Energy and Ecosystems

- Energy = ability to do work
- Thermodynamics = study of energy and its transformations

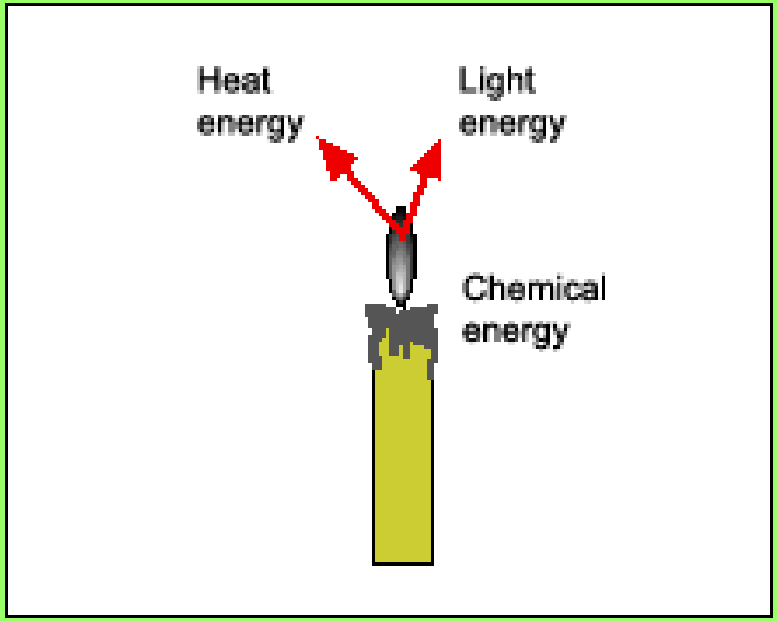
Laws of Thermodynamics

- 1st law = energy cannot be created or destroyed

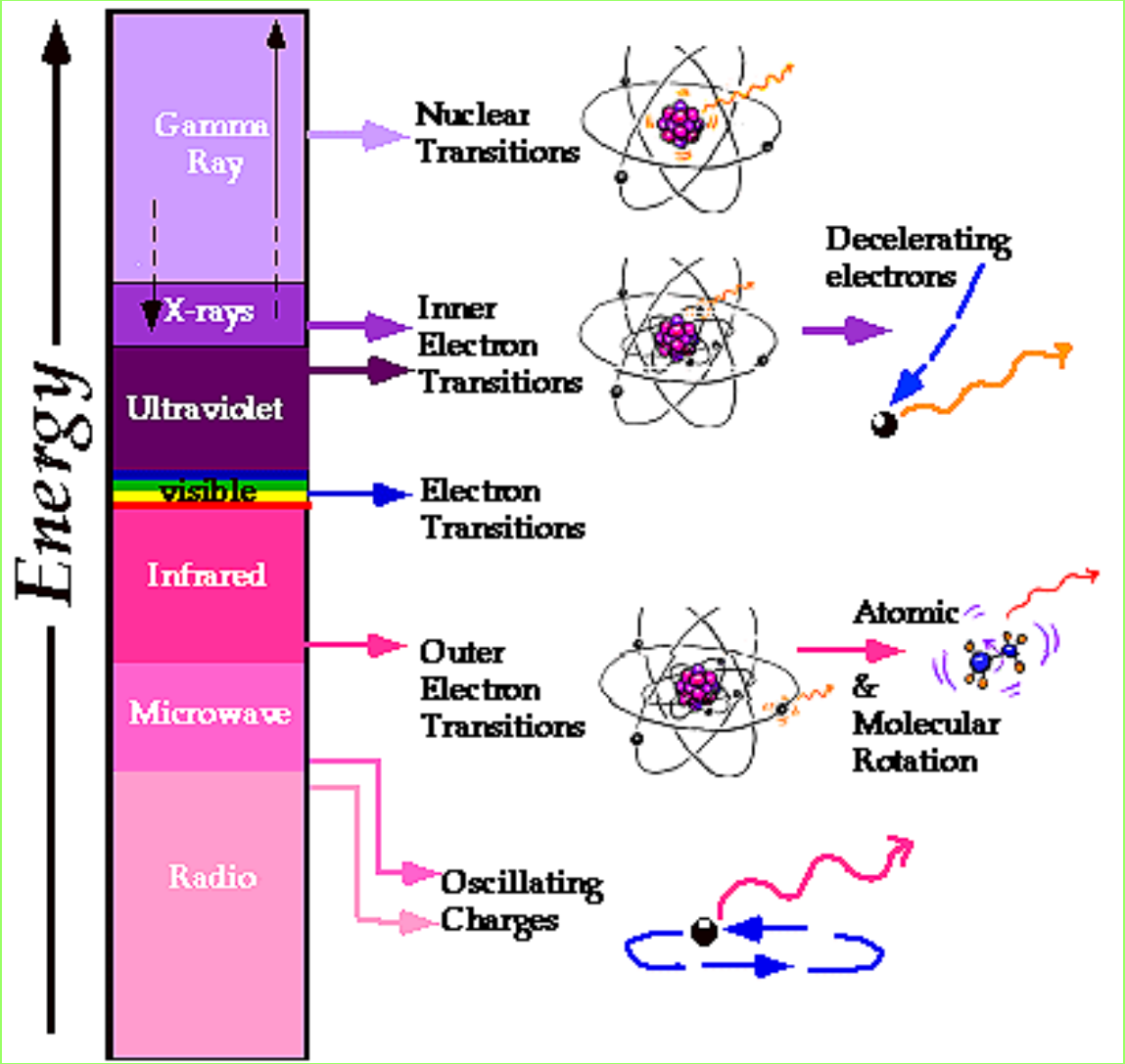
- 2nd law = energy conversions are not 100% efficient = energy is converted to heat

Forms of energy

1. Chemical energy stored in chemical bonds
   - Break chemical bonds = release energy
   - (ex: respiration, combustion)

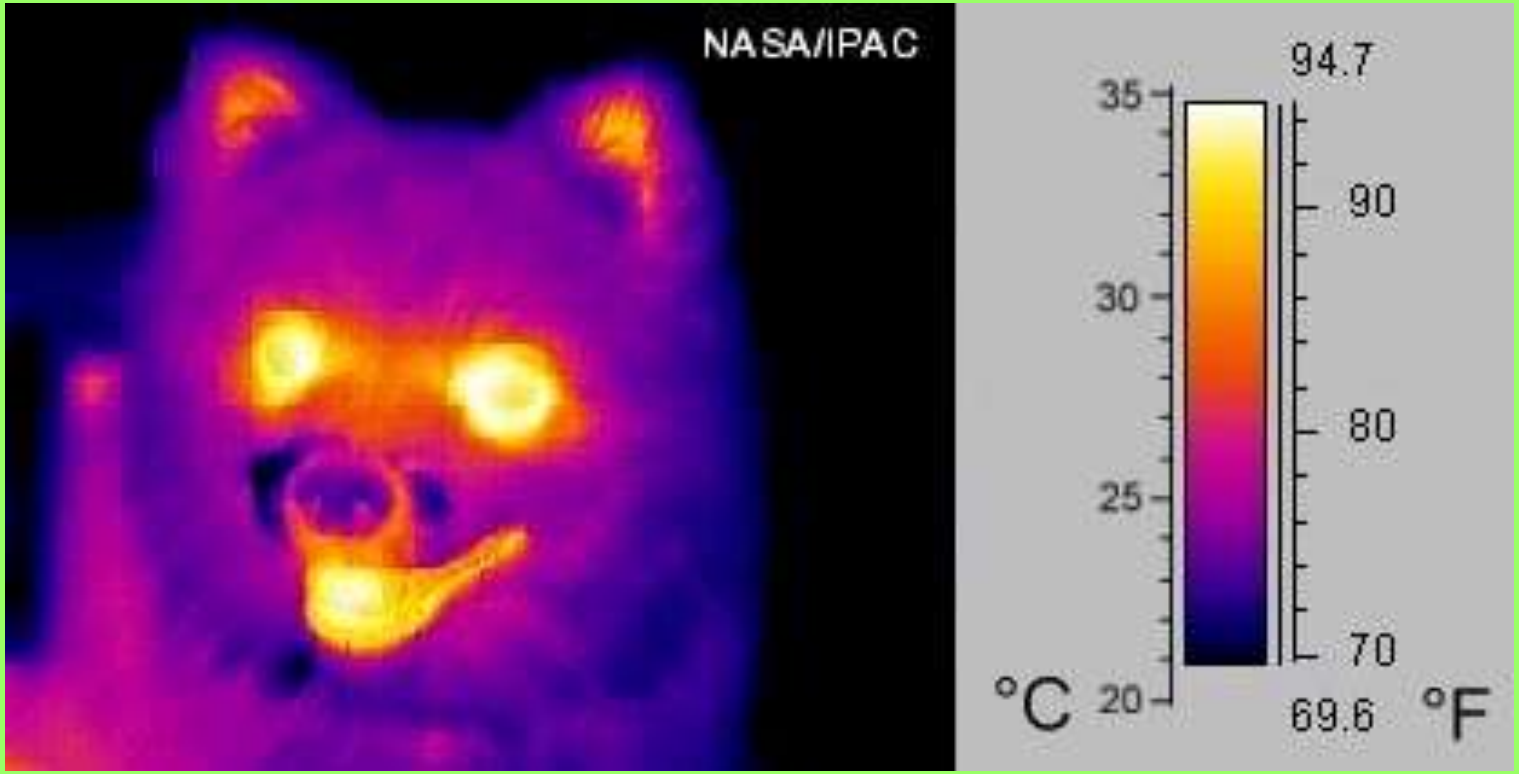


2. Radiant or solar = direct from sun (in form of electromagnetic waves)



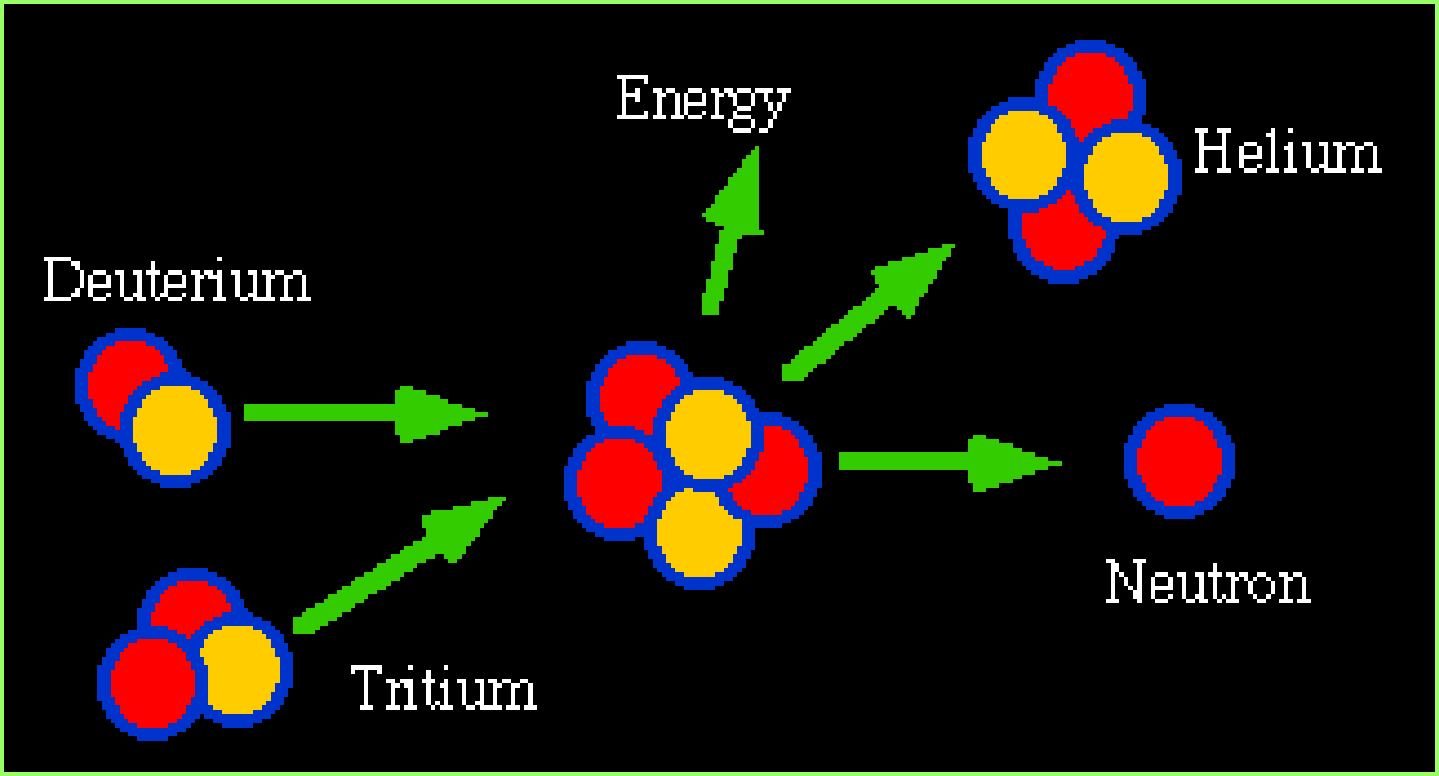
3. Heat = thermal energy (flows from hi temp (a heat source) to low temp (a heat sink)

Infrared = heat = thermal



4. Mechanical energy = kinetic =energy in motion (ex: wind spins turbines → work)

5. Nuclear = energy found within atomic nuclei released during:
   - splitting atoms = fission
   - combining nuclei = fusion



6. Electrical = flowing electrons

Units for Measuring Energy

- BTU = british thermal unit = amount of energy to raise 1lb water 1^0F
- Calories (cal) = amount of energy to raise 1g water 1^0C
- Joules (J) = force to move 1kg 1m/sec (Note: 1 cal = 4.18J)
- Watts = unit of electrical power

How many watts in a kilowatt?

Answer: 1000

More math practice

Include setup

No calculators!!!!!

Laws of Thermodynamics

First Law of Thermodynamics

Energy cannot be created or destroyed (only changed from one form to another).

Endothermic reactions

- Energy absorbed → products have more chemical energy
- Ex: Photosynthesis
- Formula:

$6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2$

Photosynthesis
= light energy absorbed
= endothermic

Exothermic reactions

- Energy released and products have less chemical energy
- Ex: respiration and combustion
- Formula for respiration:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy

Some ATP

Some heat

Respiration

- All organisms (including green plants) respire → energy

- Respiration → release energy = exothermic

- Respiration in the absence of oxygen = anaerobic respiration = fermentation

Chemical reactions

Substrates → Products

Total energy = Total energy

Why???

First Law of Thermodynamics

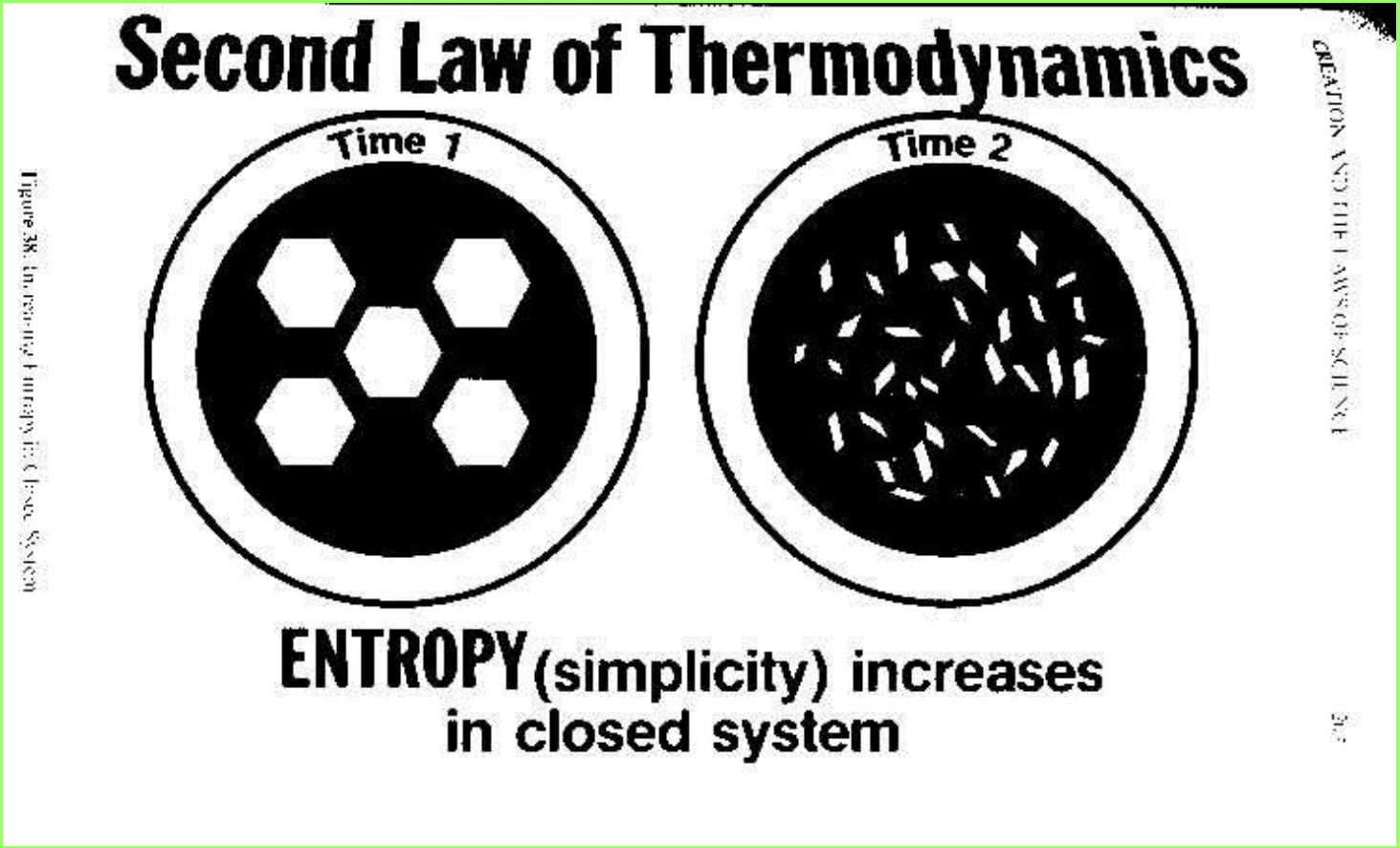
Second Law of Thermodynamics

- Part I = Energy transformations are not 100% efficient → At each energy transformation some energy is changed into heat (a less usable form of energy)

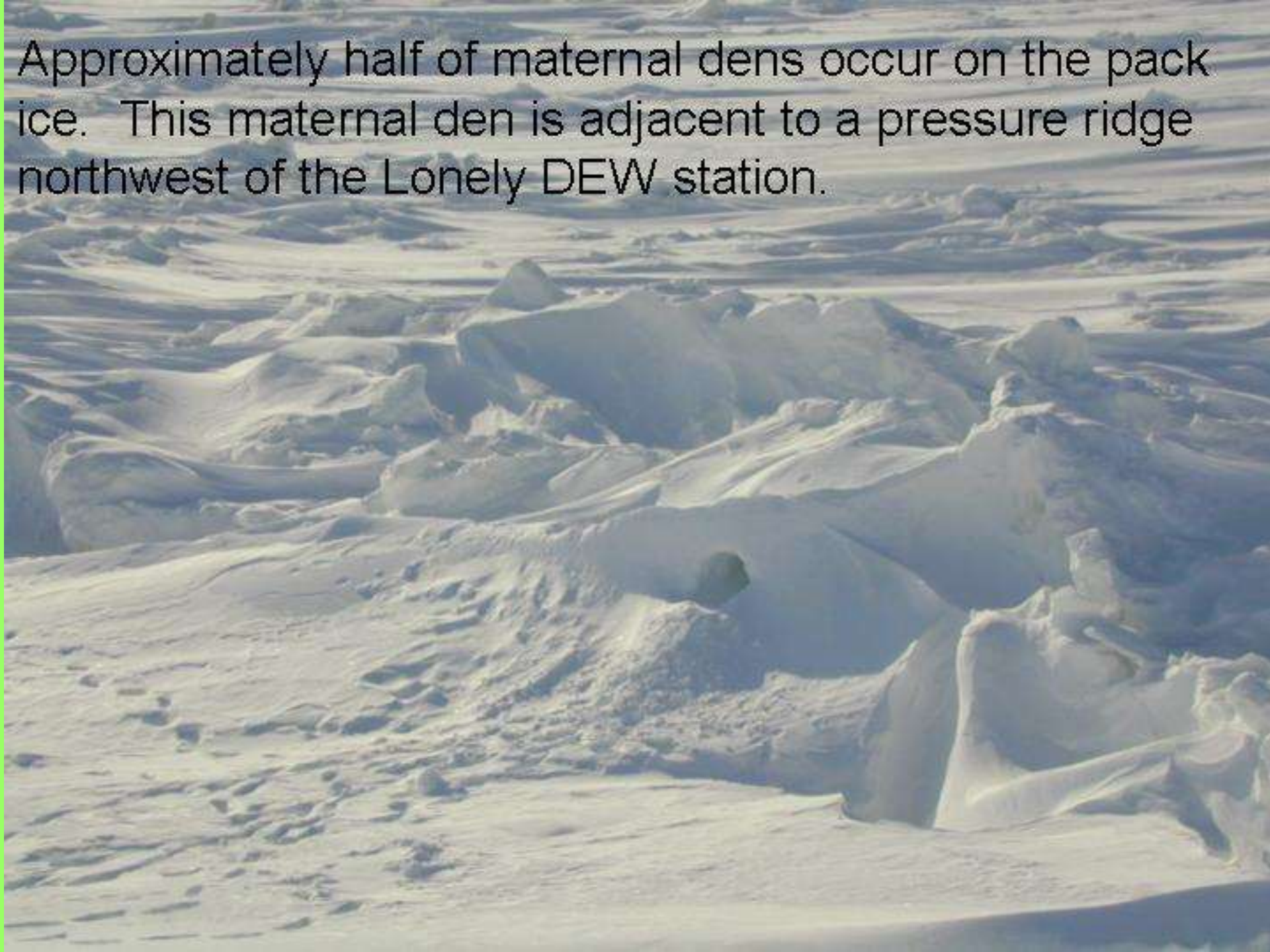
- Part II = Nature has a tendency towards increased entropy (randomness)

Entropy = randomness

- Heat = high entropy



- All organisms transform energy → give off heat radiation (infrared radiation)
- Heat can be detected using infrared sensors
- Ex: polar bear dens



Approximately half of maternal dens occur on the pack ice. This maternal den is adjacent to a pressure ridge northwest of the Lonely DEW station.


Forward-looking infrared sensor mounted on the belly of a Bell 212 helicopter.
Detecting polar bear dens with forward-looking infrared sensors (FLIR).

Find the polar bear den

Cannabis farm detected in UK

Why do organisms give off heat?

Second Law of Thermodynamics

Energy flows in ecosystems

Energy flows in 1 direction

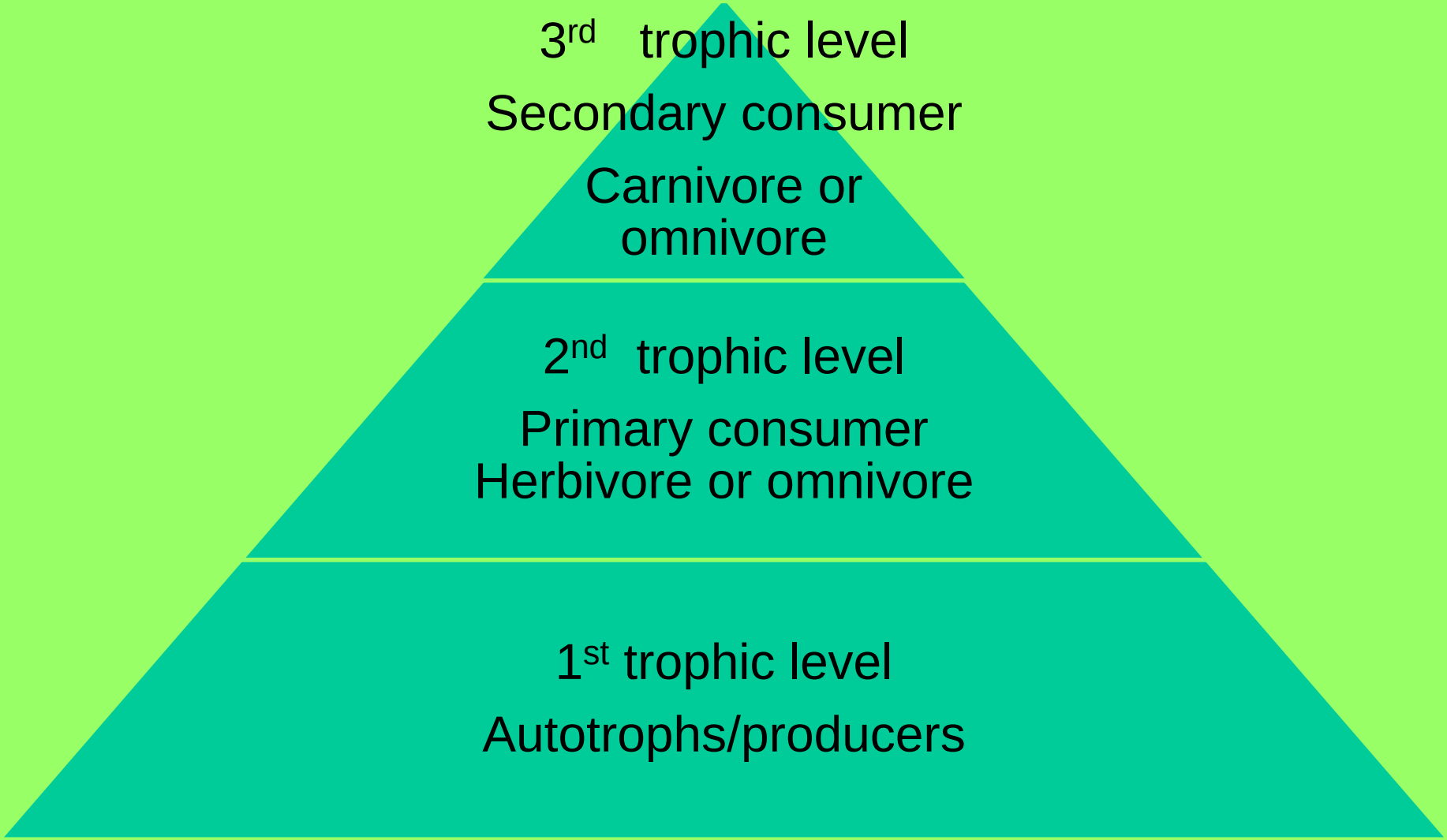
Sun→producer→consumer

10% Rule

- Only 10% of energy at each level moves to the next (ex: producer → consumer)
- 90% energy lost at each trophic level
- Why?????
- Second law of thermodynamics

Practice math problems

Trophic levels



Photosynthetic efficiency of an ecosystem =

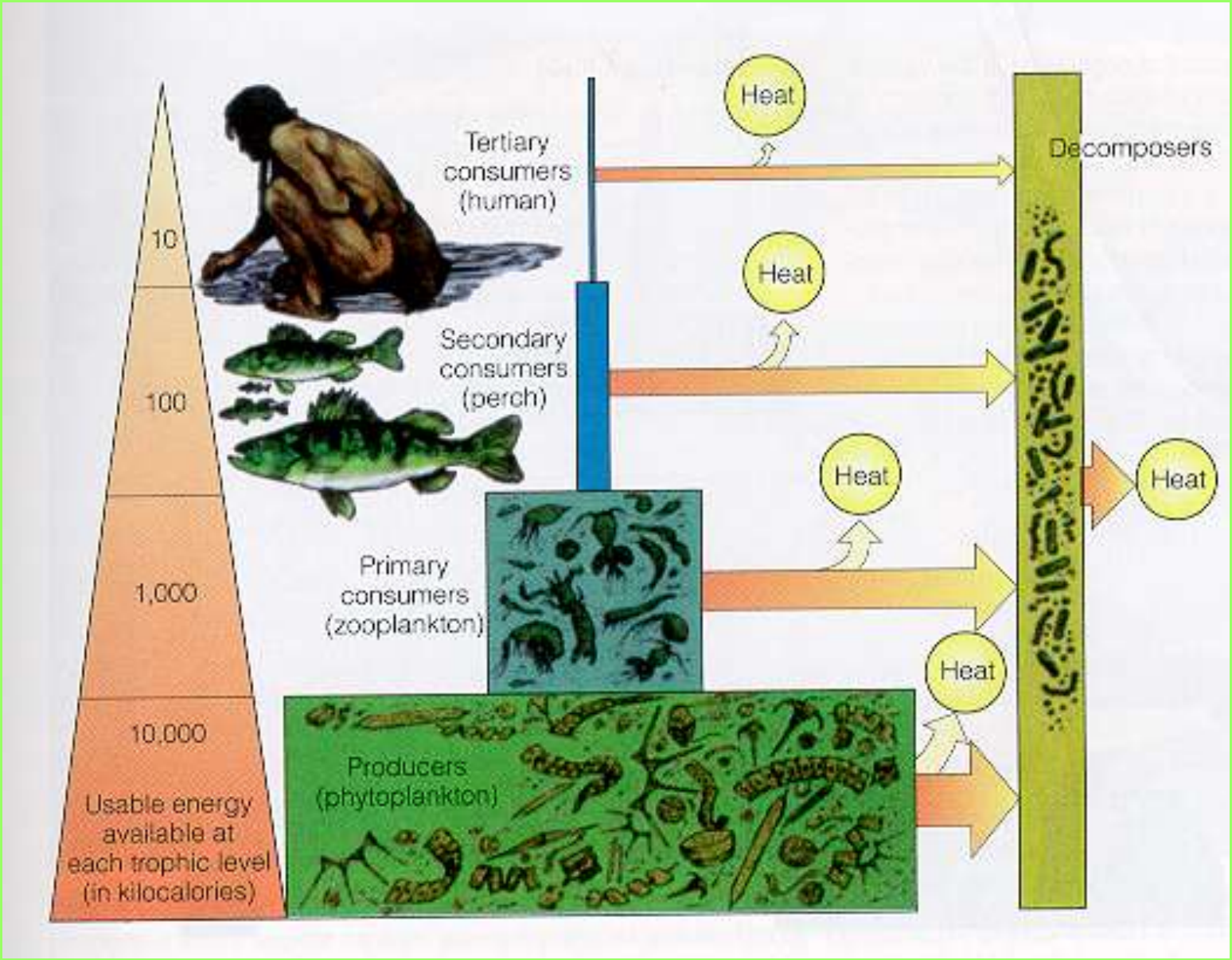
between 1% and 2%

Decomposers = Saprophytes

- Recycle nutrients NOT Energy
- Energy is always lost

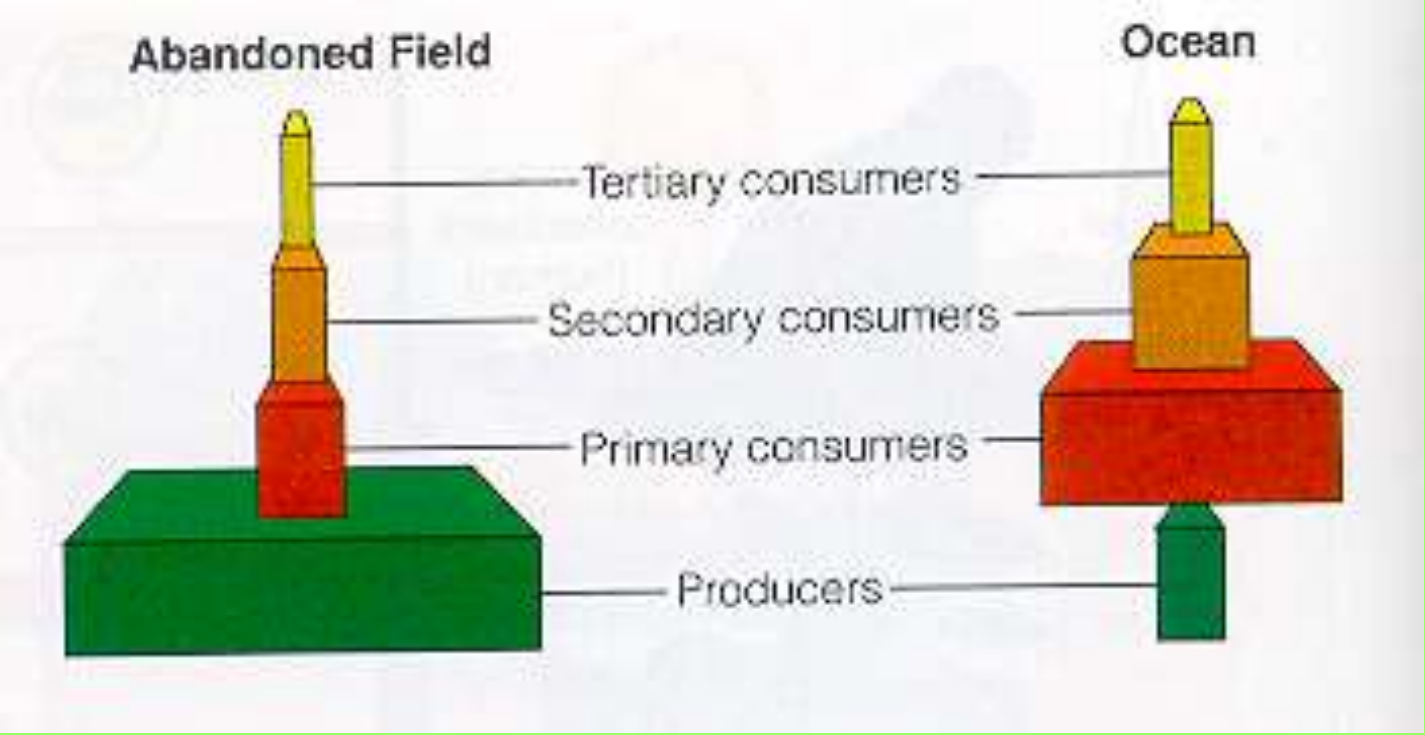
Trophic Pyramids

Pyramid of energy always decreases because usable energy is lost at each step



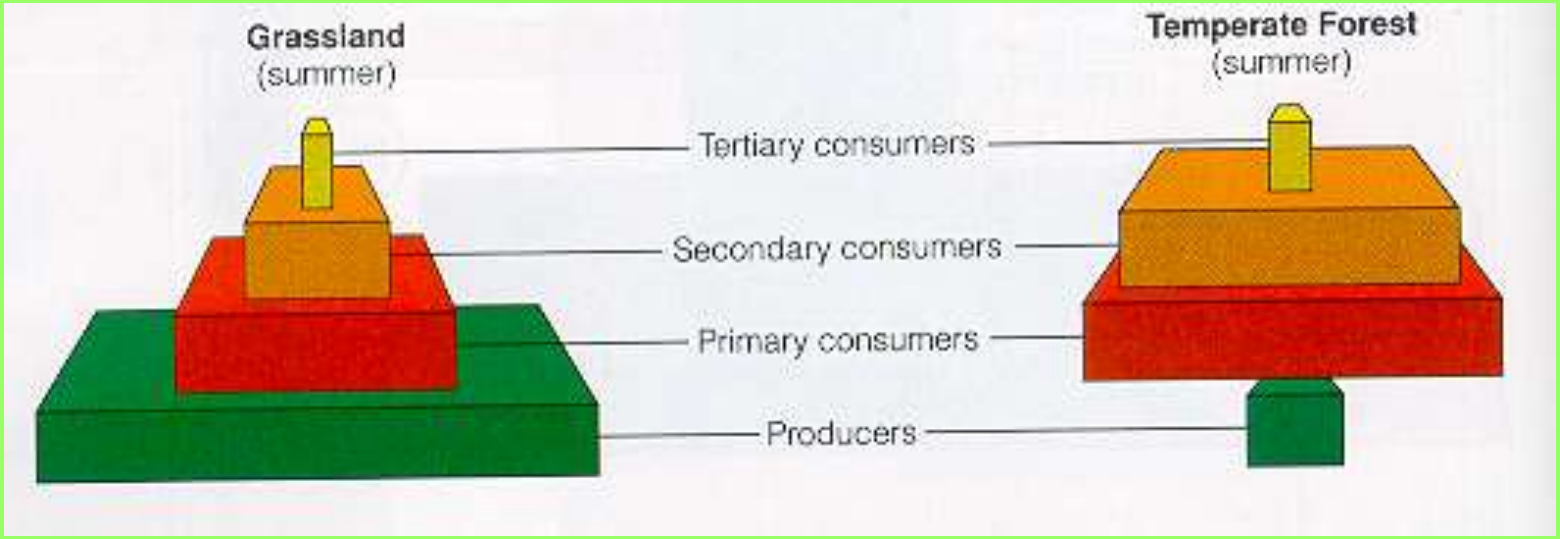
Pyramid of biomass

- Biomass = weight of organic material (g/m^2)
- Can be inverted if consumers eat most of the producers as they are made
  - ex: phytoplankton → zooplankton



Pyramid of numbers

- Shows the # of individuals at each trophic level
- Inverted pyramid occurs when small organisms (insects, decomposers…)are at higher levels



Comparing Ecosystems

- Gross Primary Productivity (GPP) = amt of energy captured by producers in an ecosystem
- Net Primary Productivity (NPP) = amount of energy available to consumers after producers respire
- Both are measured in units of energy (kcal/m^2/yr) or in terms of dry weight (g of carbon/m^2/yr)
- NPP = GPP – plant respiration

Productivity = Plants

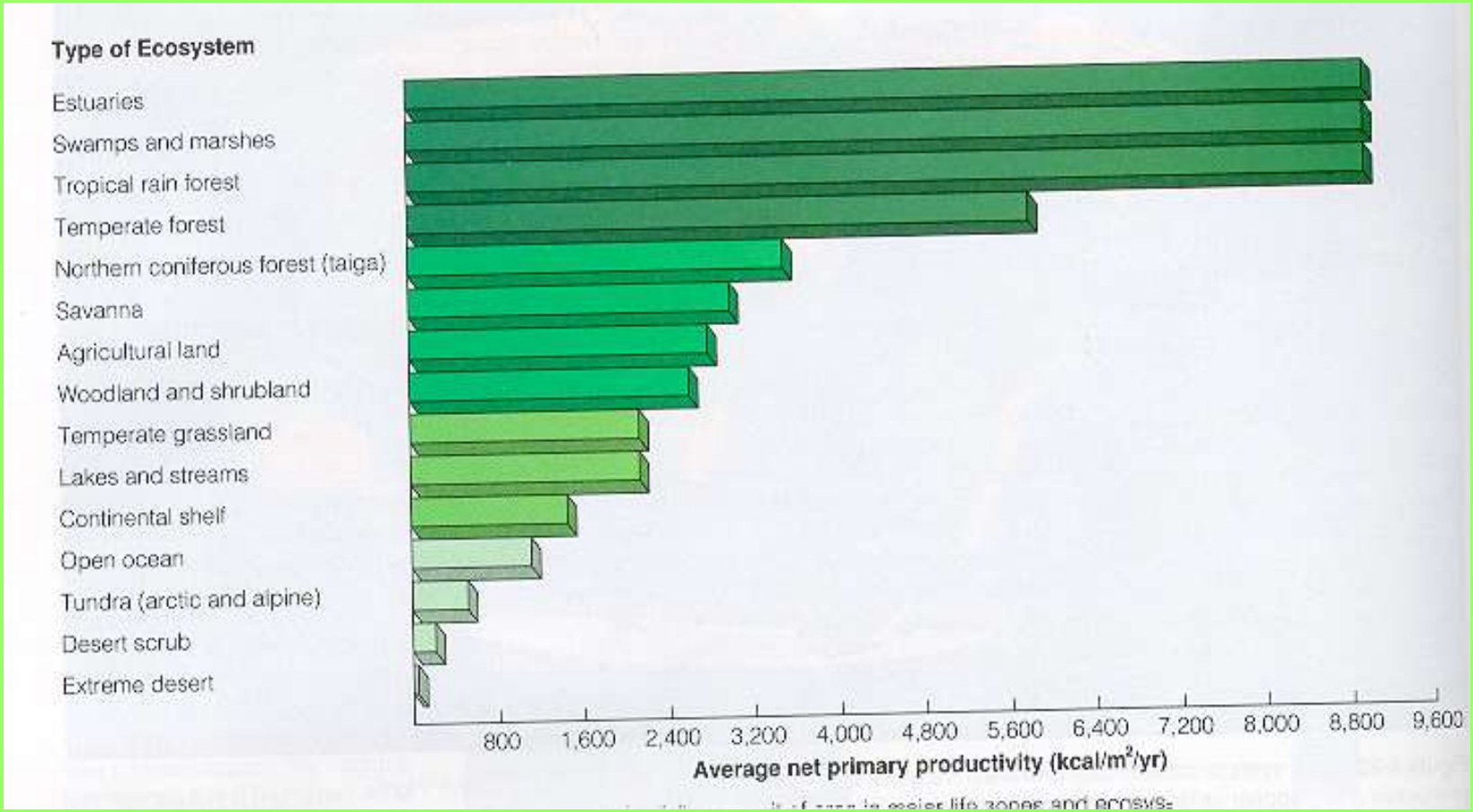
NPP practice

- NPP for river ecosystem = 8,833 kcal/m^2/yr
- Respiration by aquatic producers = 11,977 kcal/m^2/yr
- Calculate GPP

- NPP = GPP – Respiration
- 8,833 = GPP – 11,977
- GPP = 8,833 + 11,977 = 20,810 kcal/m^2/yr

Which ecosystems have high NPP?

- Per unit area:



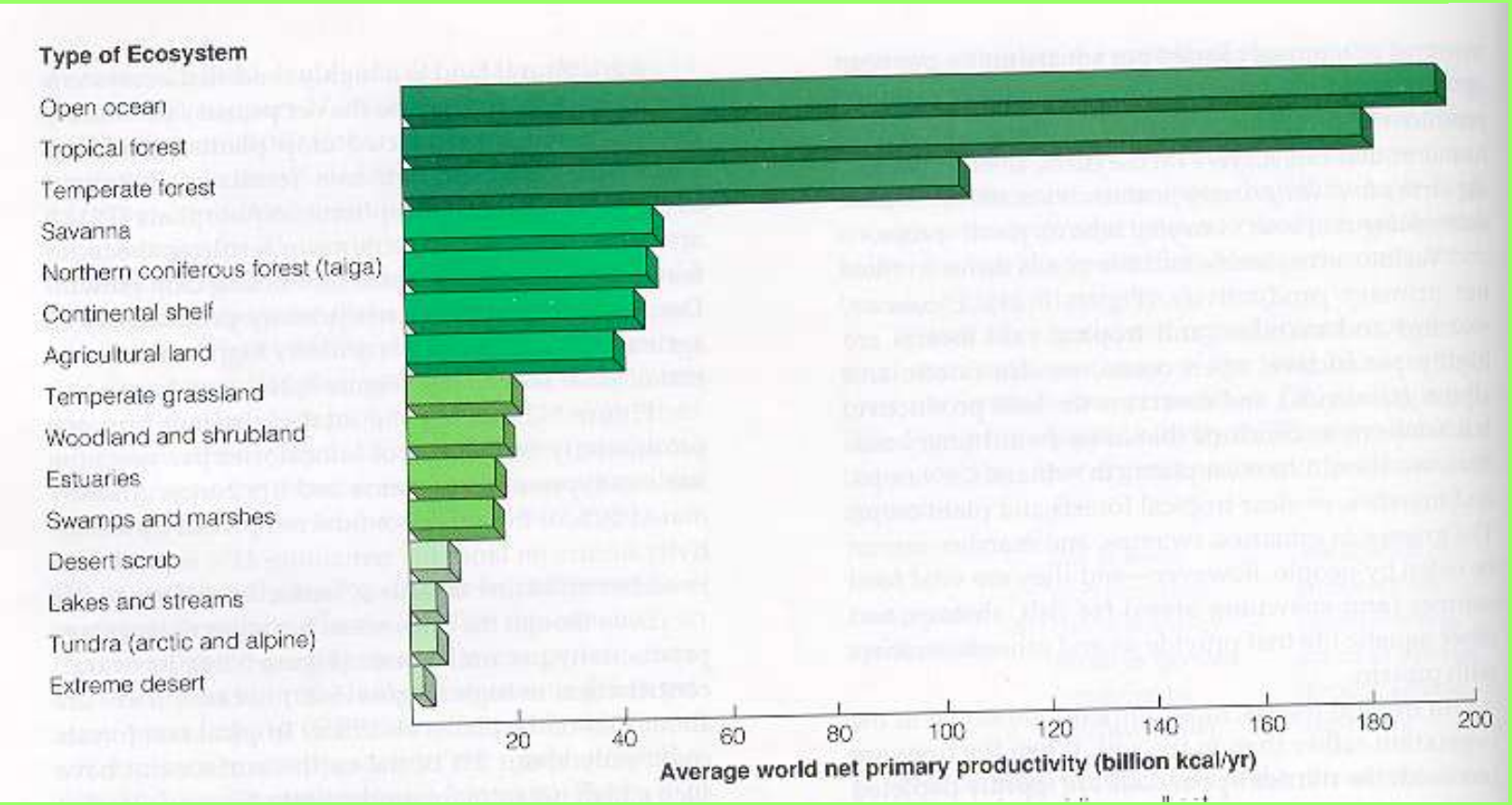
Comparing NPP's

- Rain forests = most productive land biomes

- Tundras and deserts = least

- Wetlands, swamps, and marshes that connect land and water ecosystems are extremely productive
- Algal beds, coral reefs, and estuaries = high
- Open ocean = low

NPP available in world



Note: Oceans have low NPP

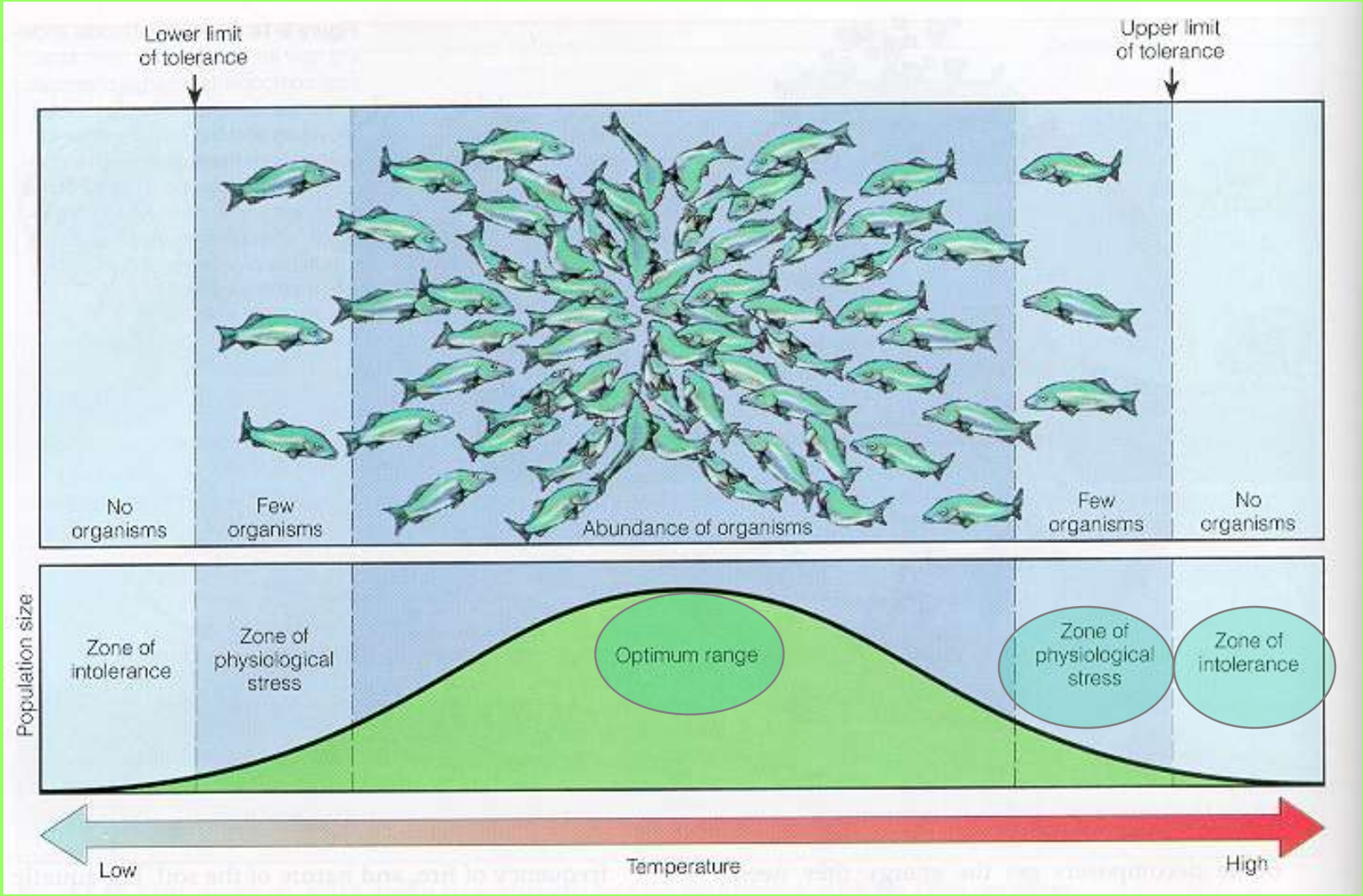
BUT

They cover 71% earths surface
→ lots of productivity

Limiting Factors

- Environmental factors that are more important for survival = limiting factors.
  - Ex. temperature, water, light, soil nutrients, salinity
  - Ex: phosphorus = limiting in freshwater ecosystems → controls algae growth

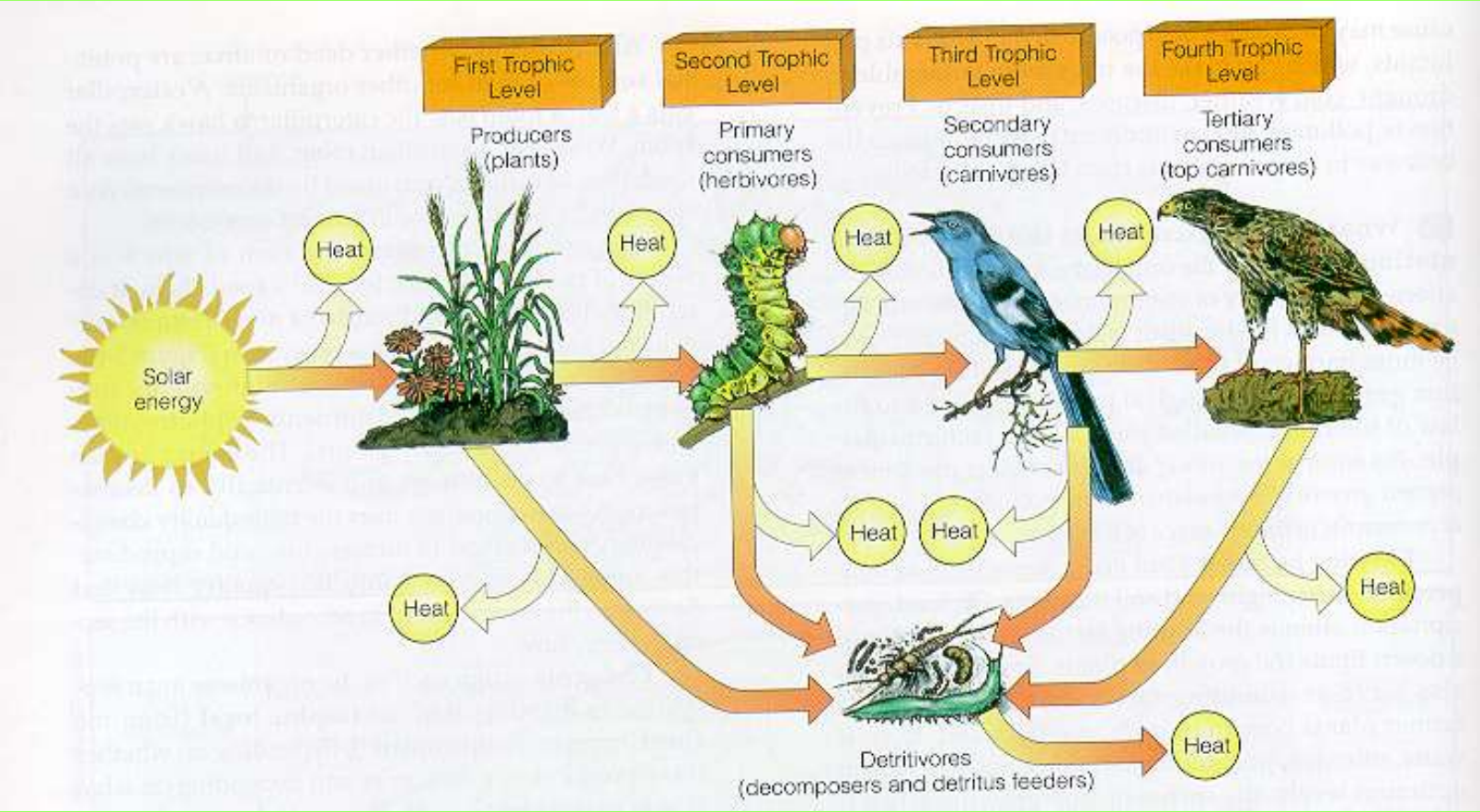
Range of Tolerance



Producer biomass limits consumer biomass

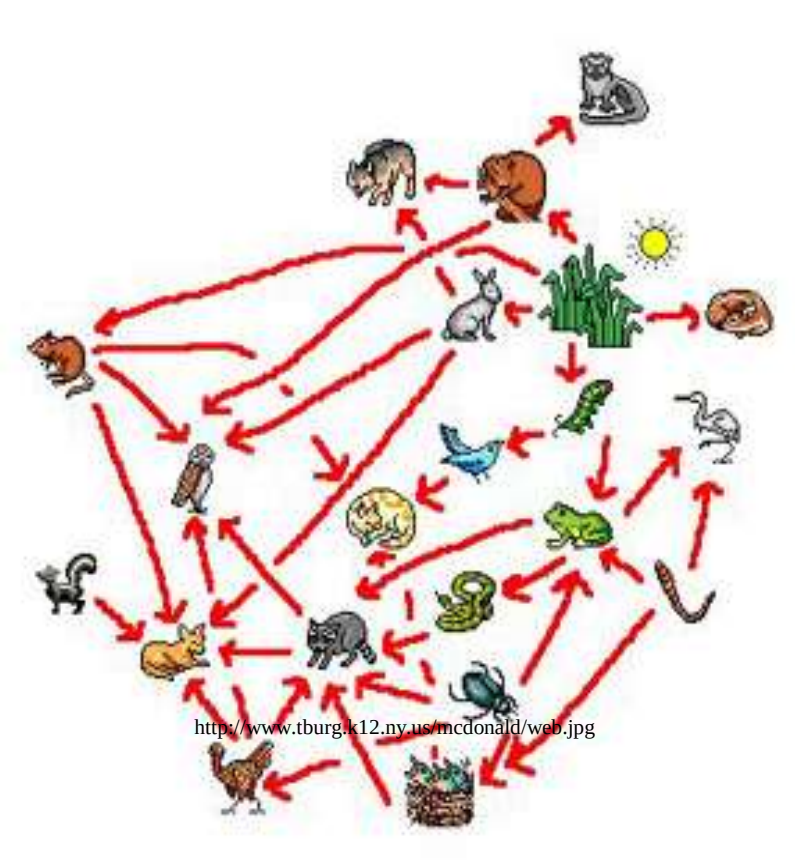
Food Chains and Food Webs

- Food chain = flow of energy from producer to consumer



Food Webs = interconnected food chains

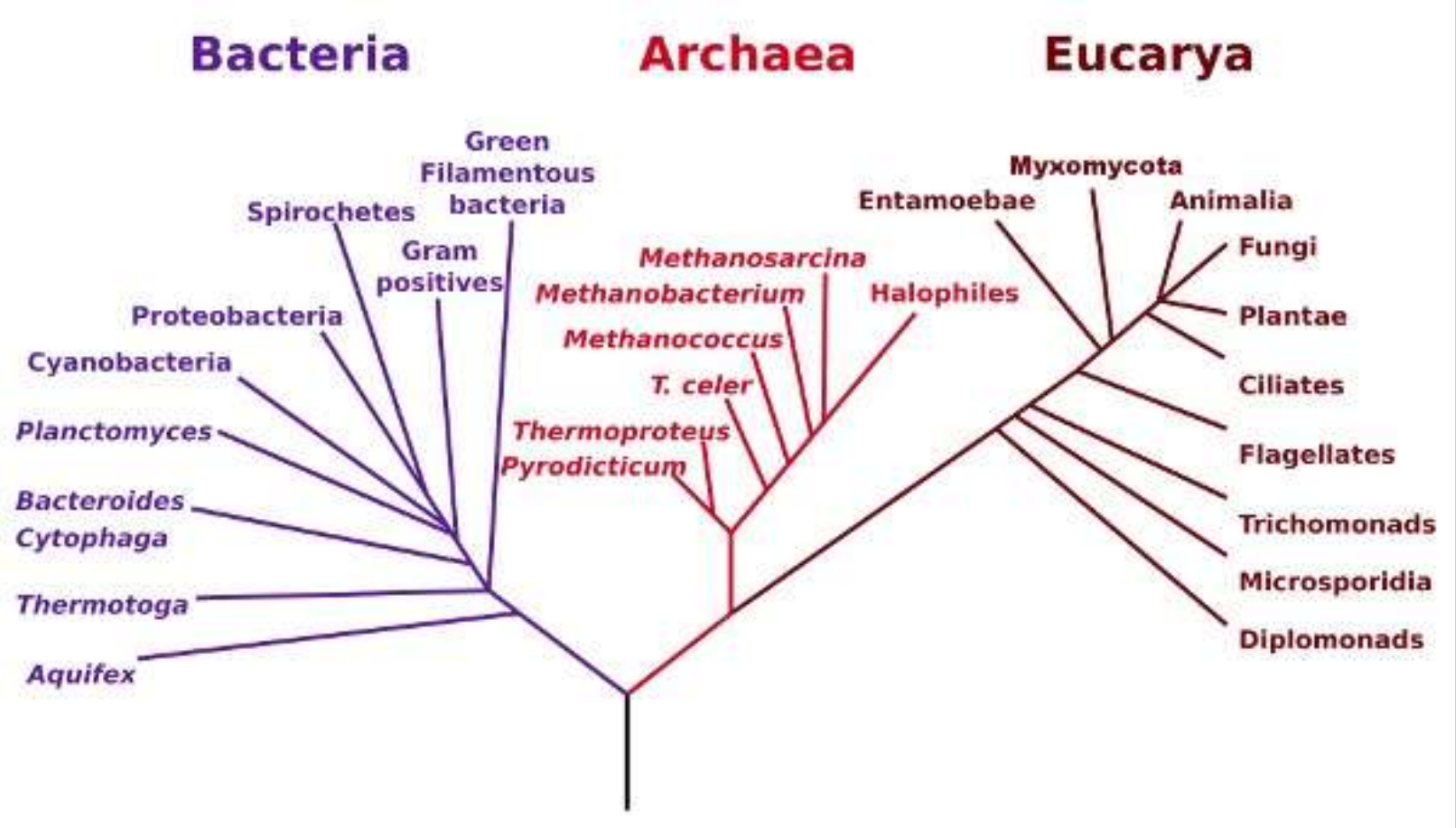
- More connections = more stable
- <u>Diversity → stability</u>



Plants and phytoplankton form the base of most food chains

- Exception = chemosynthetic bacteria form the base of food chains in hydrothermal vents

Archaebacteria = bacteria in extreme environments



Energy vocab

- 1st and 2nd laws of thermodynamics
- Infrared
- Fission and fusion
- Endothermic and exothermic
- Entropy
- 10% rule
- Archaebacteria
- Detritivores
- Saprotrophs
- Food chains and webs (be able to draw them)

Ecology

- The study of living organisms and their interaction with the nonliving environment

- Biotic (living) and Abiotic (physical env.)

Characteristics of Life

- Cell structure
- Genetic material
- Metabolism (all the chemical reactions)
- Homeostasis (maintain balance)
- Reproduction
  - Asexual
  - Sexual – increases genetic diversity
- Can undergo natural selection

Levels of biological organization

- Species (can interbreed in wild)
- Populations (1 species 1 area)
- Communities (many species 1 area)
- Ecosystems (communities + physical environ.)
- Landscape ecosystems (connecting ecosystems)
    - Large forest including streams and ponds
- Biosphere (all the ecosystems of the world)

Population Density

- # of individuals / unit area
  - Example: 3000 salamanders / acre

Practice math problems

Biodiversity

- Genetic diversity
  - Variation in genes in a population
- Species diversity
  - the # of different species in an area
- Ecological diversity
  - # different ecosystems in an area

- In all cases *diversity → stability*

Interdependence

- Within a community populations interact with each other → maintain an ecosystem
- Species depend on and affect each other

Keystone Species

- Species that play a vital role in an ecosystem
- <u>Removal of a keystone → disrupts the entire ecosystem</u>
  - Ex: wolves of Yellowstone

Habitat

- Where an organism lives
- The habitat must supply the needs of organisms (food, water, temp, O_2, and minerals.)
- Needs not met → migrate, adapt, or die

Niche

- Describes an organism's job or role in a particular area

- Examples:

Elephant niche

- Push over trees → forest openings (grasslands) → helps antelopes, zebra, and other herbivores

Decomposer Niche = Recycle Nutrients

Top predator niche

- Top predators control herbivore populations → prevent overgrazing

Organisms can share a habitat without competing if they occupy different niches !!!

Species interactions

1) Competition = fight for limited resources
   → survival of the fittest

2 types:

   a. Interspecific
   b. Intraspecific

Int**er**specific Competition

http://hyenas.zoology.msu.edu/images/crocuta/shah-lionkillingahyena.jpg

- Diff**er**ent species compete
- An increase in one species → decrease in the other
- Ex. Two tree species competing for light in the forest
- Ex: spotted hyena and lion competing for food

Interspecific Competition

- Caused by niche overlap in species
- If two species have complete niche overlap, they cannot coexist →COMPETITIVE EXCLUSION

Northern spotted owls

- https://www.youtube.com/v/LJL7XD5DU7A

Comp. exclusion and non-native species

- Non-native species often out-compete native species when introduced into an area

- Examples

http://www.invasive.org/eastern/images/768x512/0002030.jpg

Eurasian watermilfoil

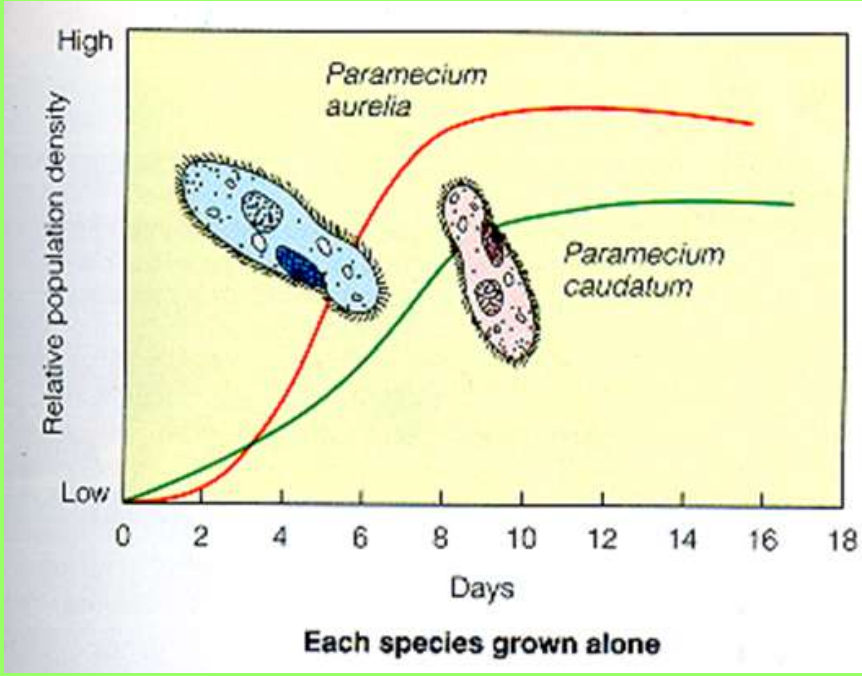
Zebra mussels (introduced into Great Lakes via ballast water)

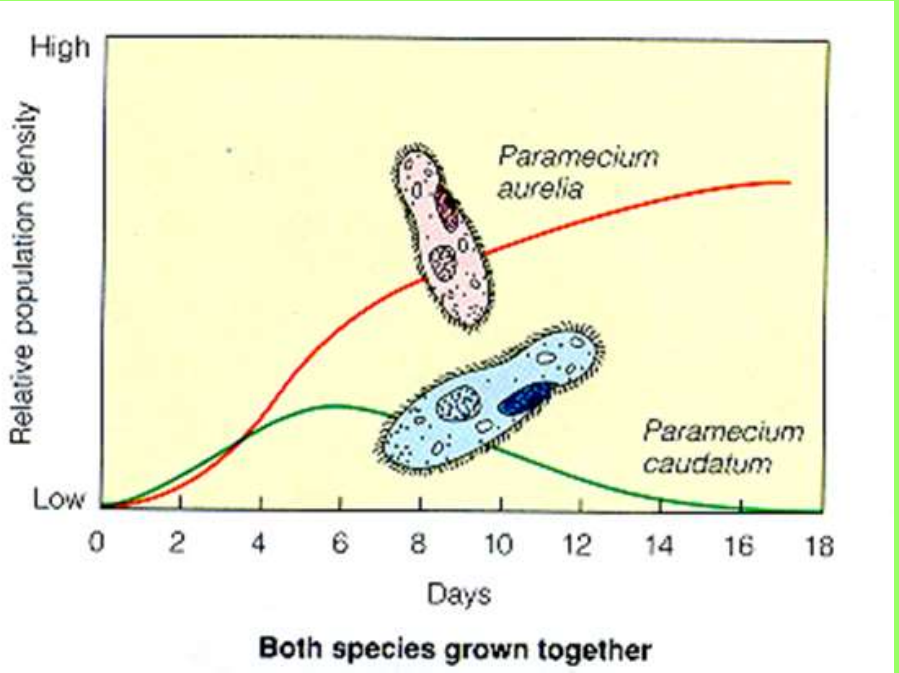
Purple loosestrife

Gause's Comp. Exclusion Experiment

- Two species of *Paramecium* can be grown in a vial using a food source.
- grown separately →both survive
- Grown together → only one with competitive advantage survives

Gauses competitive exclusion experiment





Intraspecific Competition

- Between members of <u>same</u> species (space, food, mates)
- Leads to stable population regulation
  - More variation in pop. → inc. stability
- Ex

http://cache.eb.com/eb/image?id=6673

http://www.laspilitas.com/comhabit/pictures/creosote.jpg

Red-winged blackbirds

Larger testes in males in the north than the south due to increased competition for mates in regions w/ shorter breeding seasons

Creosote Bushes

- Secrete an herbicide that inhibits growth of other plants

Ways to reduce competition/allow coexistence of competitors

1. Resource partitioning = Species divide up the resource

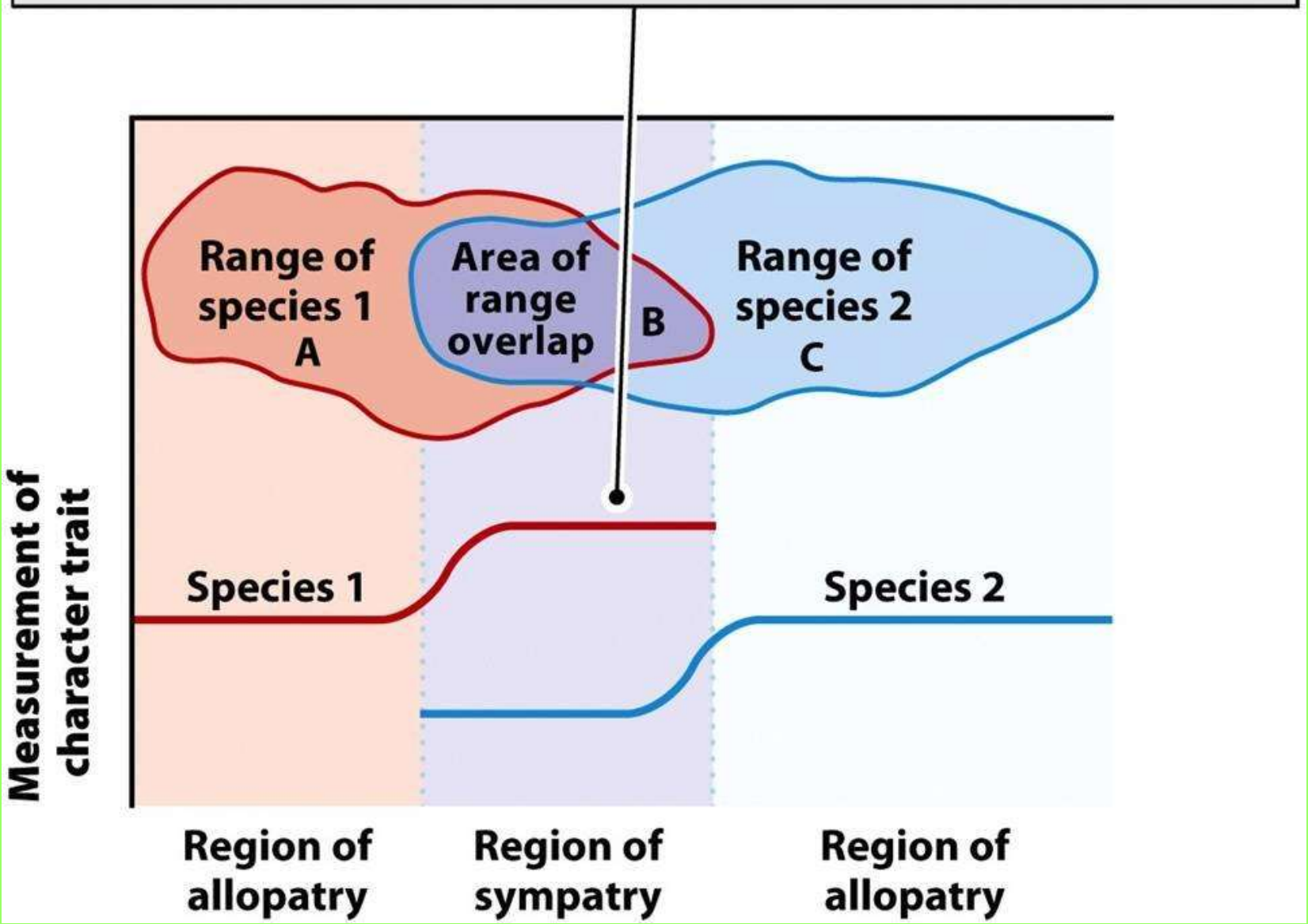
Ex: MacArther's Warbler studies

2) Character displacement

2. When two similar species exist in some portion of their ranges, small variations (physical or behavorial) become exaggerated

http://www.bio.unc.edu/faculty/servedio/Lab/dirsel%20copy.jpg

Character traits of two closely related species differ more where they are sympatric than where they are allopatric.



Ecological character displacement:

Sensory bias:

Predation

- Removal (killing) of animals or plants by other animals

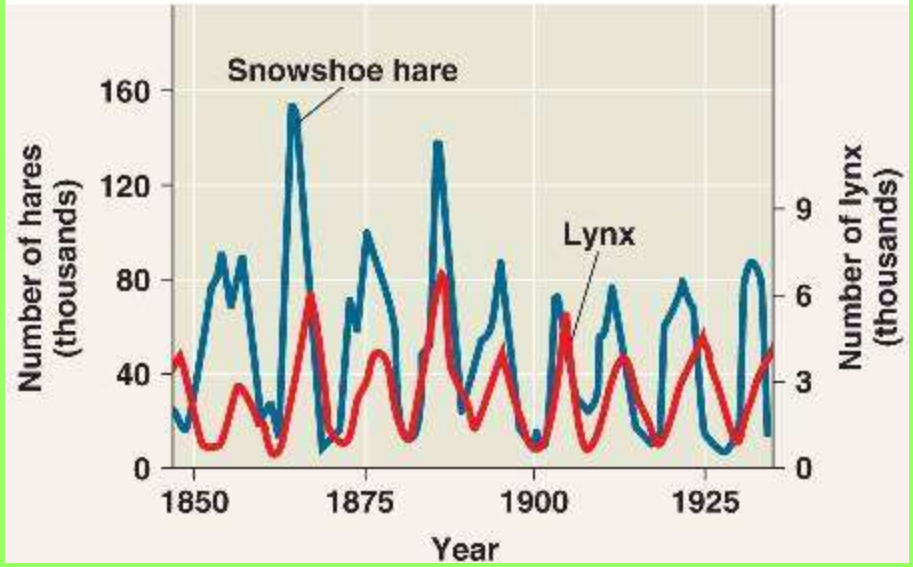
Role of predators in an ecosystem

- Predators remove the sick and weak individuals

- → greater access to resources for survivors

- increase gene pool strength (survival of fittest)

When predators and prey coexist, what population patterns do we see?



Characteristics of Predator-Prey cycles

- 1) Prey population must be greater than predator → predator growth

- 2) population spike in prey → increase in predator (time lag is due to slow rate of reproduction)

Examples of Predator-Prey cycles

- Lynx and hare
- Coyotes and rabbits

Adaptations of prey to limit predation

- Good escape ability (ex. Ostriches)
- Behavior (blowfish)
- External protection (spines on cacti and porcupines)
- Camouflage (arctic hares, walking sticks)
- Chemical warfare (skunks, insects, butterflies)
- aposematic or warning coloration (frogs, skunks)
- Mimicry (Monarchs and Viceroys)

Mimicry

Monarch Butterfly

Viceroy Butterfly

Adaptations of predators to catch prey

- Pursuit and ambush (strong legs, sharp teeth, wings, heightened senses, ability to see at night)

- Strategic (camouflage, hunting in packs, hunting at night)

Interspecific Interactions: Symbiosis

3 Types of symbiotic relationships

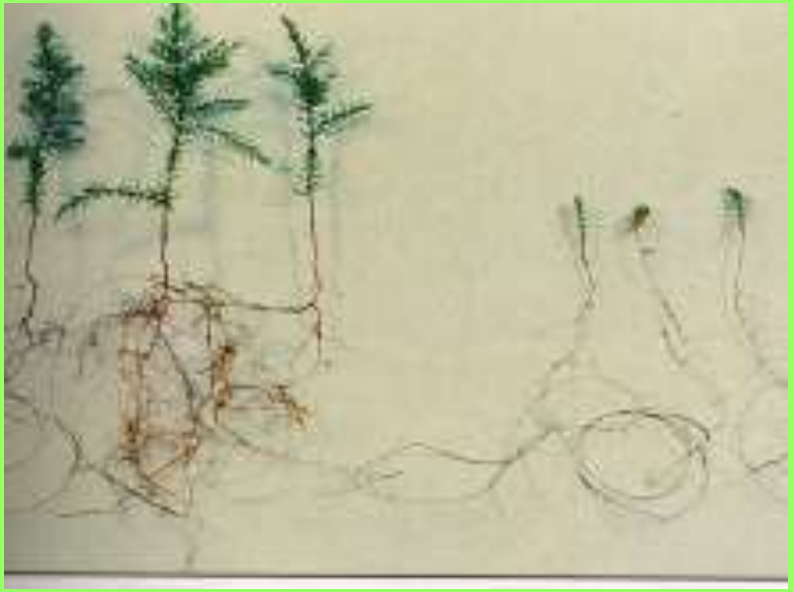
Type of relationship	Species 1	Species 2
Mutualism		
Commensalism		
Parasitism		

Characteristics of symbiotic relationships

- Symbiosis is an intimate relationship between members of two or more species
- Some species adapt in response to each other → co-evolution
- Can be very specific
- A change in one species often has large effects on a second species

Mutualism

- Both species benefit
- It can be facultative (helpful to both but not necessary for survival)
- ex. Rhinos and oxpeckers
- trees and mycorrhizae, rhizobium bacteria and legumes
- Pollination



- **OR**

Mutualism

- Obligate meaning that it is required for the survival of both species
- ex. Yucca and yucca moth, lichens (algae and fungi)

Commensalism

- Commensalism = one species benefits, and the other neither benefits, nor is harmed
- examples:
- Epiphytes and trees
- Barnacles on whales

Parasitism

Parasitism occurs when one species is harmed and the other species benefits

- Special case of predation, except
  - parasite is smaller than host
  - parasite remains assoc. with host, weakens it over time
  - rarely kills it

Ex. Lampreys
tapeworms
mistletoe

Parasitoidism

Parasitoidism = parasite (parasitoid) routinely kills the host

http://www.ars.usda.gov/is/graphics/photos/mar01/k5069-23i.jpg

Usually is insect to insect
Ex: tracheal mite parasites kill honeybees

Can be used to control pest populations
Ex. Wasps lay their eggs in insect hosts (wood boring beetles, aphids, caterpillars…)

Table 45.1 Types of Interactions Between Two Species

Type of Interaction	Direct Effect of Interaction*	
	Species 1	Species 2
Neutral	0	0
Commensalism	+	0
Mutualism	+	+
Interspecific competition	−	−
Predation	+	−
Parasitism	+	−

Zombies

Fact or Fiction

The Strange Science of the Living Dead

On Sinister pond

What's going on?

A. Toxic sludge from a local factory is causing mutations in the frogs

B. Random mutations are causing the deformities

C. The frogs are being zombified by symbiotic parasites.

The case of the fearless rat: Why are the rats suicidal?

a) Alien abduction
b) They've been zombified by a symbiotic parasite
c) fiction

Why do these relationships exist

Interdependence and evolution

- Species depend on and affect each other in an ecosystem.

- Evolution = change in traits of a population over time
- Best adapted survive and reproduce

- Co-evolution can occur when there are intimate relationships between species.

Traits that allow you to evolve

- Niche utilization
- Reproduction strategies

Review

- Identify Country with
- largest boreal forests
- Largest deciduous forest stands
- Most desertification
- Most rain forests

Know

- Symbiotic relationships
- Predation
- Types of competition
- MacArthurs studies
- Archaebacteria
- Eubacteria
- Eukaryotes

- Succession primary vs secondary
- Trophic levels and pyramids
- 10% rule
- Type of land with highest level of protection
- Economic incentives
- How to draw a food web (with arrows)
- Integrated pest management