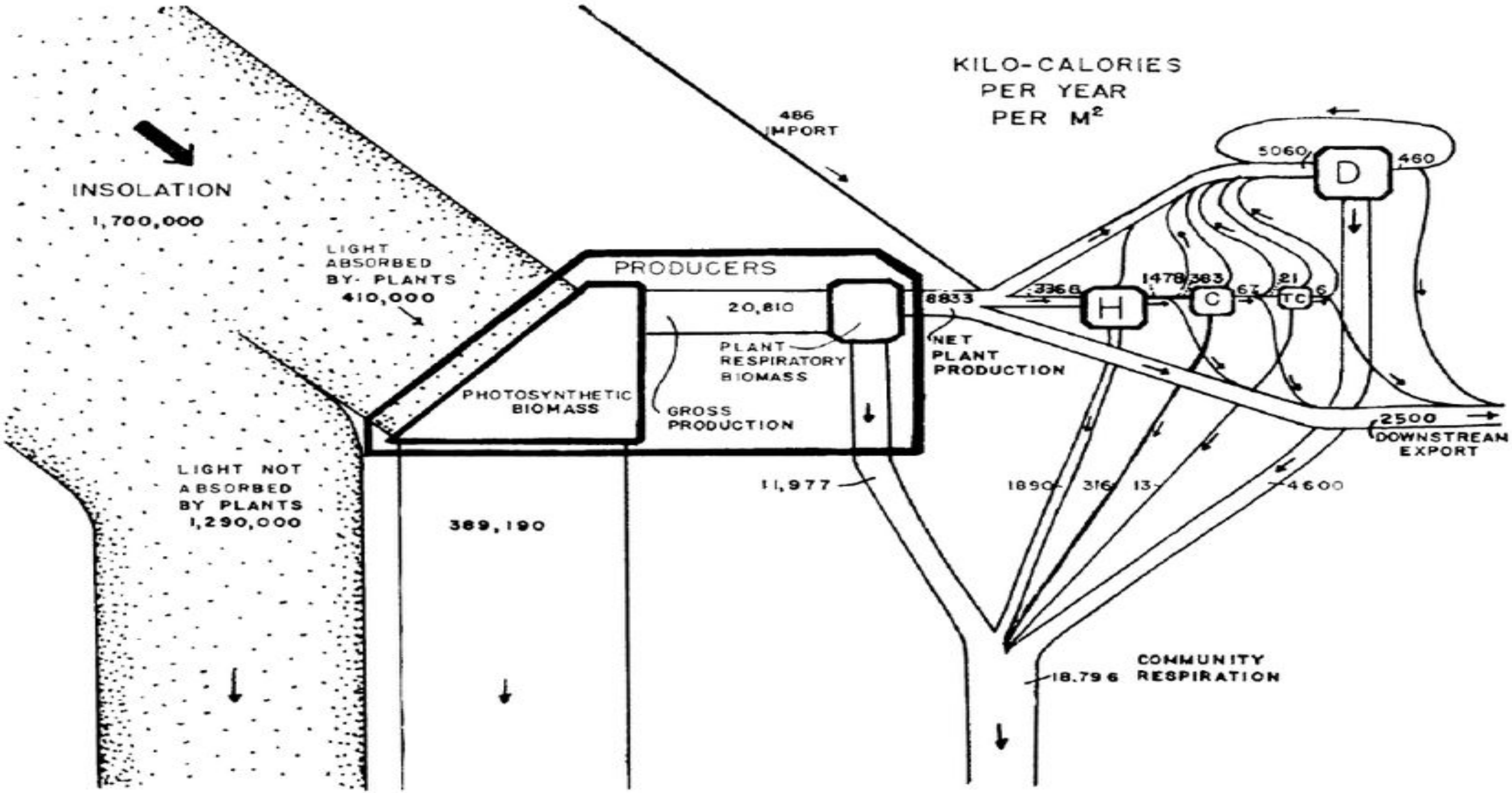
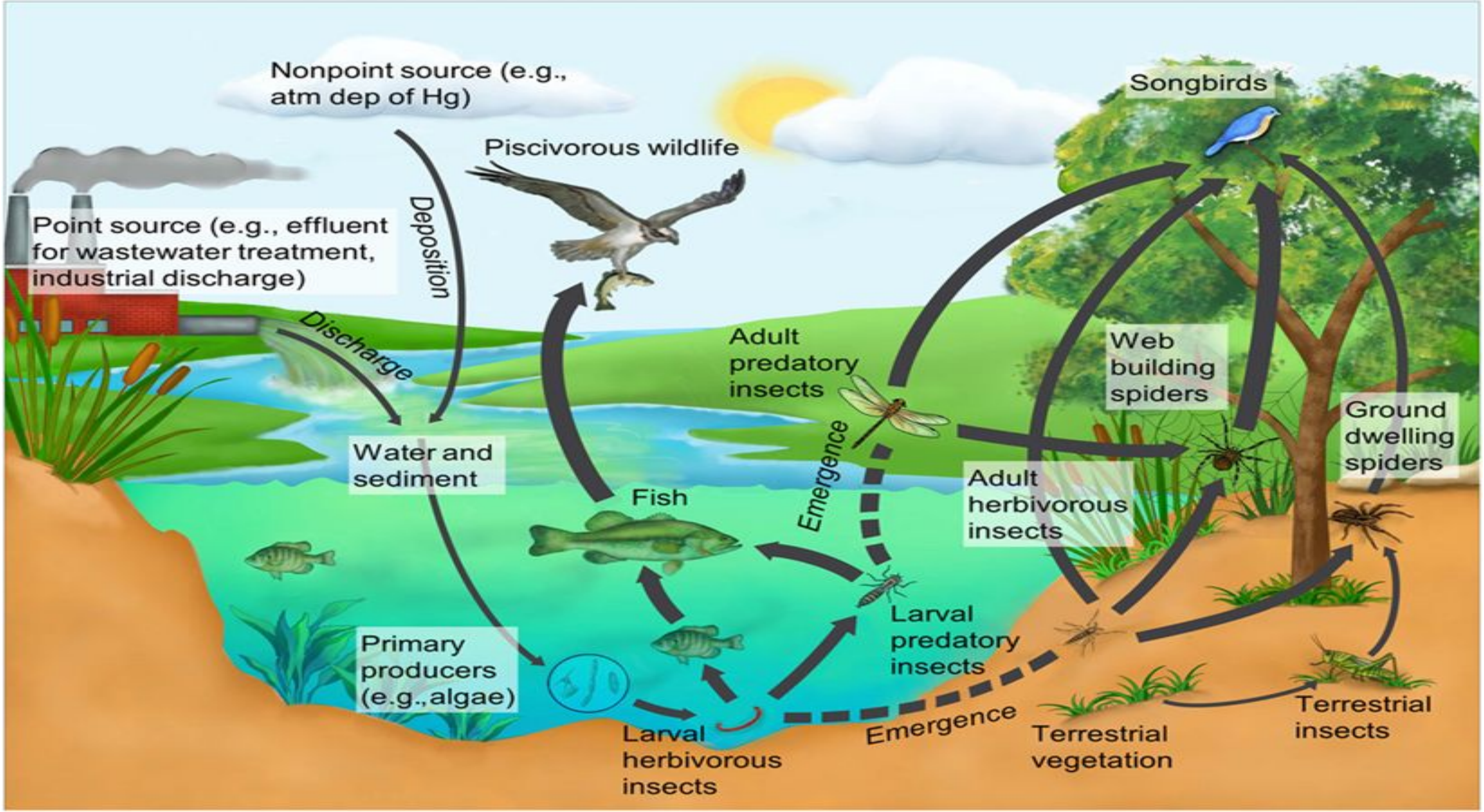
Universal Energy Flow Model (E.P. Odum, 1959)

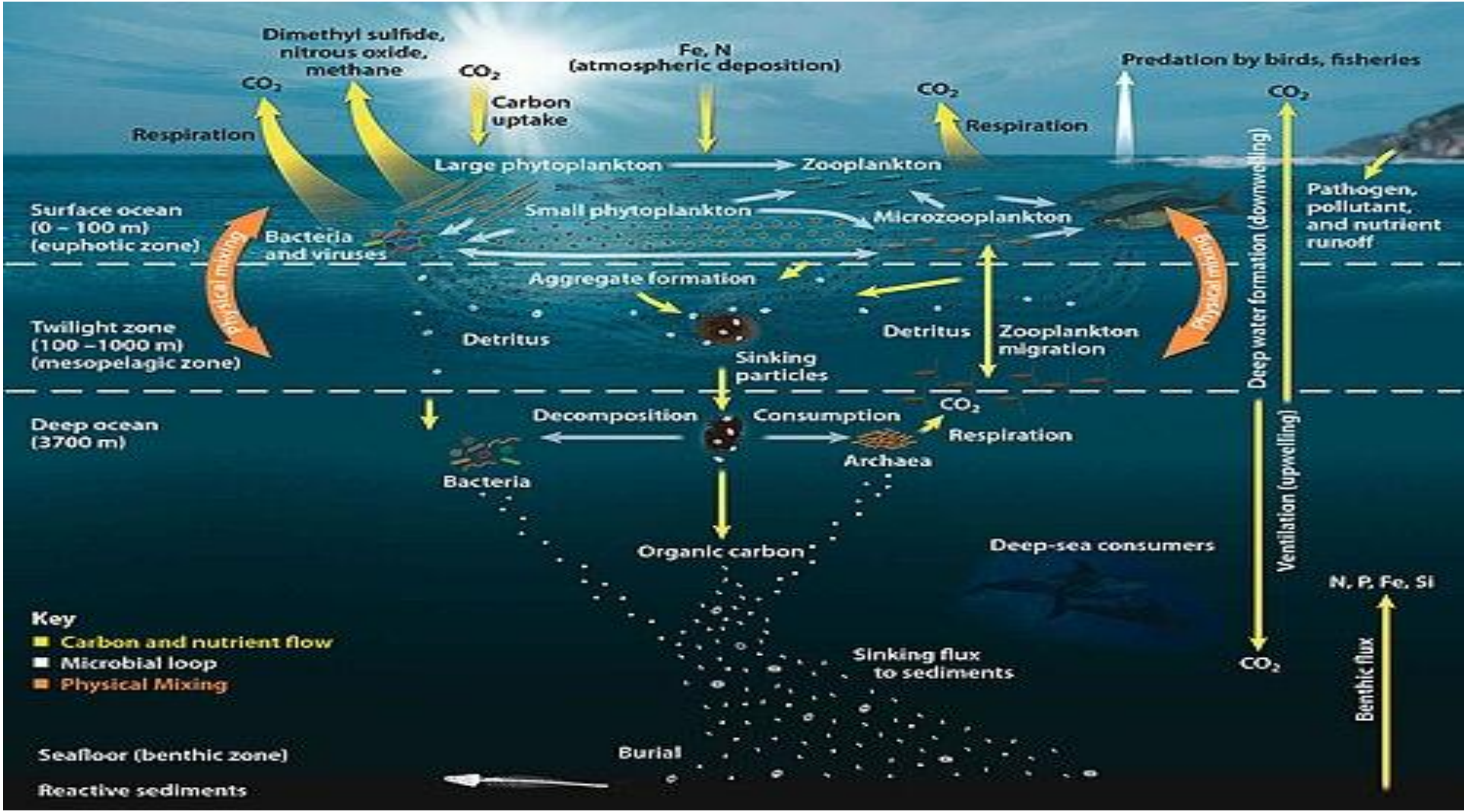


Food Chain: Its is a energy sequence of links or **trophic level** that start with a species that eats no other species and ends with a species that is eaten by no other species.

Food Web: At each **trophic level**, number of different species are interconnected via multiple pathways resembling complex web, referred as Food web.

Trophic level is each step or position that an organism occupies in a food chain or food web, based on its source of energy. It represents how energy and nutrients flow through an ecosystem.


Nonpoint source (e.g., atm dep of Hg)
Songbirds
Piscivorous wildlife
Point source (e.g., effluent for wastewater treatment, industrial discharge)
Deposition
Discharge
Adult predatory insects
Web building spiders
Ground dwelling spiders
Water and sediment
Emergence
Adult herbivorous insects
Fish
Larval predatory insects
Primary producers (e.g.,algae)
Terrestrial insects
Larval herbivorous insects
Emergence
Terrestrial vegetation


Dimethyl sulfide, nitrous oxide, methane
CO2
CO2
Carbon uptake
Fe, N (atmospheric deposition)
Predation by birds, fisheries
CO2
Respiration
CO2
Respiration
Large phytoplankton
Zooplankton
Small phytoplankton
Microzooplankton
Bacteria and viruses
Pathogen, pollutant, and nutrient runoff
Surface ocean (0 – 100 m) (euphotic zone)
Physical mixing
Physical mixing
Aggregate formation
Twilight zone (100 –1000 m) (mesopelagic zone)
Detritus
Detritus
Zooplankton migration
Sinking particles
Deep water formation (downwelling)
Ventilation (upwelling)
Deep ocean (3700 m)
Decomposition
Consumption
CO2
Respiration
Bacteria
Archaea
Organic carbon
Deep-sea consumers
N, P, Fe, Si
Key
Carbon and nutrient flow
Microbial loop
Physical Mixing
Sinking flux to sediments
CO2
Benthic flux
Burial
Seafloor (benthic zone)
Reactive sediments

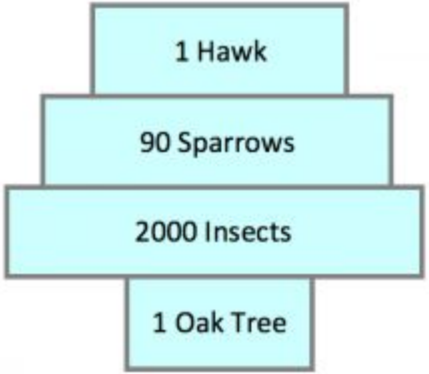
Energetic Hypothesis (Hutchinson, 1959)

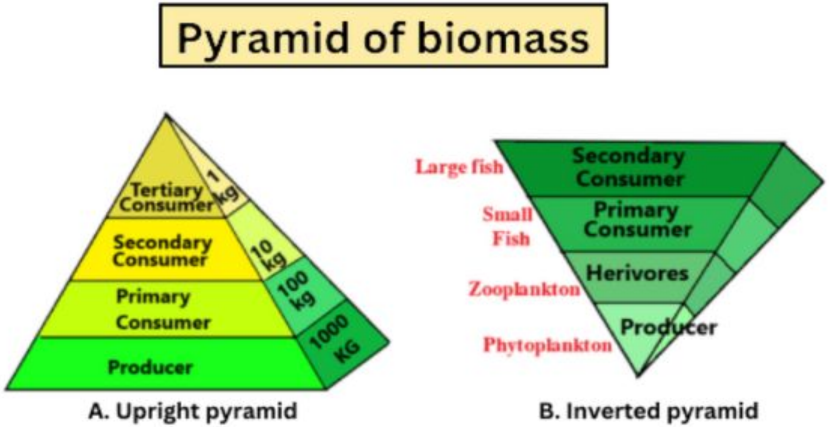
In case of energy flow through an ecosystem, the number of trophic levels is limited because of the decreasing availability of energy resulting from the inefficiencies in energy transfer from one trophic level to another. Thus, chains should not be longer in ecosystem with higher primary productivity.

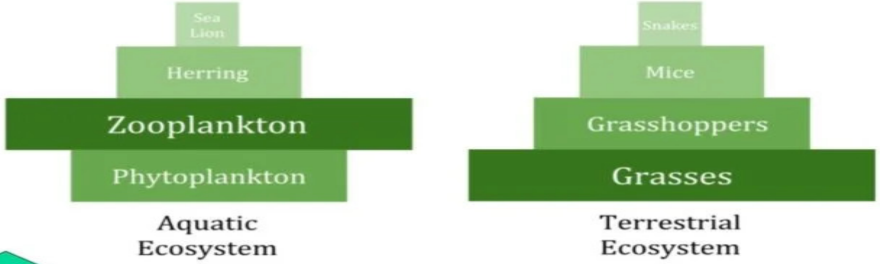
Dynamical Hypothesis (Pimm and Lawton, 1978)

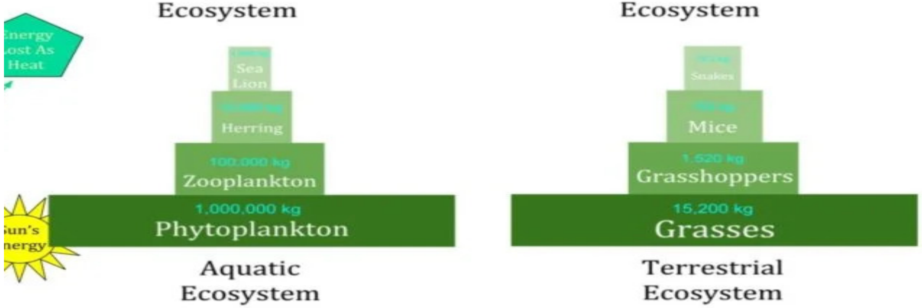
According to this hypothesis, food chains should be longer in ecosystems that are not subjected to disturbance by catastrophic events including fires, flooding, drought, widespread disease, etc. Ecosystems with longer chains take longer to return to equilibrium, once disturbed, thus they are less likely to persist in nature.

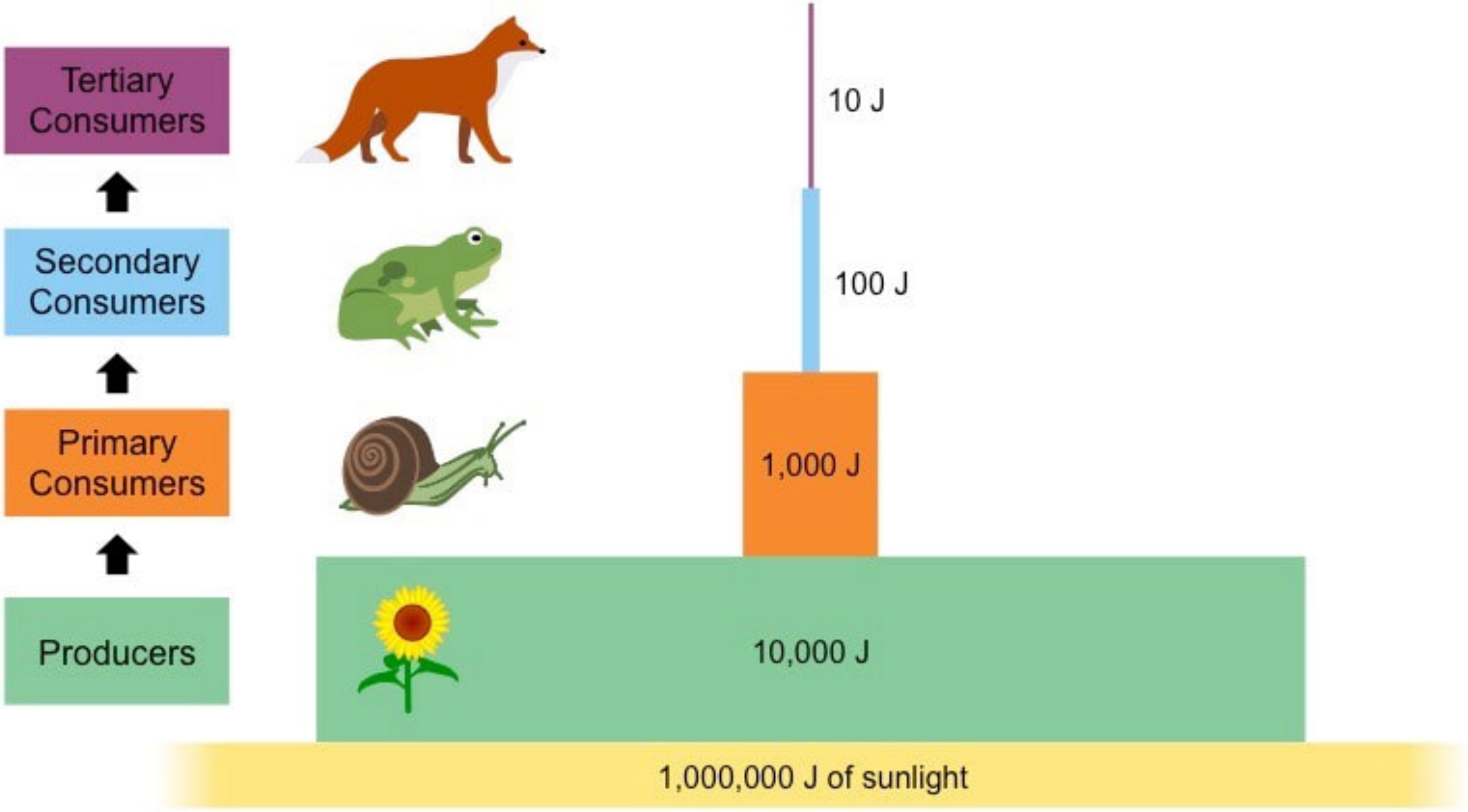
- Energy Pyramid
- Biomass Pyramid
- Number Pyramid



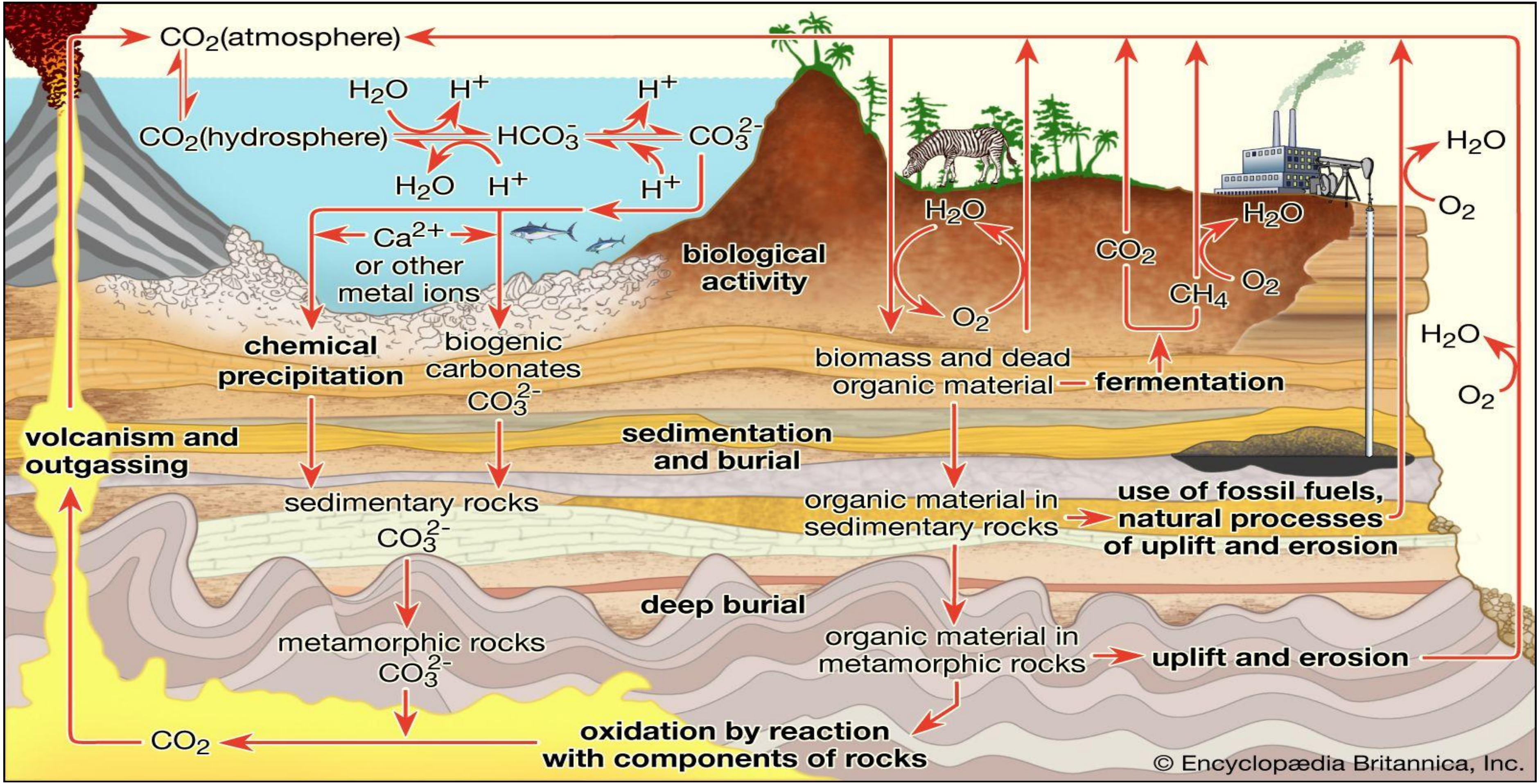


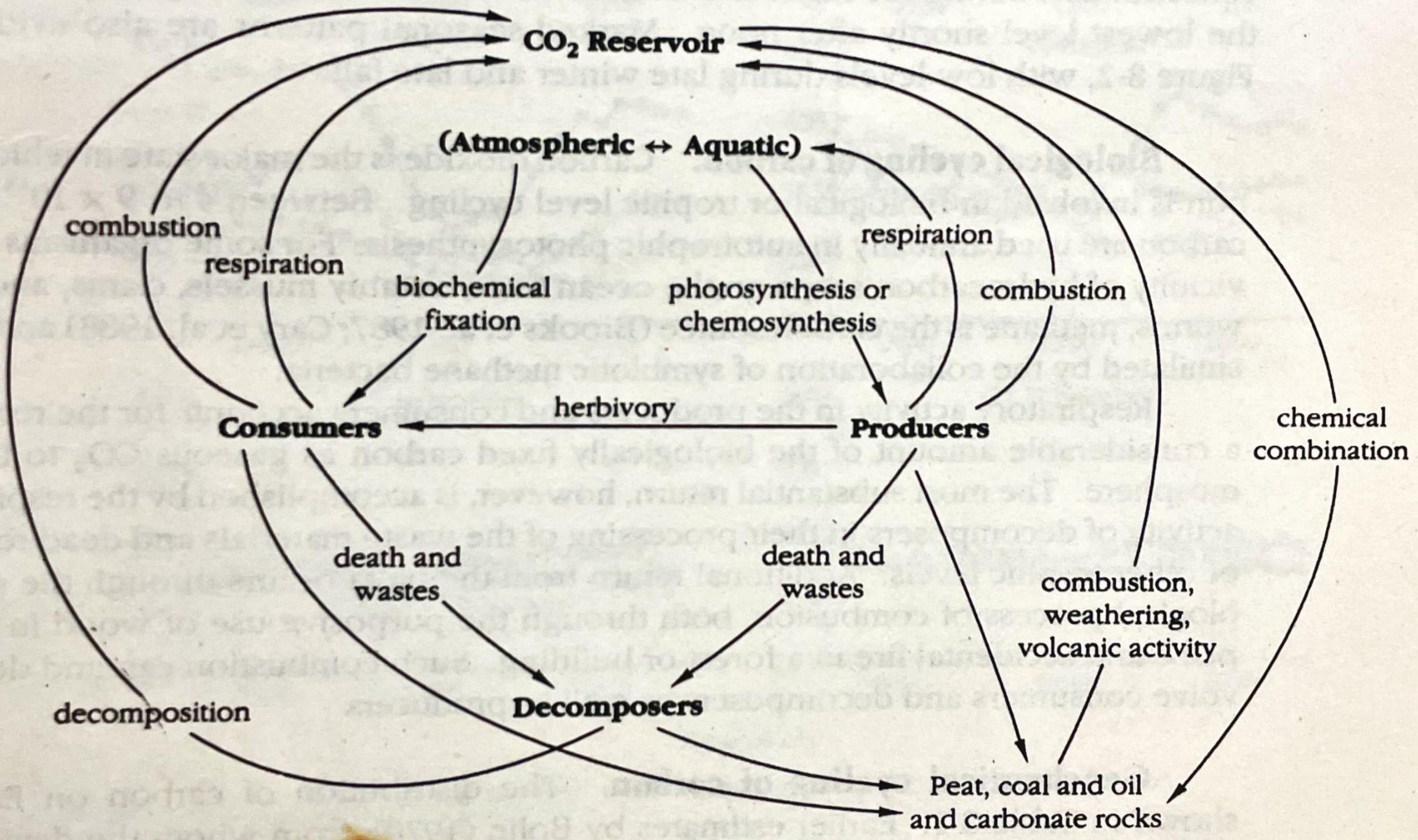





Tertiary Consumers
Secondary Consumers
Primary Consumers
Producers
10 J
100 J
1,000 J
10,000 J
1,000,000 J of sunlight

Global Carbon Cycle




CO_2 Reservoir
(Atmospheric ↔ Aquatic)
combustion
respiration
biochemical fixation
photosynthesis or chemosynthesis
respiration
combustion
herbivory
Consumers
Producers
chemical combination
death and wastes
death and wastes
combustion, weathering, volcanic activity
decomposition
Decomposers
Peat, coal and oil and carbonate rocks

- Carbon constitute 49% of their dry weight.

- Carbon returned to the environment about as fast as it is removed.

- The basic movement of carbon is from the atmospheric reservoir to producers to consumers and from these groups to the decomposers and back to the reservoir.

Biological Recycling of Carbon

- Carbon dioxide is major state in which carbon is involved carbon is involved in biological trophic level cycling.
- For some organisms dwelling on the ocean floor (mussels, clams, worms, etc), methane can be the source of carbon.
- The methane in the ocean floor dwellers is assimilated by the collaboration of symbiotic methane bacteria.

- Respiratory activity in the producers and consumers, accounts for the return of a considerable amount of biologically fixed carbon as gaseous CO_2 to the atmosphere.
- Most substantial return is accomplished by the respiratory activity of decomposers in their processing of the waste materials and dead remains.
- Additional return from the biota occurs through the non biological process of combustion of wood and fossil fuels.

Geochemical cycling of carbon

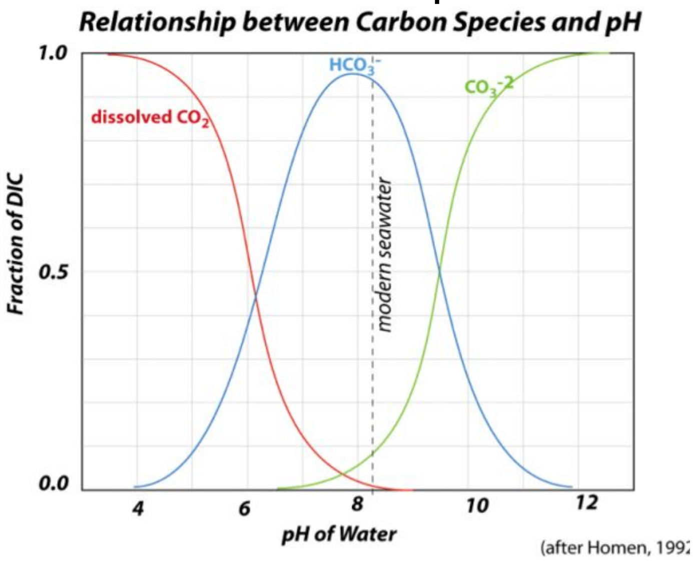
- Major fraction of carbon is stored in the geologic component of the environment, out of which large portion is inorganic and in sedimentary form.
- It also indicates that major supply of carbon to the Earth's surface, where it is biologically involved is by erosion and metamorphism of sediments.
- Sedimentary carbon include animal remains such as protozoan remnants, coral & mollusks shells, echinoderm and vertebrate skeletal material, carbonate rocks.

- A number of aquatic plants occurring in alkaline waters release calcium carbonate as a byproduct of photosynthetic assimilation.
- On weathering and dissolution of carbonate rocks, the bound carbon returns to the atmospheric-aquatic reservoir.

Aquatic-atmospheric interchange of carbon

- The interplay between atmospheric and aquatic carbon is critical component of carbon recycling in the environment.

$$\text{Atmospheric } CO_2 \quad \downarrow\uparrow \quad \text{Dissolved } CO_2 + H_2O \leftrightarrows H_2CO_3 \leftrightarrows H^+ + HCO_3^- \leftrightarrows H^+ + CO_3^{=}$$



- Interchange between the phases occurs through diffusion. Passage into the aquatic phase also takes place through precipitation.
- Dissolved CO_2 combines with water in the soil or in aquatic ecosystem to form carbonic acid (H_2CO_3) in a reversible reaction. H_2CO_3 dissociates into H_2 and

  bicarbonate ions (HCO_3^-) and further into carbonate ions CO_3^{--}.
- The direction of the reaction depends on the concentration of the components. The net movement of carbon between the different carbon species is much more complicated and also dependant on the pH of the water.
- Thus, manipulation of pH and CO_2 concentration affects the ability of the system to achieve equilibrium.

Inter-Species Relationships

Symbiosis

- Neutralism
- Competition
- Parasitism
- Predation
- Commensalism
- Protocooperation
- Mutualism