ENVE203
Environmental Engineering Ecology
(Oct 01, 2012)

Elif Soyer

'Ecosystems and Energy'

What is Ecology?

Ernst Haeckel (19th century)

two Greek words

eco ‘house’ *logy* ‘study’

ecology ‘the study of one’s house’

What is Ecology?

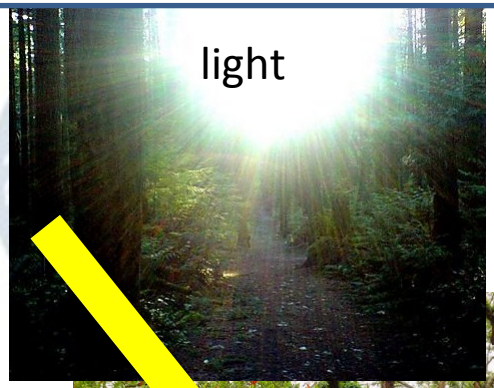
The environment (one's house)

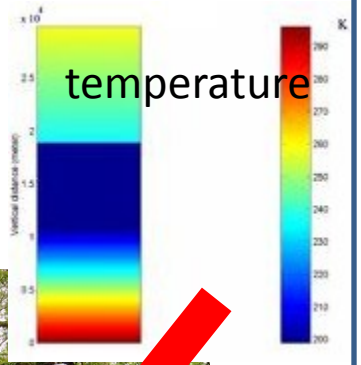
biotic (living) environment

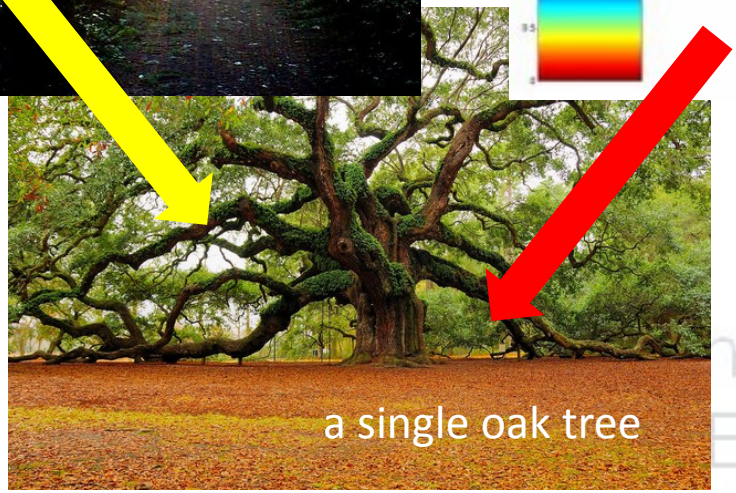
all organisms

abiotic (nonliving, or physical) surroundings

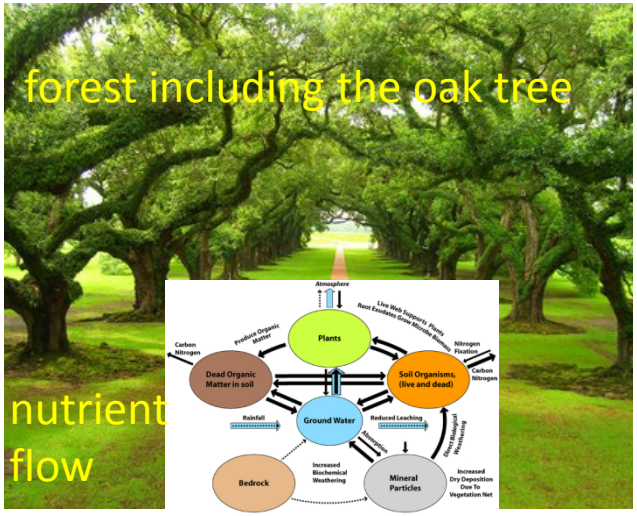
living space,
temperature,
sunlight,
soil,
wind, and
precipitation







all living organisms



Focus of ecology depends on what questions we are trying to answer...

Ecology

- Broadest field within the biological sciences
- Linked to every other biological discipline
  - Geology
  - Earth sciences
  - Chemistry
  - Physics
  - Biological organisms
  - Economics, politics

How does the field of ecology fit into the organization of the biological world?

Life; high degree of organization

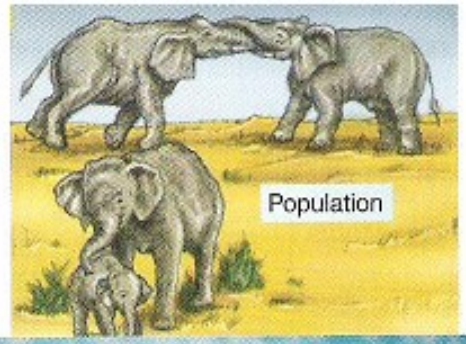
- Atoms → molecules
- Molecules → cells
- Cells in multicellular organisms → tissues
- Tissues → organs
- Organs → body sistems
- Body sistems → individual organisms

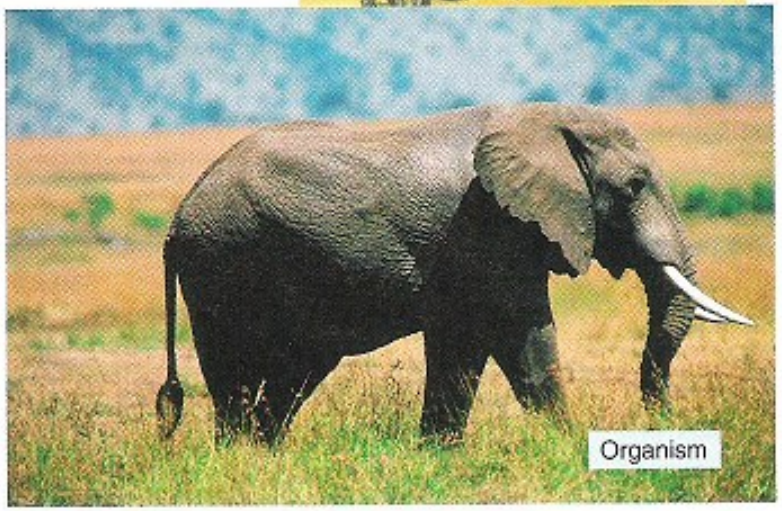
Ecologists interested in levels of biological organizations...

Individuals of the same **species** occur in **populations**

Species: A group of similar organisms whose members freely interbreed with one another

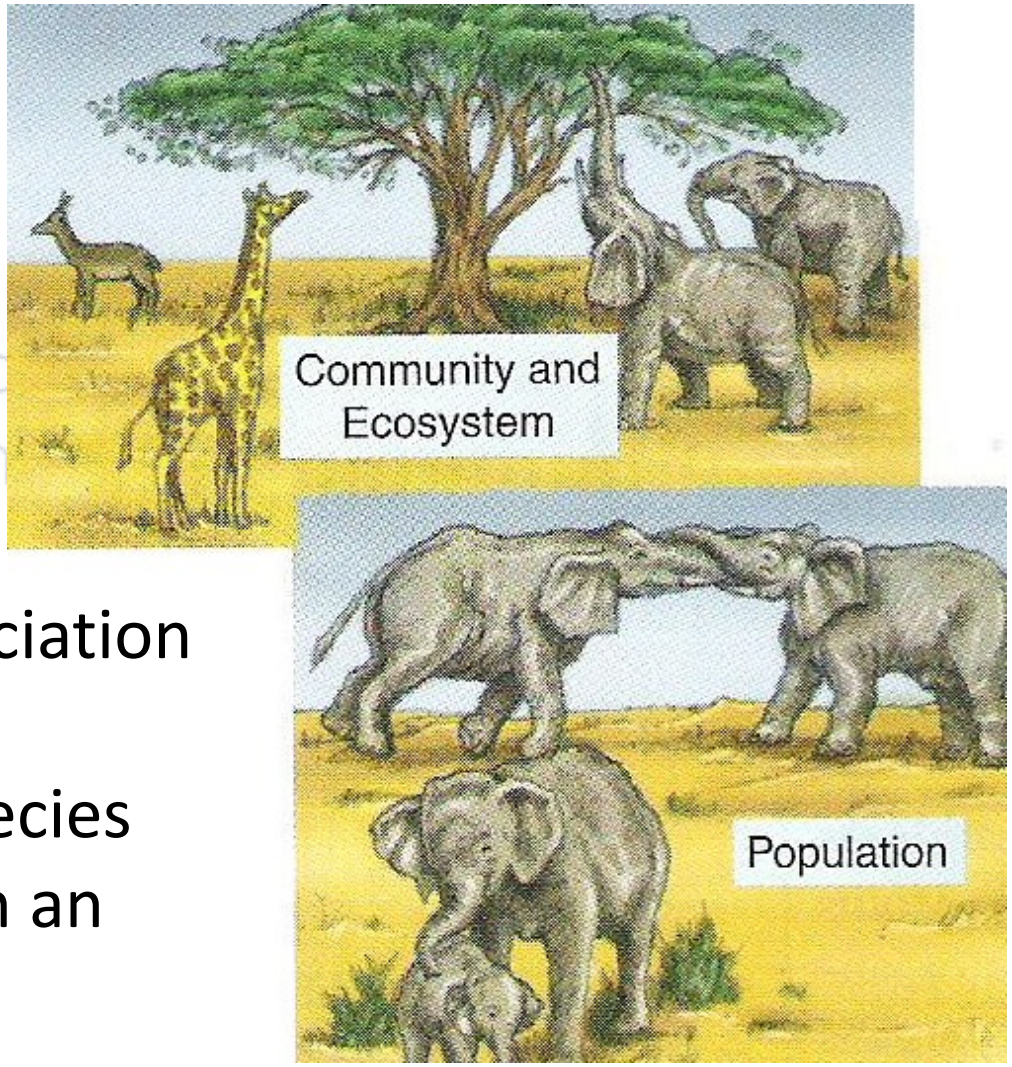
Population: A group of organisms of the same species that live in the same area at the same time





Ecologists interested in levels of biological organizations…

Populations are organized into **communities**



Community: A natural association that consists of all the populations of different species that live and interact within an area at the same time

Ecologists interested in levels of biological organizations...

Characterization of communities

- Number and kinds of species that live there
- How organisms interact with one another (e.g. feeding relationships –who eats whom?)

Ecosystem

Ecosystem is a more inclusive term than **community**

Ecosystem: A community and its physical environment

All the biotic interactions of a community as well as the interactions between organisms and their abiotic environment

Ecosystem

A forest ecosystem

A pond ecosystem

An ocean ecosystem

....

Biological

Physical

Chemical components

form a complex, interacting network of energy flow and materials cycling

Ecosystem processes regulate

global cycles of

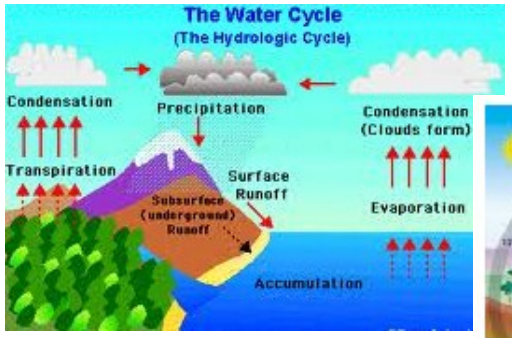
water,

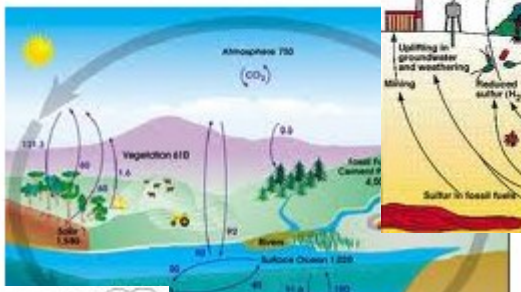
carbon,

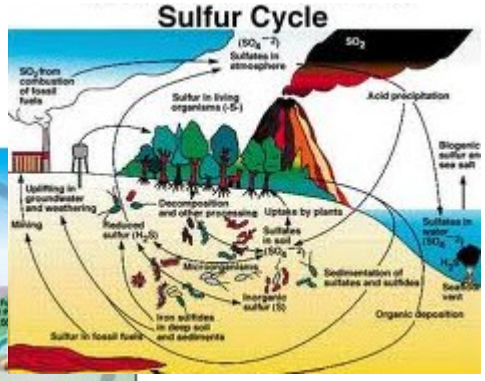
nitrogen,

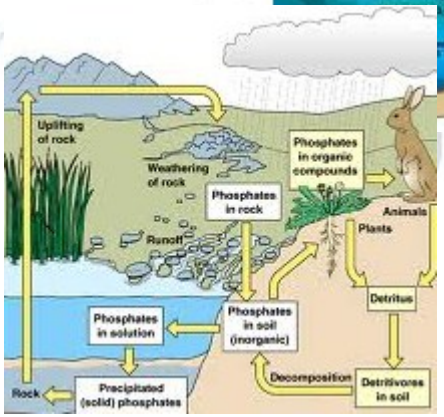
phosphorus, &

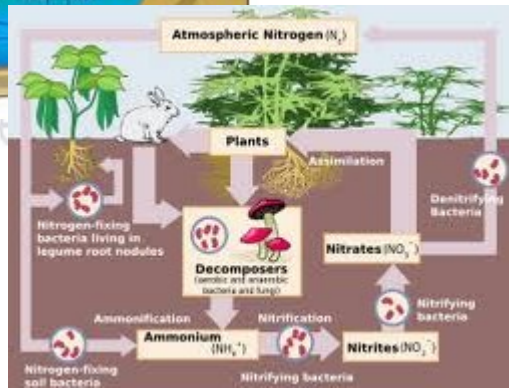
sulfur







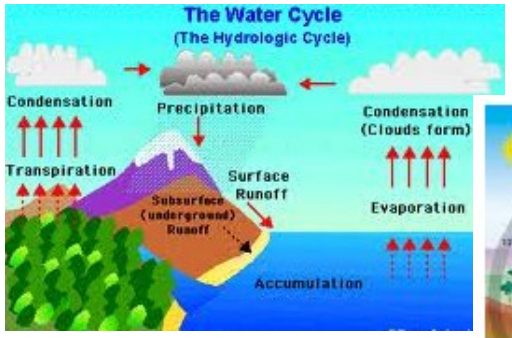


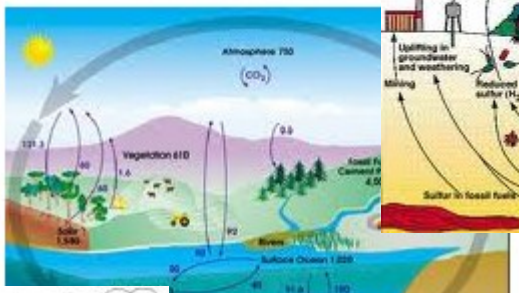


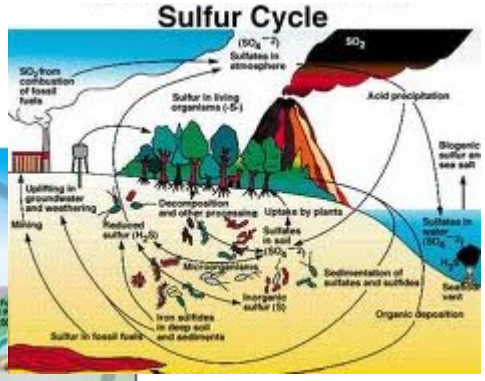
essential to the survival of humans and other organisms

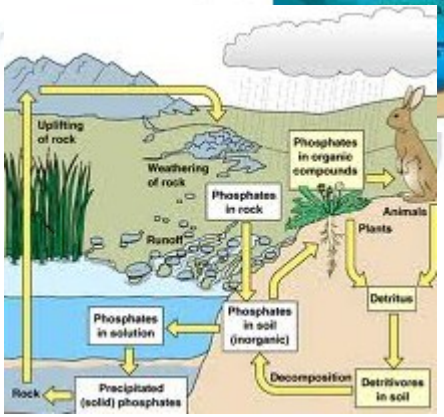
As humans increasingly alter ecosystems

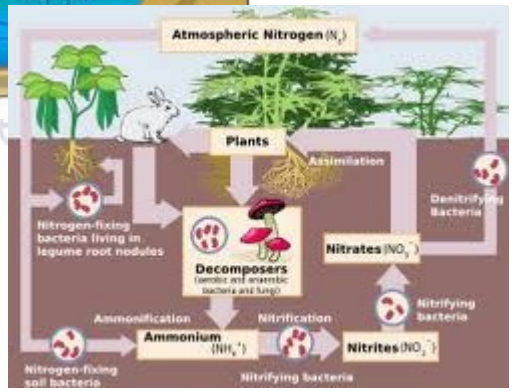
Natural functioning of ecosystems is changed









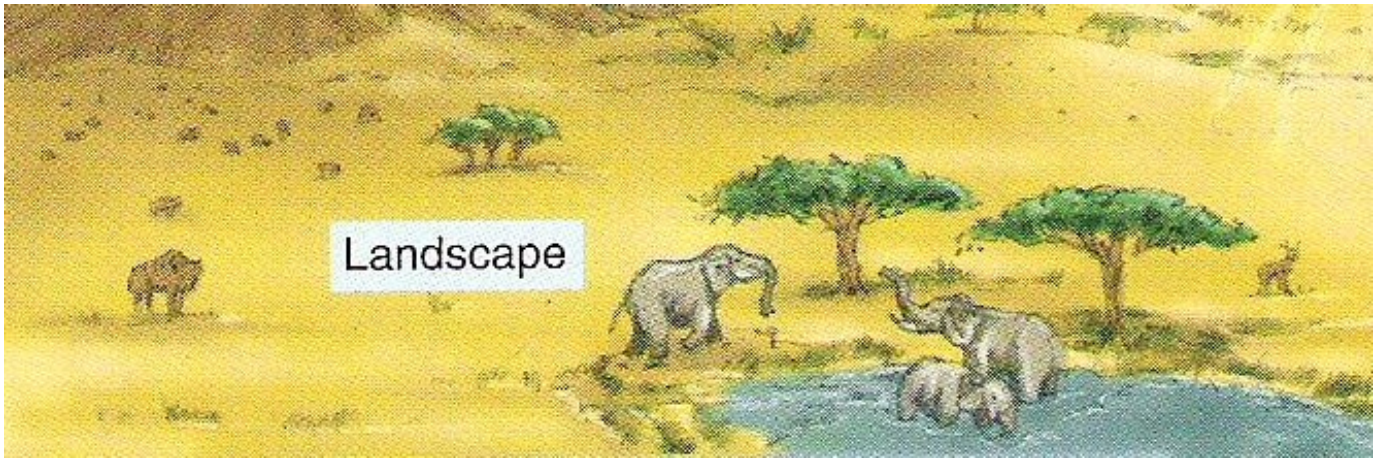


How these changes will affect the sustainability of our life-support system?

Landscape ecology

- Subdiscipline of ecology
- Studies ecological processes that operate over large areas

<u>Landscape</u>: A region that includes several interacting ecosystems



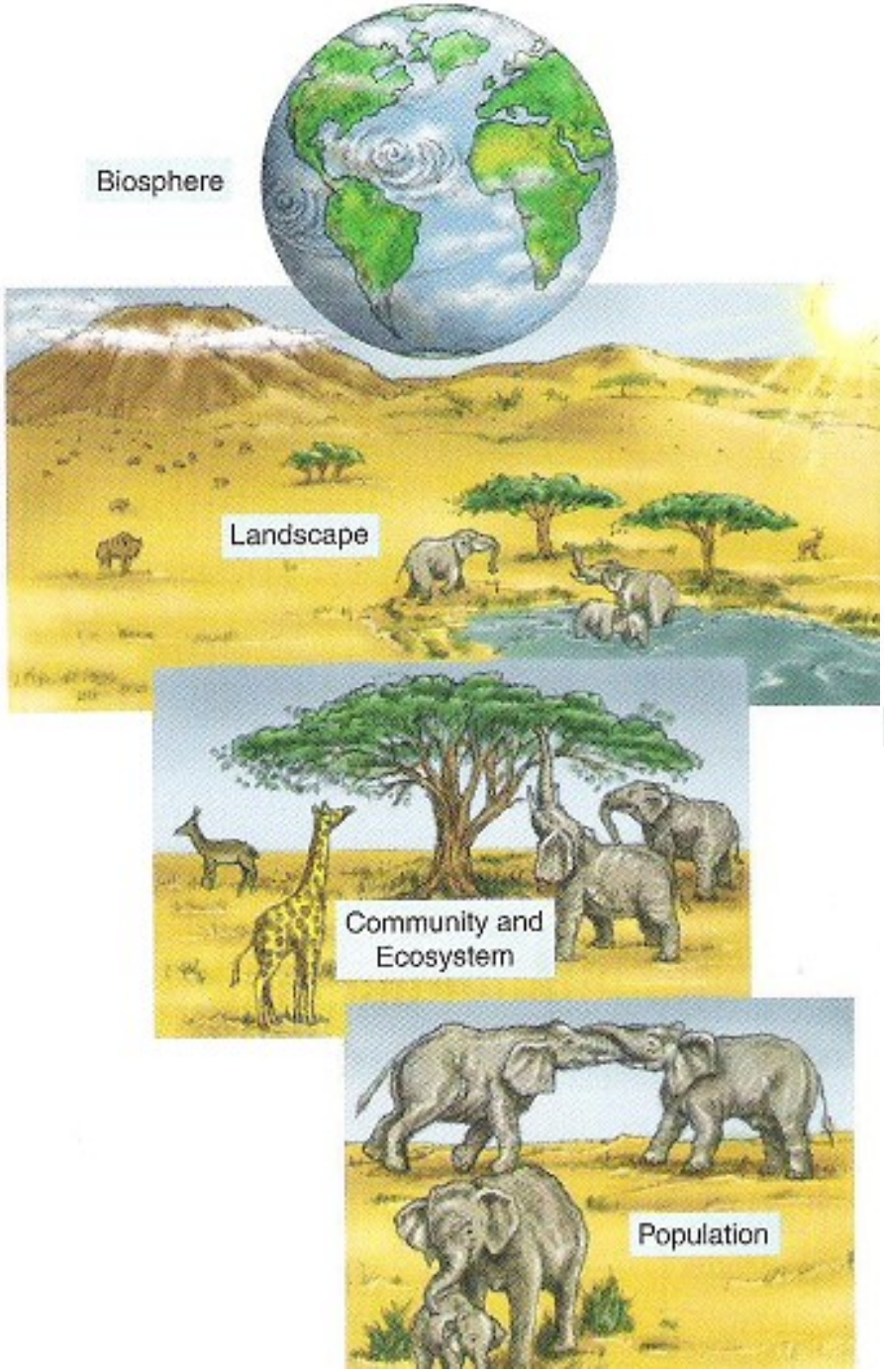
Biosphere

Organisms of the biosphere

- Earth's communities
- Ecosystems
- Landscapes

depend on one another and the Earth's pysical environment:

- Atmosphere
- Hydrosphere
- Lithosphere

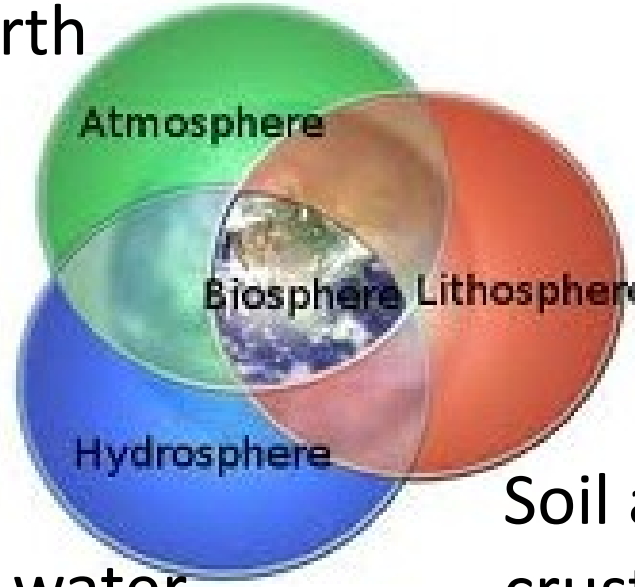


Biosphere

The parts of Earth's atmosphere, ocean, land surface, and soil that contain living organisms

Biosphere

Gaseous envelope surrounding Earth



Soil and rock of Earth's crust

Earth's suppy of water

Ecologists who study the Biosphere:
Global interrelationships among Earth's atmosphere, land, water, and organisms

Energy of life

Energy of life

- Biosphere is filled with life

Organisms survive only as long as the environment continuously supplies them with energy

- Where do these organisms get the energy to live?
- How do they harness this energy?

Energy of life

Energy: Capacity or ability to do work

Any biological work in organisms

- growing
- moving
- reproducing
- repairing damaged tissues

requires energy

Energy

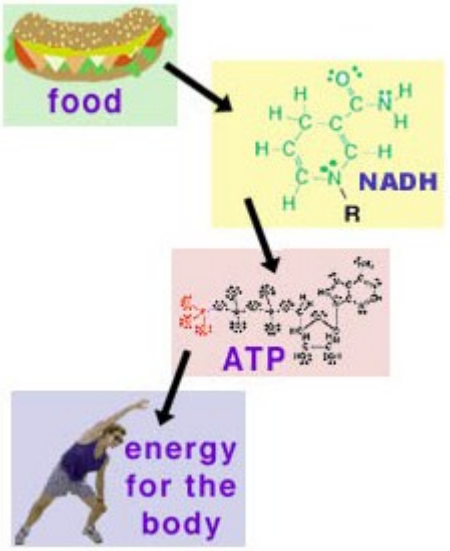
- Chemical
- Radiant
- Thermal
- Mechanical
- Nuclear
- Electrical

Biologists generally express energy in units of

Work (kilojoules, kJ)

Heat (kilocalories, kcal)

Chemical Energy



- Stored in the bonds of molecules

How organisms use chemical energy?

Foods contain chemical energy

Energy relases when chemical bonds are broken

Radiant energy

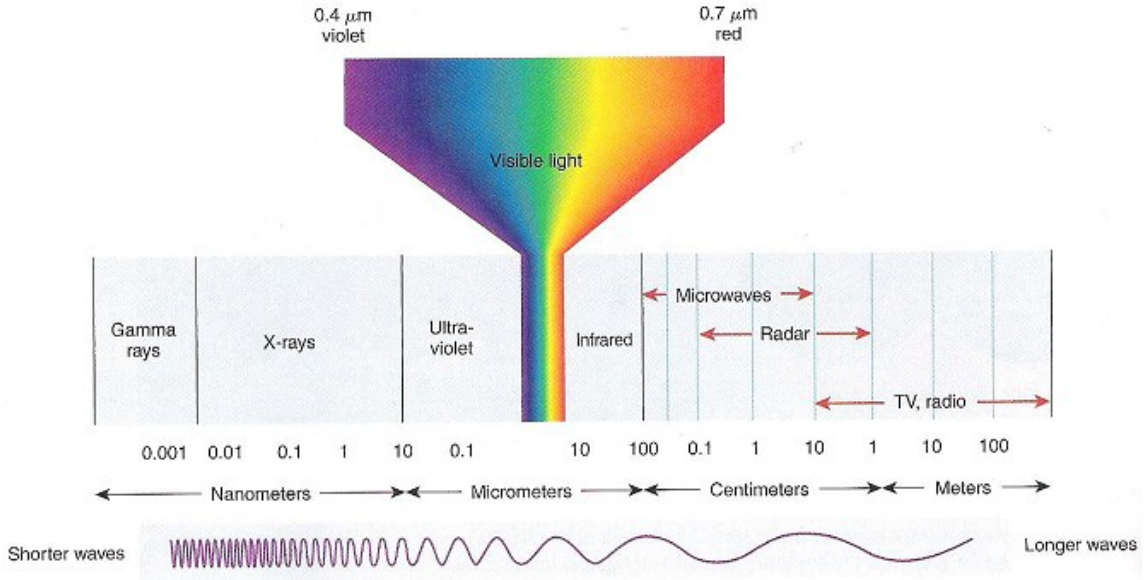
Energy that is transmitted as electromagnetic waves

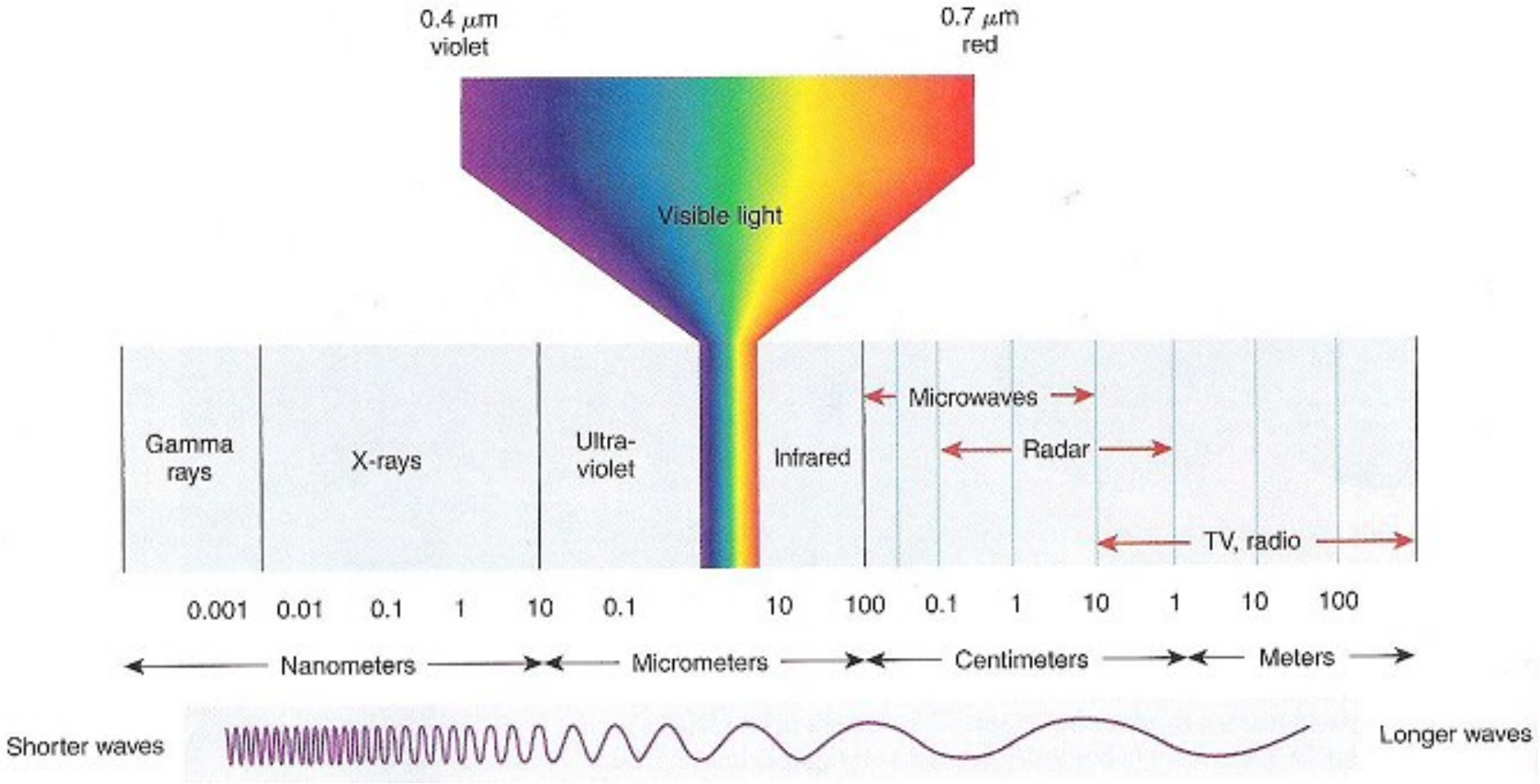
- Radio waves
- Visible light
- X-rays

Solar energy

Radiant energy from the sun

- Ultraviolet radiation
- Visible light
- Infrared radiation




0.4 μm
violet
0.7 μm
red
Visible light
Gamma rays
X-rays
Ultra-violet
Infrared
Microwaves
Radar
TV, radio
0.001
0.01
0.1
1
10
0.1
10
100
0.1
1
10
1
10
100
Nanometers
Micrometers
Centimeters
Meters
Shorter waves
Longer waves

Thermal energy

- Heat that flows from an object with a higher temperature to an object with a lower temperature

Heat source: an object with a higher temperature

Heat sink: an object with a lower temperature

Mechanical energy

- Energy in the movement of matter

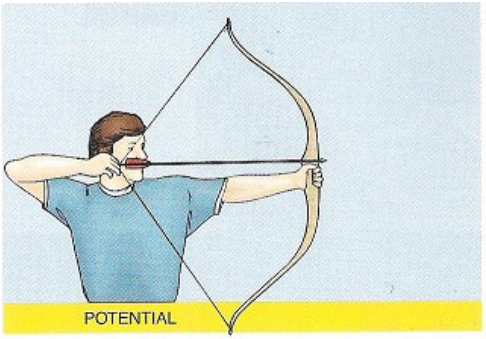
Nuclear energy

- Matter contained in atomic nuclei can be converted into nuclear energy

Electrical energy

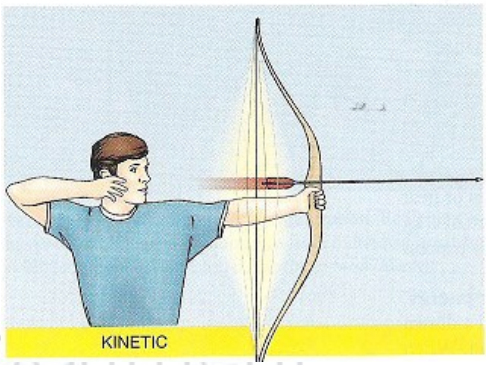
- Energy that flows as charged particles

Energy



Existance

- Potential energy (stored energy)
- Kinetic energy (energy of motion)



Energy changes from one form to another

Thermodynamics

The study of energy and its transformations

1st Law of Thermodynamics

Energy cannot be created or destroyed

It can change from one form to another

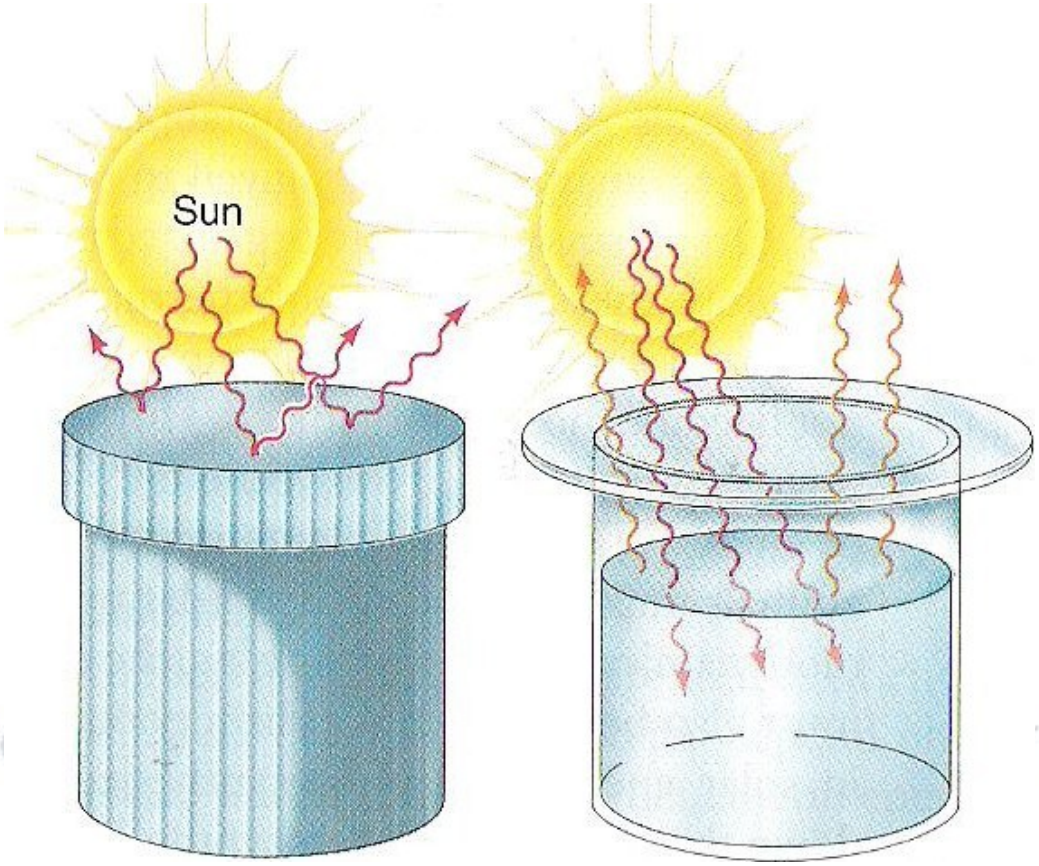
1st Law of Thermodynamics

An organism

- absorb energy from its surroundings
- give up some energy into its surroundings

but the total energy content of the organism and the surroundings is always the same

An organism cannot create the energy it requires to live; it must capture the energy from the environment to use for biological work



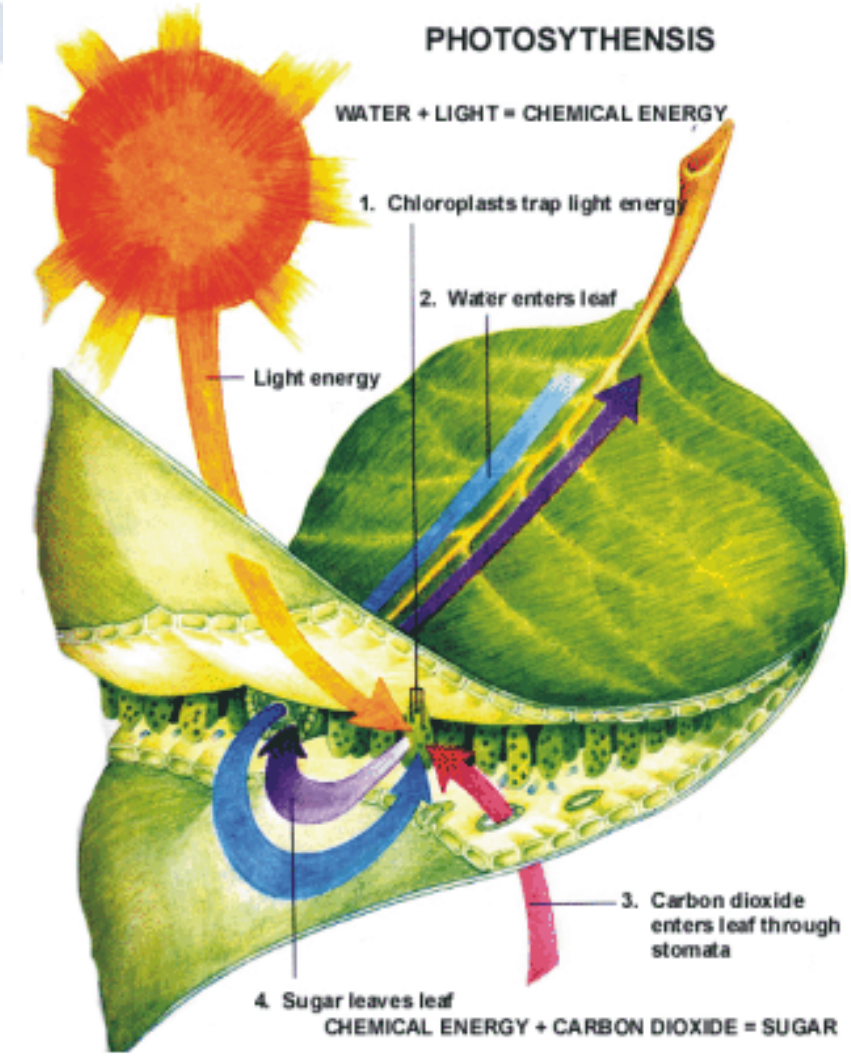
Closed system

- Energy is not exchanged between a closed system and its surroundings
- A thermos bottle is an approximation of a closed system.
- Closed systems are rare in nature

Open system

- Energy is exchanged between an open system and its surroundings
- Earth is an open system. It receives energy from the sun, and this energy eventually escapes Earth as it dissipates into space

1st Law of Thermodynamics



2nd Law of Thermodynamics

When energy is converted from one form to another, some of it is degraded into

HEAT,

a less usable form that disperses into the environment

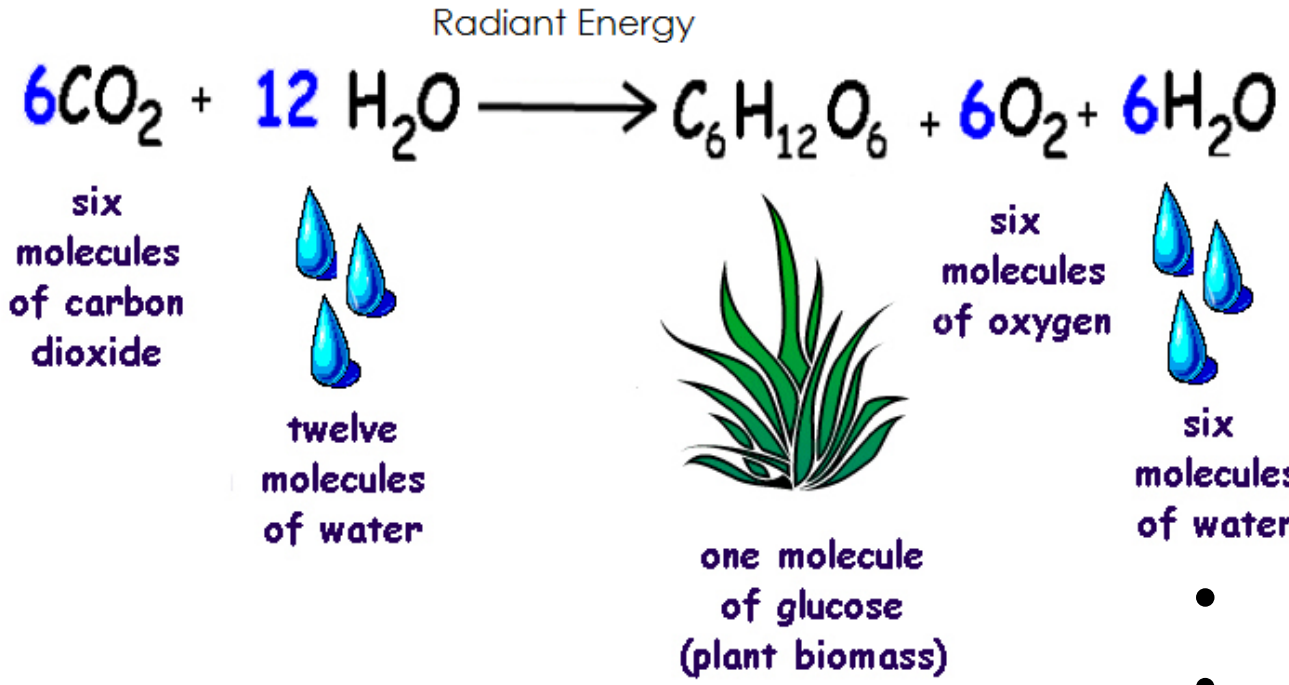
2nd Law of Thermodynamics

- Total amount of energy is not decreasing with time

however

- Total amount of energy in the universe available to do work decreases over time

Photosynthesis



- Plants
- Some bacteria
- Algea

- A biological process
- Light energy from sun is captured
- Transformed into the chemical energy of carbohydrate (sugar) molecules

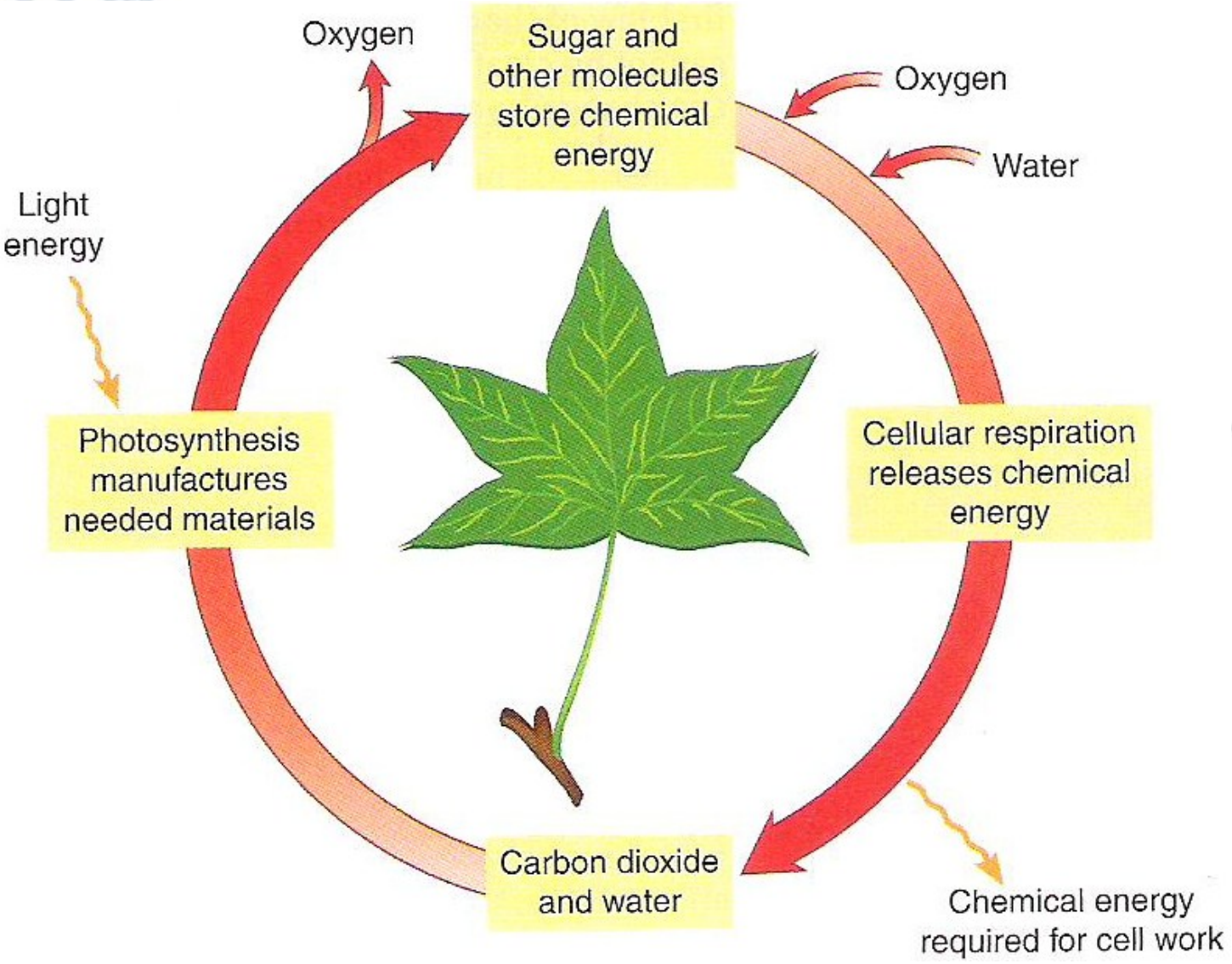
Cellular respiration

- Chemical energy that plants store in carbohydrates and other molecules is released within the cells of plants, animals, or other organisms

- Aerobic cellular respiration:

Molecules (e.g. glucose) broken down in the presence of O_2 and H_2O into CO_2 and H_2O, with the release of energy

Photosynthesis and Cellular Respiration



Energy Flow

The passage of energy in a one-way direction through an ecosystem

- All organisms respire to obtain energy
- Cellular respiration breaks molecules apart
- Energy becomes available for work
- As the work is accomplished, energy escapes the organisms and dissipates into the environment as heat
- Heats radiates into space

Once an organism has used energy, it becomes unusable for all other organisms

Organisms of an Ecosystem

Three categories on the basis of how they obtain nourishment:

- Producers
- Consumers
- Decomposers

Producers (Autotrophs)

two Greek words

auto 'self' *tropho* 'nourishment'

Manufacture organic molecules from simple inorganic substances, generally CO_2 and H_2O, usually using the energy of sunlight

i.e. most producers perform the process of PHOTOSYNTHESIS

Producers (Autotrophs)

on land

Plants are the most significant producers

in aquatic environments

Algea and certain types of bacteria

Consumers (Heterotrophs)

two Greek words

heter ‘different’ *tropho* ‘nourishment’

Animals are consumers
Use bodies of other organisms as a source of food energy and bodybuilding materials

Primary Consumers (Herbivores or plant eaters)

- Eat producers
- Rabbits and deer

Flesh-eating carnivors (eat other animals)

Secondary Consumers

eat primary consumers

Tertiary Consumers

eat secondary consumers

Examples: Lions, lizards, and spiders

Omnivores

- Eat a variety of organisms (both plant and animal)

- Examples: Bears, humans

Detritus feeders or detritivores

- Consume detritus

Detritus: Organic matter that includes animal carcasses, leaf litter, and feces

Detritus feeders work with microbial decomposers to destroy dead organisms and waste products

Decomposers (saprotrophs)

two Greek words

sapro 'rotten' *tropho* 'nourishment'

Heterotrophs that break down dead organic material and use the decomposition products to supply themselves with energy

Decomposers (saprotrophs)

- Release simple inorganic molecules (e.g. CO_2 and mineral salts) that producers can use

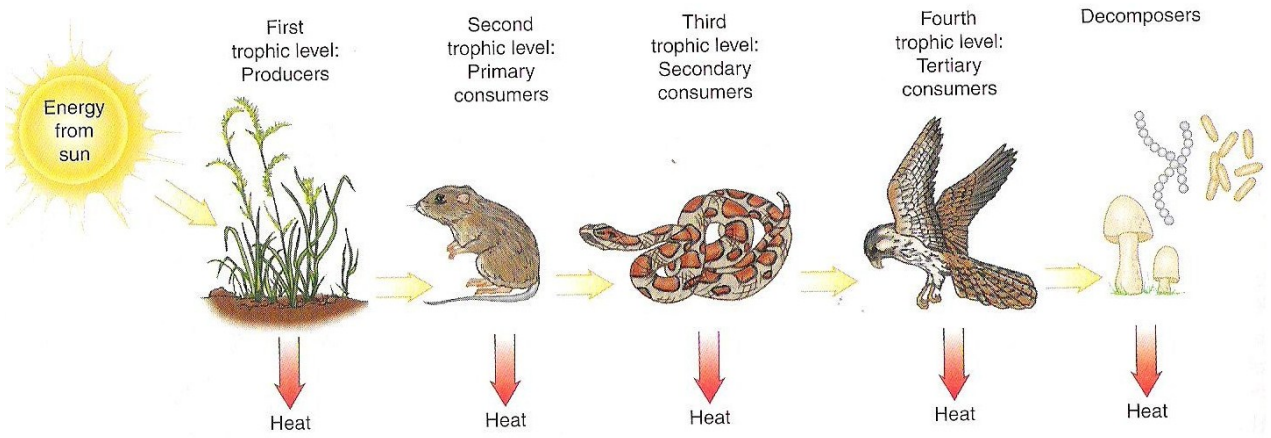
- Bacteria and fungi

Path of Energy Flow: Who Eats Whom in Ecosystems

- In an ecosystem, energy flow occurs in food chains

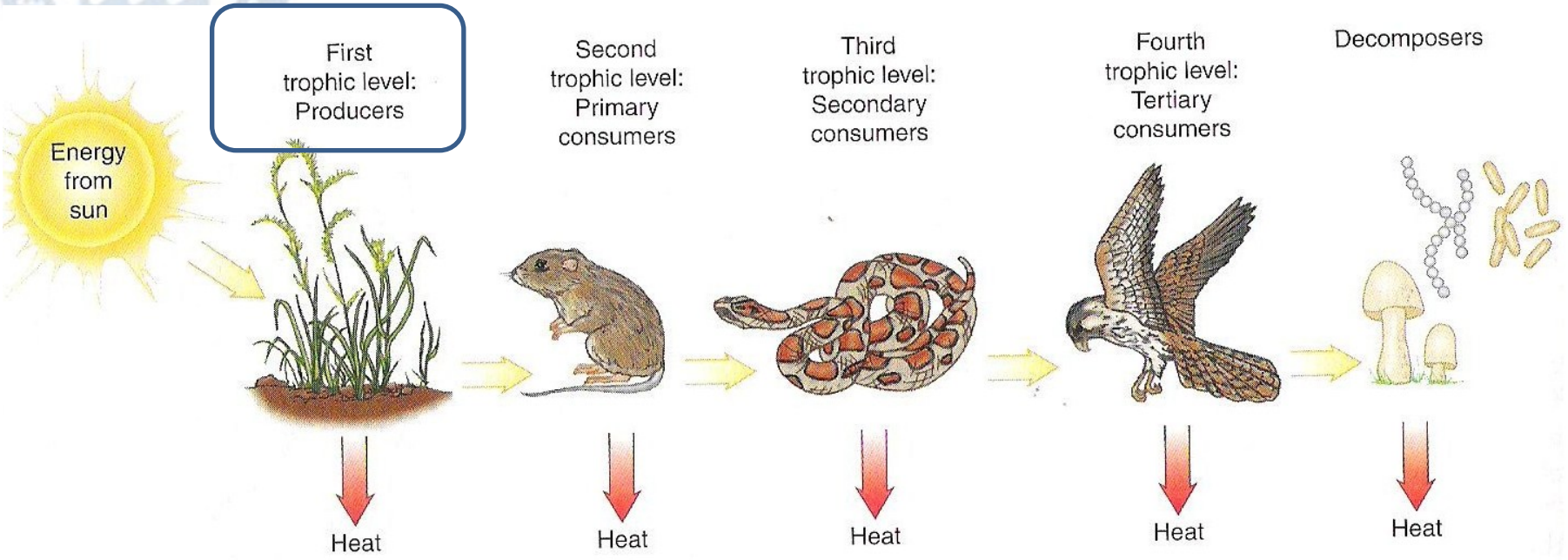
Food chains:

Energy from food passes from one organism to the next in a sequence



Path of Energy Flow: Who Eats Whom in Ecosystems

Each level, or 'link' in a food chain is a trophic level



Producers (photosynthesizers): 1st trophic level

Primary consumers (herbivores): 2nd trophic level

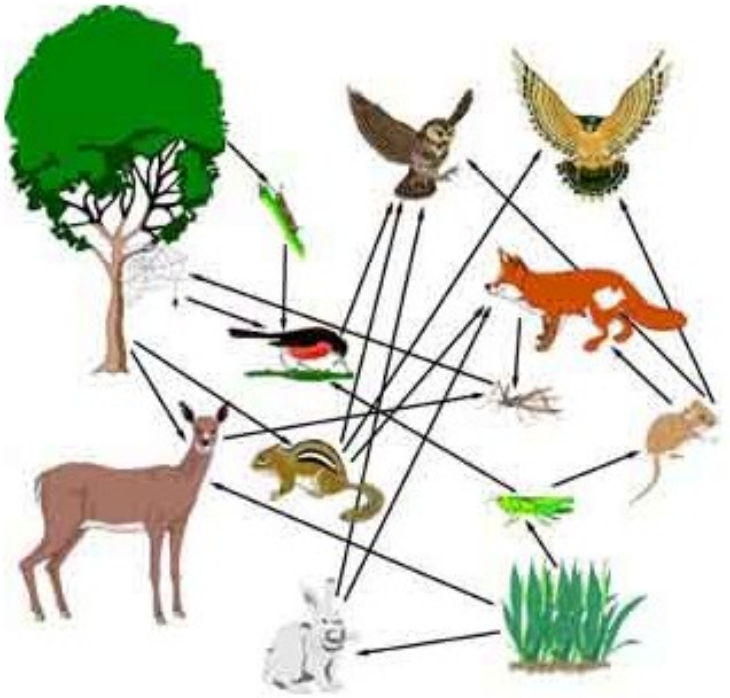
Secondary consumers (carnivores): 3rd trophic level

...

At every step in a food chain are decomposers (respire organic molecules in the carcasses and body wastes of all members in a food chain)

Path of Energy Flow: Who Eats Whom in Ecosystems

- Simple food chain rarely occur in nature
- Flow of energy and materials takes place in accordance with a range of food choices for each organisms envolved
- Numerous alternative pathways
- A food web is more realistic than a food chain



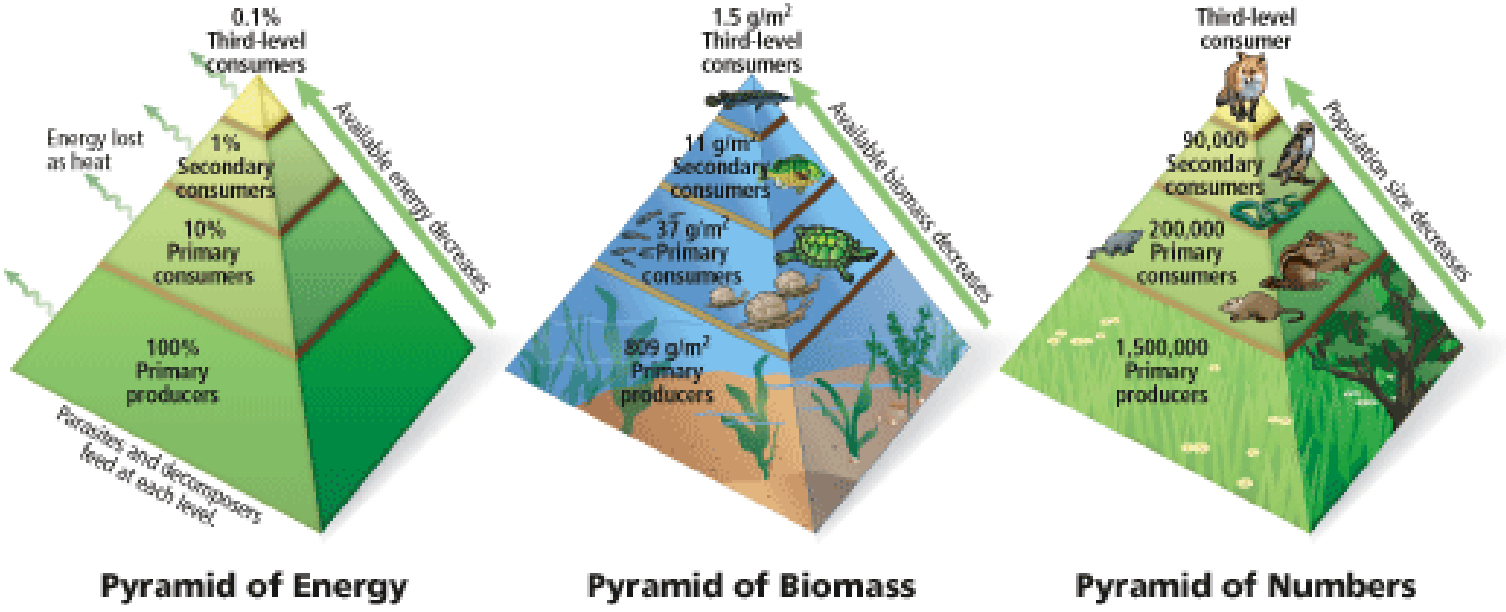
Path of Energy Flow: Who Eats Whom in Ecosystems

- Energy flow in ecosystems is linear, or one way
- Moves from one organism to the next
- Once used by an organism; lost as heat, unavailable


1 Pitch pine
2 White oak
3 Barred owl
4 Gray squirrel
5 Eastern chipmunk
6 Eastern cottontail
7 Red fox
8 White-tailed deer
9 Red-tailed hawk
10 Eastern bluebird
11 Red-winged blackbird
12 Blackberry
13 American robin
14 Woodpecker
15 Red clover
16 Bacteria and fungi
17 Worms and ants
18 Moths
19 Deer mouse
20 Spiders
21 Insect larvae
22 Insects
23 Fungi

Ecological Pyramids

- A graphical representation of the relative energy values of each trophic level
- Main types
  - A pyramid of numbers (#)
  - A pyramid of biomass (g/m^2)
  - A pyramid of energy ($kcal/m^2/year$)

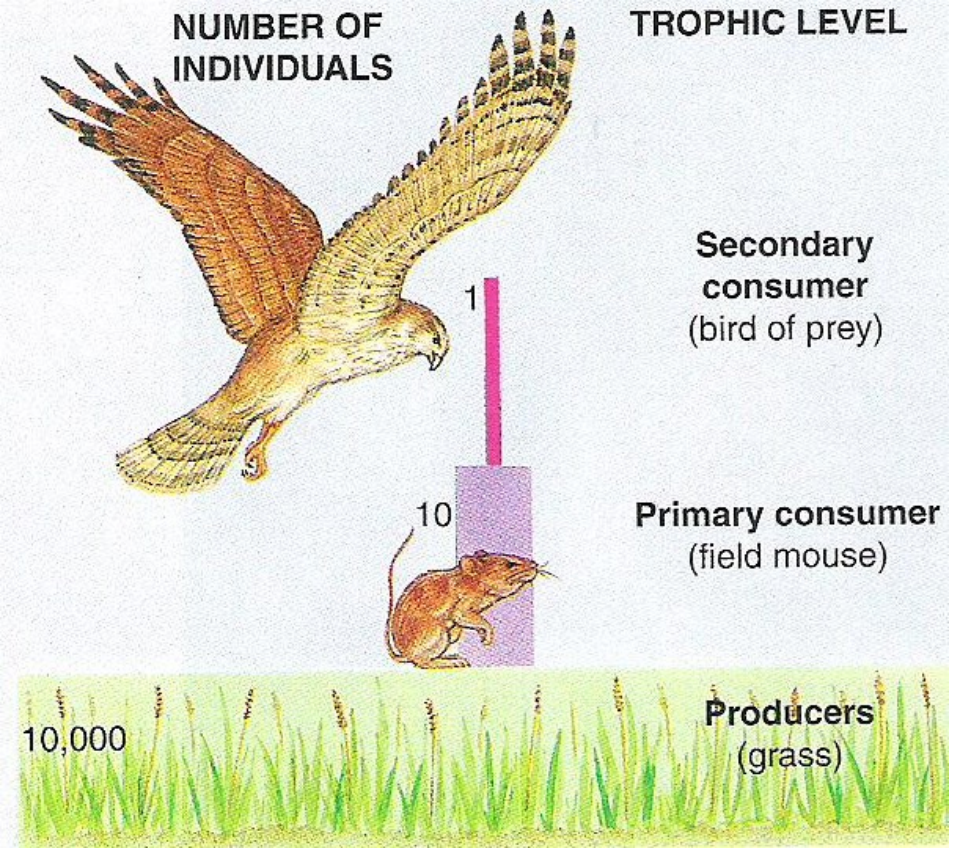


Ecological Pyramid of Numbers

- Shows the number of organisms at each trophic level
- Greater numbers illustrated by a larger area for that section of the pyramid

Organisms at the base most abundant

Fewer in each successive level



Ecological Pyramid of Numbers

Inverted pyramids of numbers

Higher trophic levels have *more* organisms than lower trophic leves

Often observed among decomposers, parasites, and similar organisms

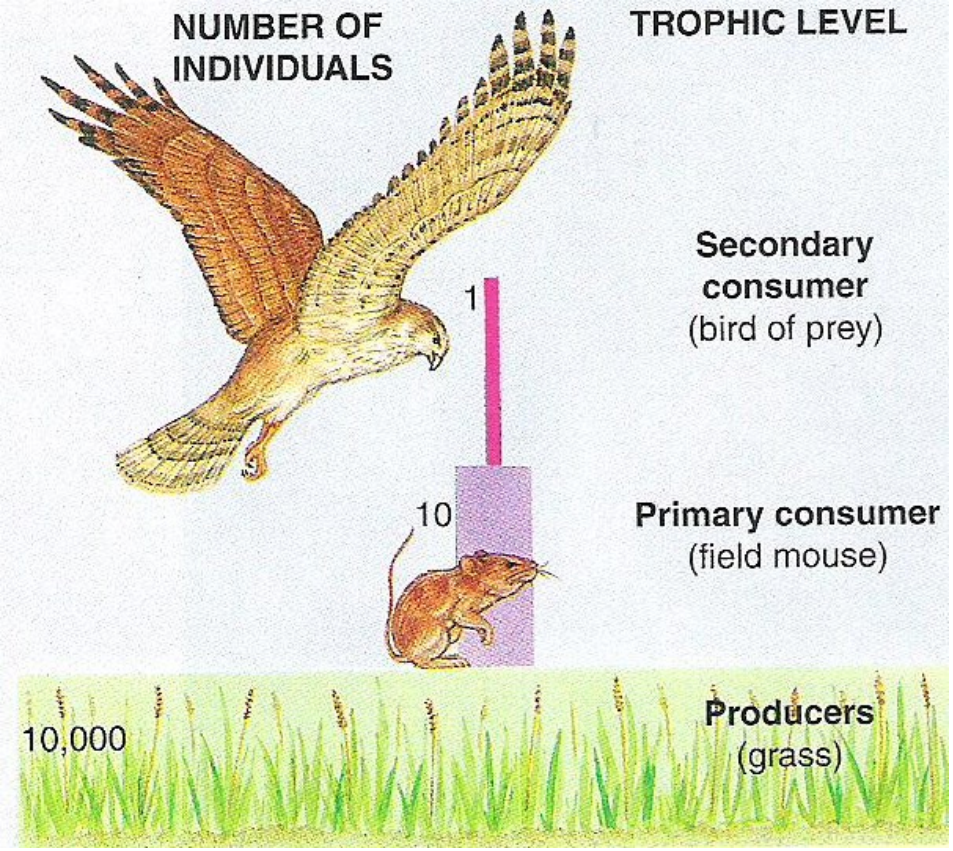
A tree &
Thousands of leaf-eating insects!

Ecological Pyramid of Numbers

Limited usefulness

Do not indicate the <u>biomass of the organisms</u> at each level

Do not indicate the <u>amount of energy transferred from one level to another</u>



Ecological Pyramid of Biomass

- Illustrates the total biomass at each successive trophic level

Biomass:

Quantitative estimate of the total mass, or amount of living material

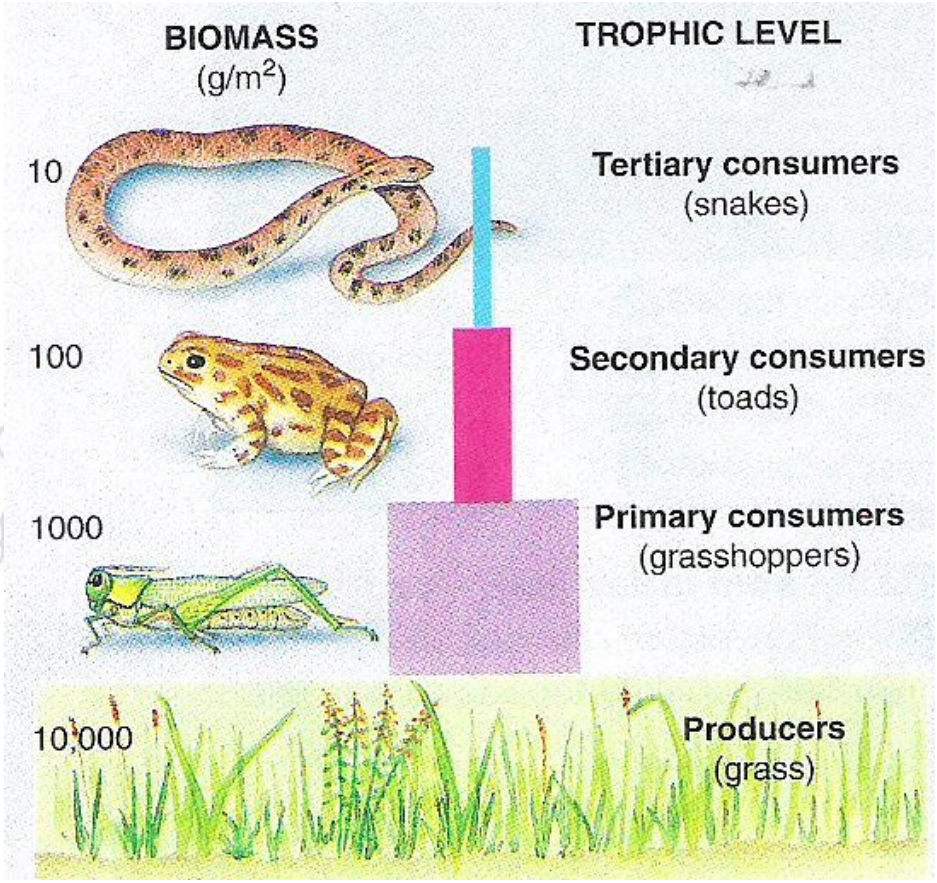
Indicates the amount of fixed energy at a particular time

Units: total volume, as dry weight, as live weight

Ecological Pyramid of Biomass

Typically illustrates a progressive reduction of biomass in succeeding trophic levels

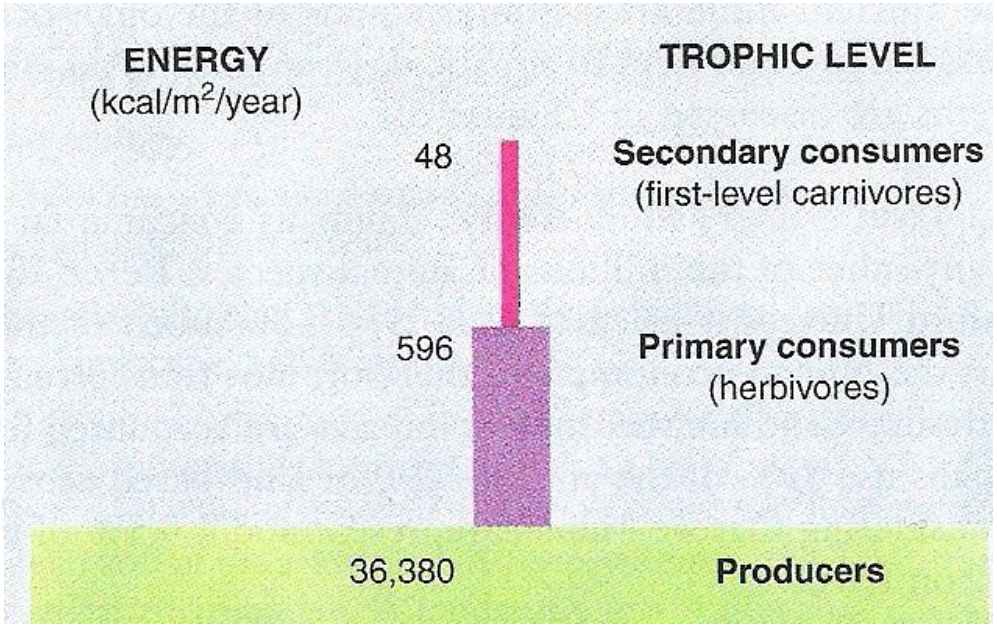
Although carnivores do not eat vegetation, a great deal of vegetation is required to support them



Ecological Pyramid of Energy

- Illustrates the energy content of the biomass of each trophic level

- These pyramids always have large energy bases and get progressively smaller through succeding trophic levels



Most energy dissipates into the environment when going from one trophic level to the next

Food webs are short because of the dramatic reduction in energy content at each trophic level

Ecosystem Productivity

Gross Primary Productivity (GPP)

Rate at which energy is captured during photosynthesis

Net Primary Productivity (NPP):

Energy in plant tissues after cellular respiration (plants respire to provide energy for their own use)

Rate, at which the organic matter is actually incorporated into plant tissues for growth

primary

plants occupy the first trophic level in food webs

Ecosystem Productivity

Net primary productivity (plant growth per unit area per unit time) = **Gross primary productivity** (total photosynthesis per unit area per unit time) – **Plant cellular respiration** (per unit area per unit time)

Units:

Energy

(kilocalories of energy fixed by photosynthesis per square meter per year)

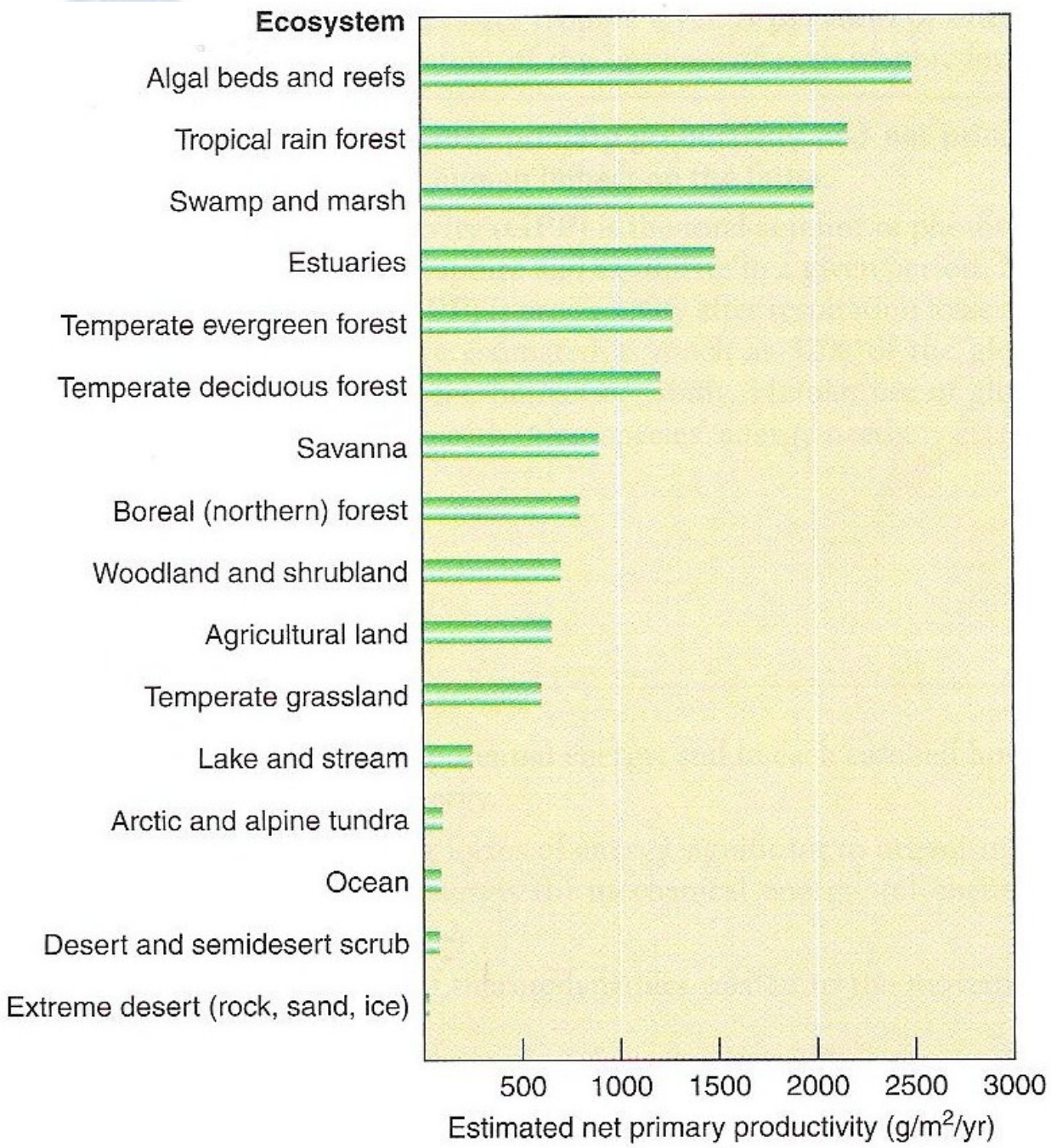
Dry weight

(grams of carbon incorporated into tissue per square meter per year)

Ecosystem Productivity

- Only the energy NPP is available for food for an ecosystem's consumers
- Consumers use most of this energy for obtaining food and avoiding predators and to maintain and repair cells and tissues
- Any energy remains is used for growth (*secondary productivity*)

Any environmental factor that limits an ecosystem's primary productivity limits secondary productivity by its consumers



Estimated annual net primary productivities (NPP) for selected ecosystems