *older* than polar communities this allows more time for speciation to occur AND the *growing season* is 5X as long in tropical communities.

  - **Climate**: Tropical climates receive more *solar energy* and *water* than polar communities

Essentially you can measure evapotranspiration (evaporation form soil & plants) and get a good estimate of biodiversity in an area. This makes sense since evapotranspiration is a function of solar

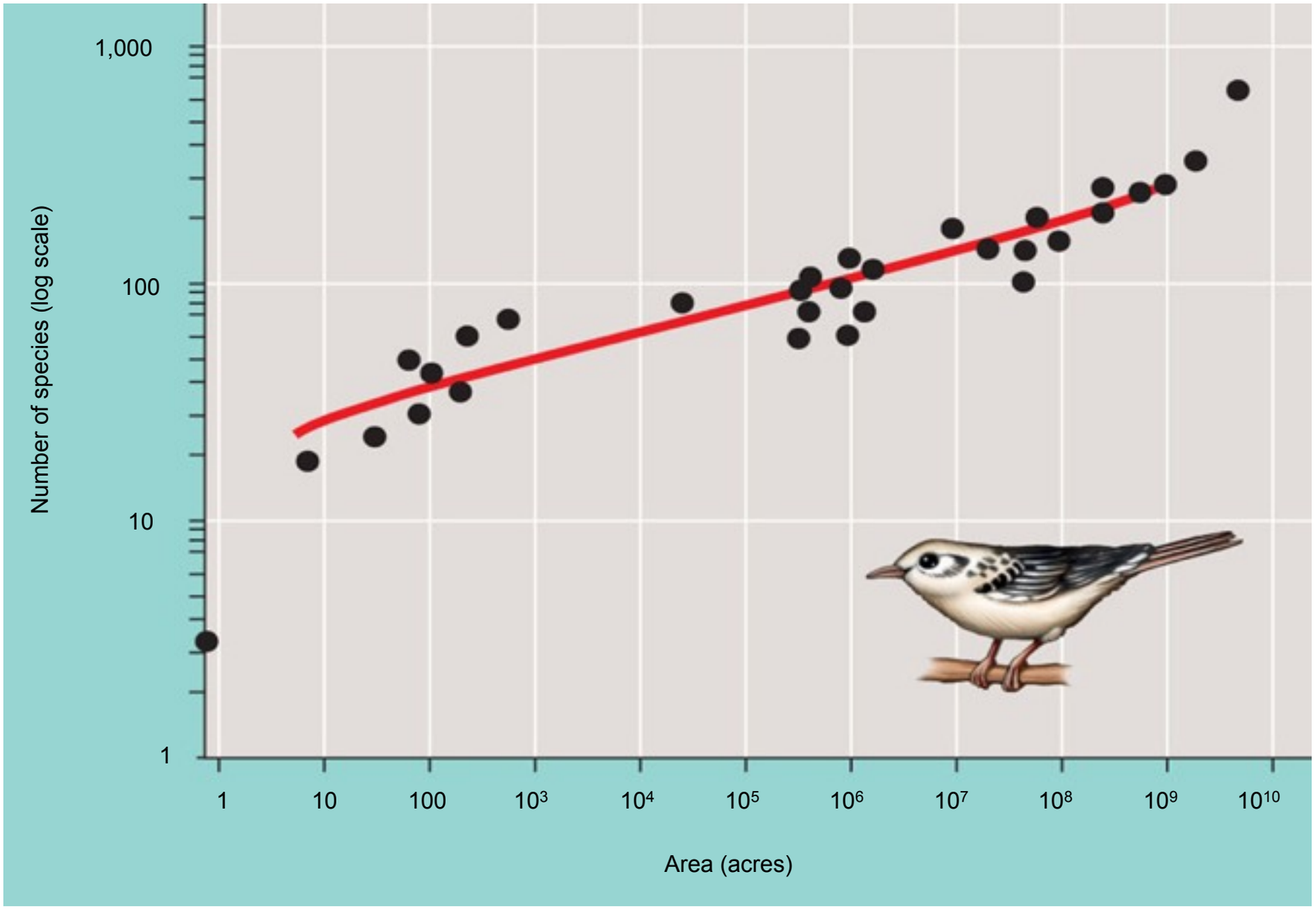




What happens to the size of mammals as you move towards the poles? Why?

B. Area

- *All factors equal the greater the geographical area, the greater the biodiversity.*
  - more area = more habitats and niches

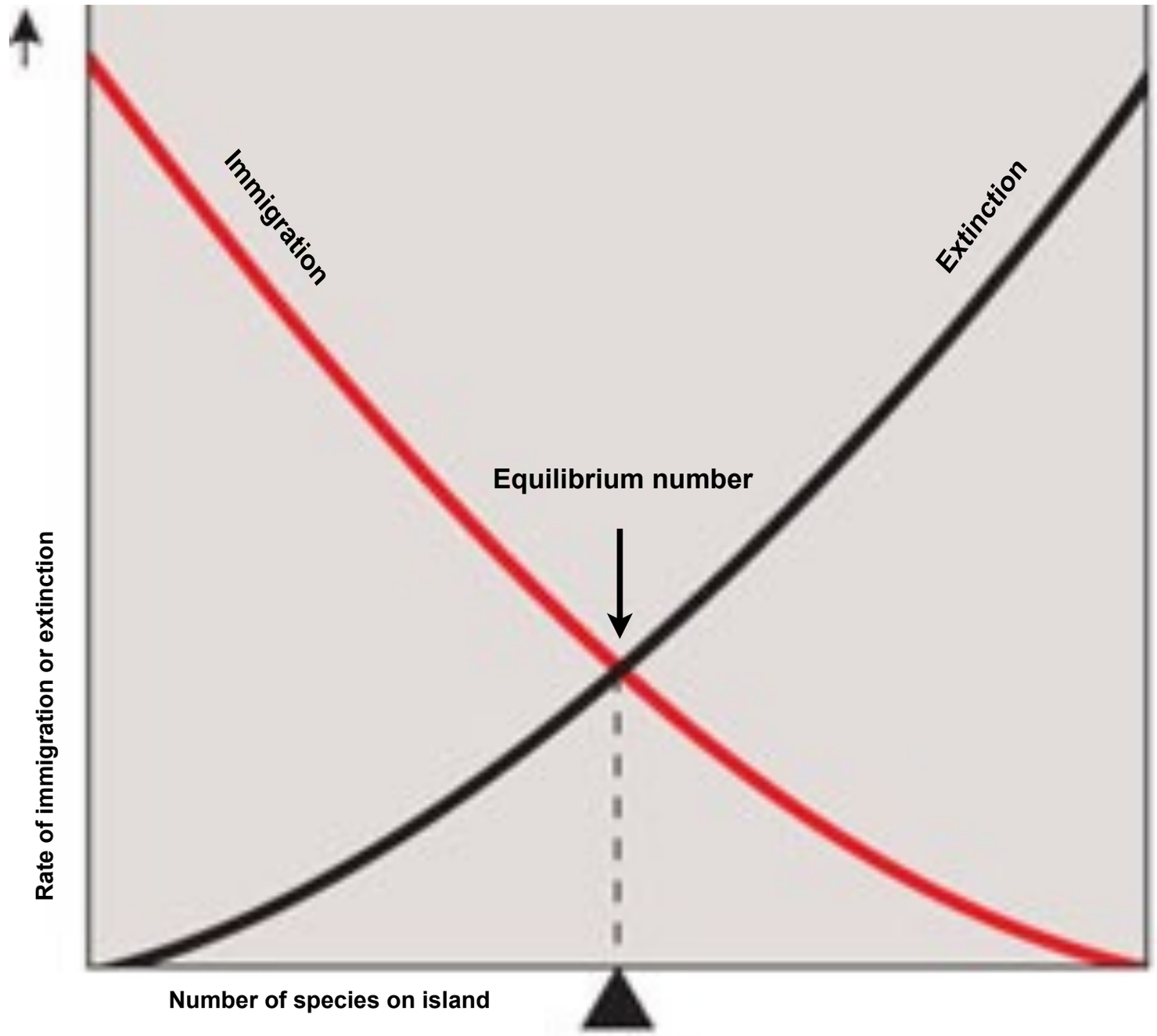


C. *Island* Equilibrium Model

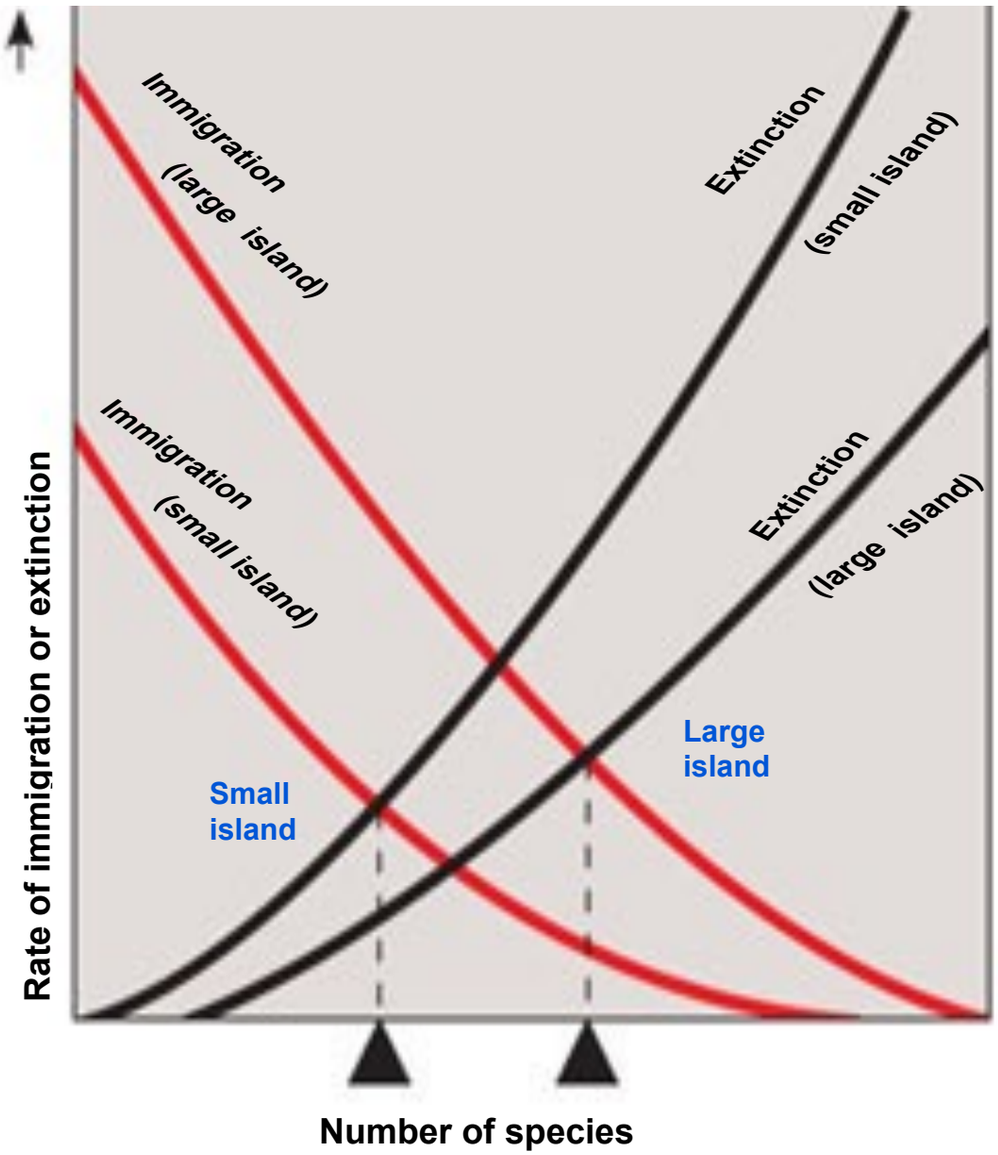
- This includes all "*island habitats*" not just oceanic islands. An "*island*" can be any patch of suitable habitat surrounded by unsuitable habitats.
  - Two factors determine the number of species on an island.
    - Immigration & Extinction
  - Two physical features affect immigration and extinction.
    - Size & Distance (from mainland or suitable habitat)

These factors determine the number of species on an island

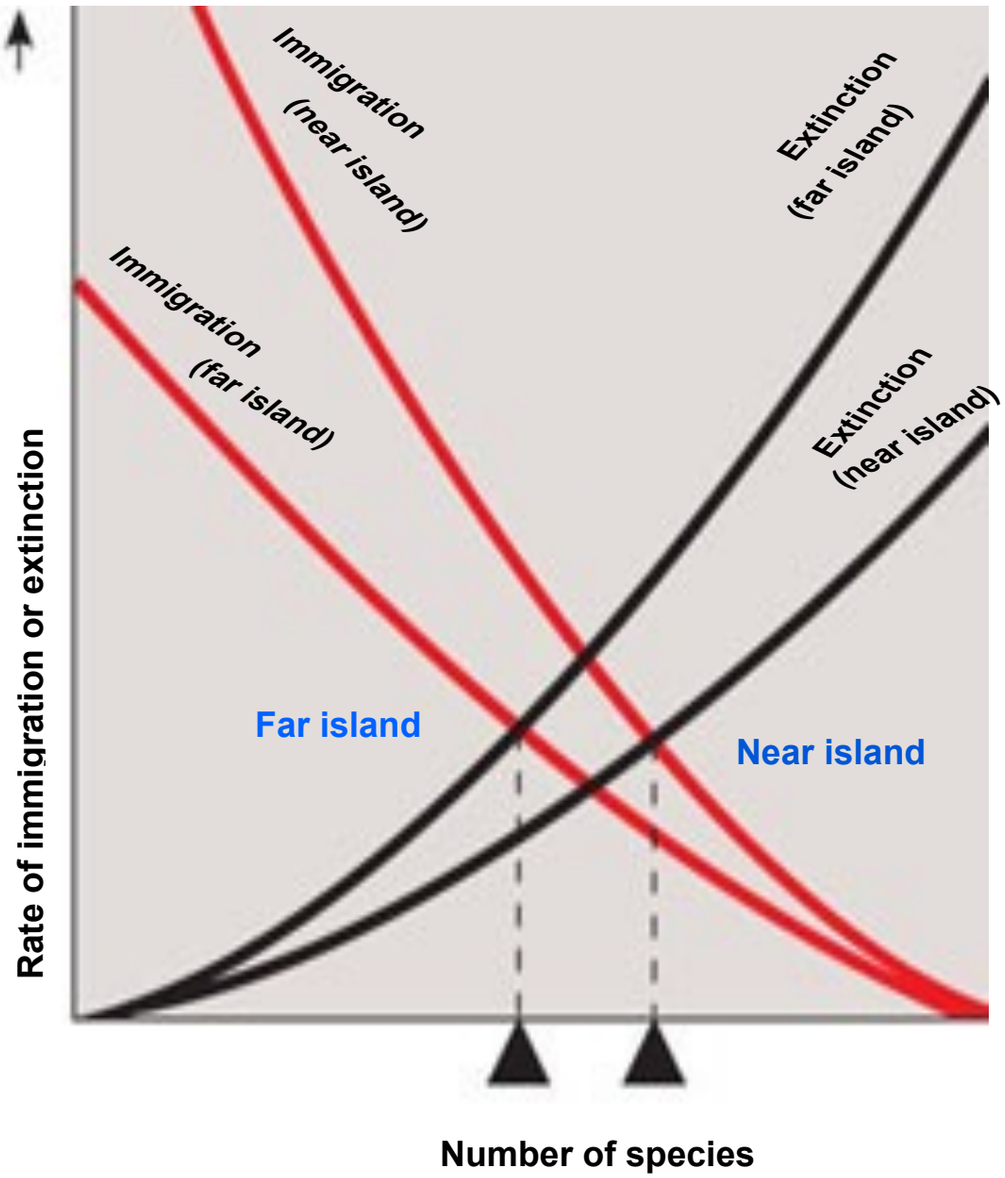
Immigration and extinction rates. The equilibrium number of species on an island represents a balance between the immigration of new species and the extinction of species already there.



These physical features affect immigration and extinction.



Effect of island size. Large islands may ultimately have a larger equilibrium number of species than small islands because immigration rates tend to be higher and extinction rates lower on large islands.



Effect of distance from mainland. Near islands tend to have larger equilibrium numbers of species than far islands because immigration rates to near islands are higher and extinction

(54) Community Ecology

v.

Main Idea: Pathogens effect community structure.

PATHOGENS ALTER COMMUNITY STRUCTURE

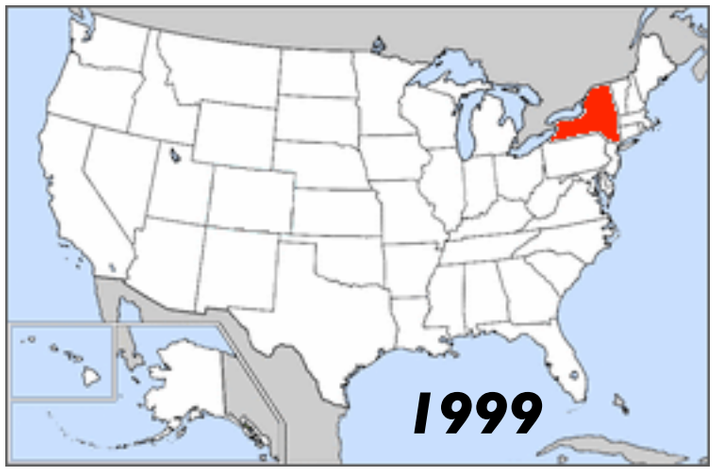
- **Pathogens** are disease causing organisms
  - They include: bacteria, fungi, protists, viruses, viroids, prions
- Their *impact* can be *swift and extensive*
- They have a greater effect when introduced into new habitats
  - new hosts have not had time for natural selection to select for resistant individuals
- Humans are equally vulnerable

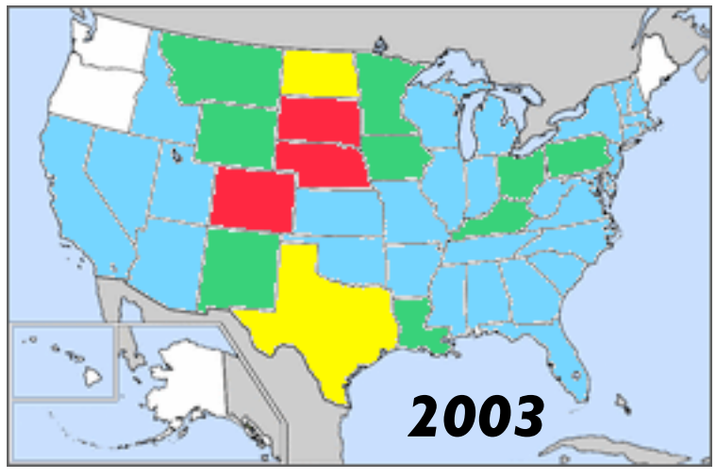
A. Pathogens & Community Structure

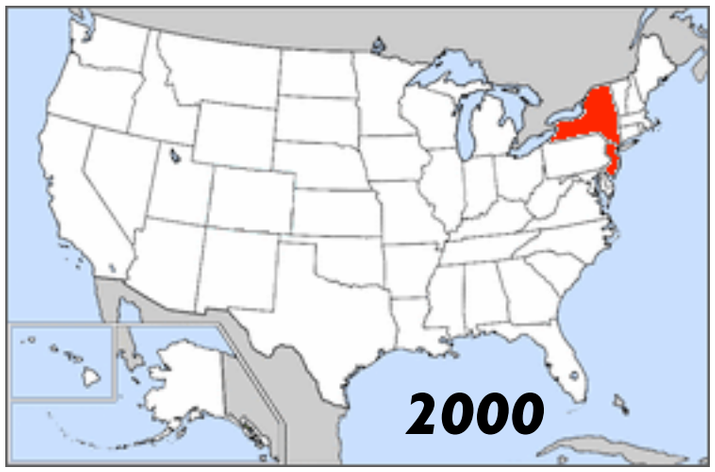
- Pathogens have effected both aquatic and terrestrial communities
- Human activities are moving pathogens around the world at unprecedented rates
  - Emerging human disease include: Resistant TB, Swine Flu, West Nile virus, SARS

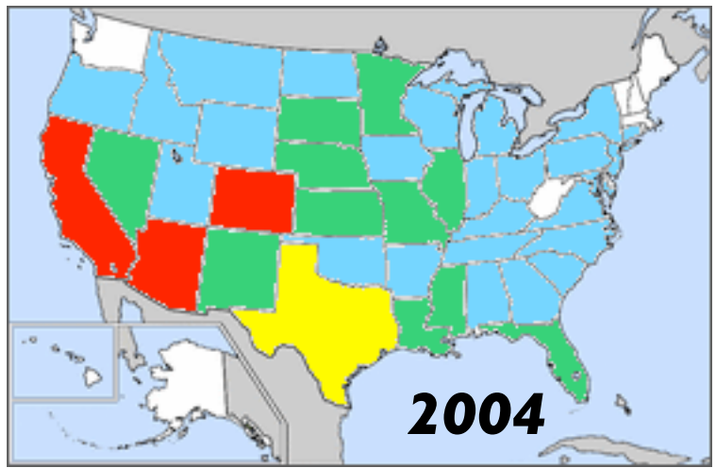
B. Community Ecology & Zoonotic Disease

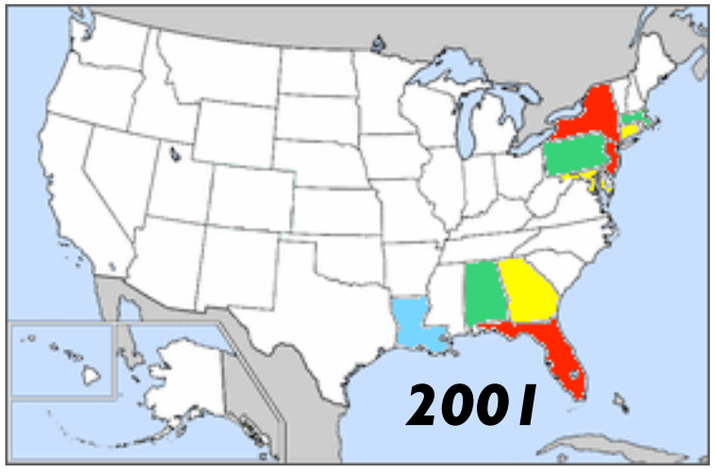
- *Zoonotic pathogens* are transferred to humans from other animals
- The intermediate species that passes the pathogen on to humans is called a *vector*, they include: mosquitoes, lice, ticks
- Knowledge of these interactions help us to track and maybe reduce the effects of these zoonotic pathogens.

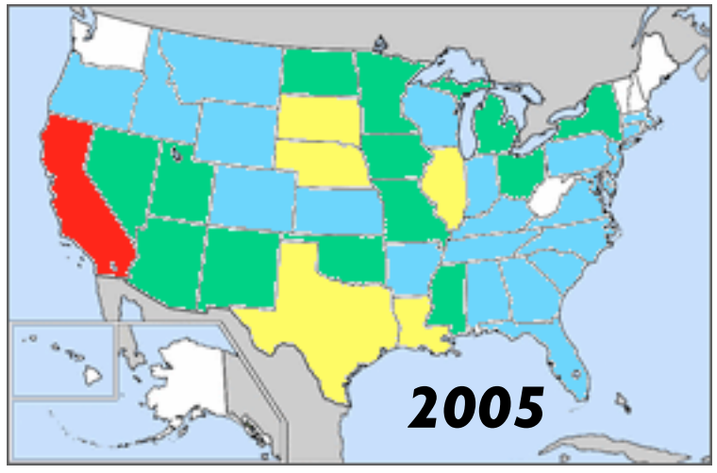


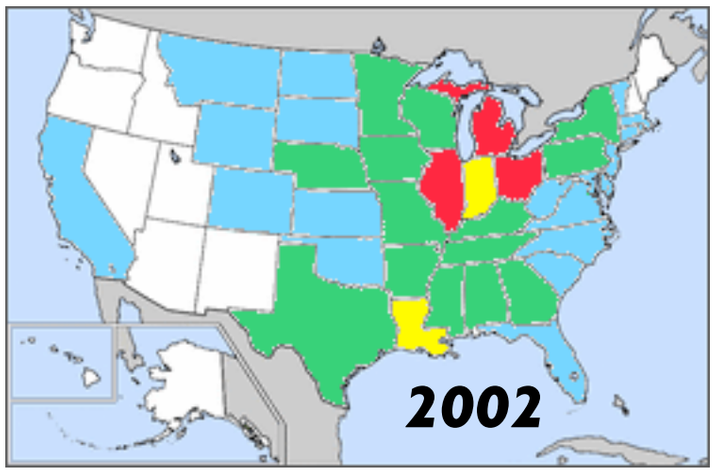


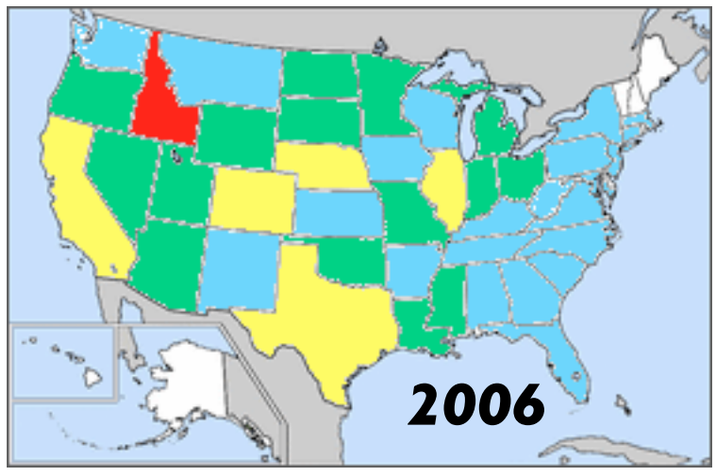












West Nile Virus

- white - no cases
- blue - less than 1%
- green - between 1% and 5%
- yellow - between 5% and 10%
- red - over 10%

	Cases	Deaths	Mortality Rate
1999	62	7	11%
2000	21	2	10%
2001	66	10	15%
2002	4156	284	7%
2003	9862	264	3%
2004	2539	100	4%
2005	3000	119	4%
2006	4269	177	4%
2007	3623	124	3%
2008	1356	44	3%
2009	720	32	4%
2010	981	45	4%

Stop and Think

Compare the richness of birds to snakes and lizards using the Island Biogeography Model. Explain.