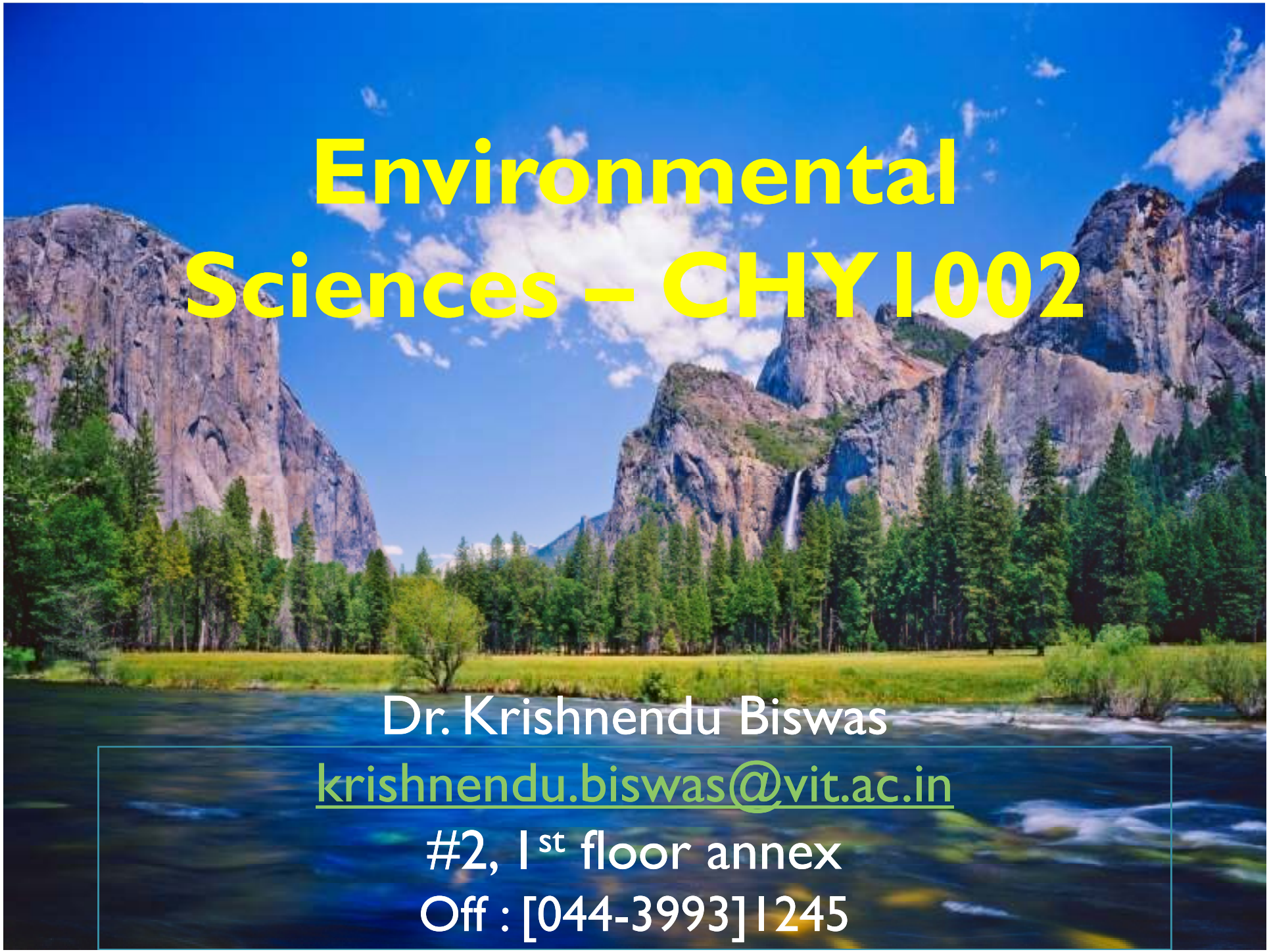


Environmental Sciences – CHY1002

Dr. Krishnendu Biswas
krishnendu.biswas@vit.ac.in
#2, 1st floor annex
Off : [044-3993]1245

Syllabus

Module-1	**Environment and Ecosystem** Key environmental problems, their basic causes and sustainable solutions. IPAT equation. Ecosystem, earth – life support system and ecosystem components; Food chain, food web, Energy flow in ecosystem; Ecological succession- stages involved, Primary and secondary succession, Hydrarch, mesarch, xerarch; Nutrient, water, carbon, nitrogen, cycles; Effect of human activities on these cycles.
Module-2	**Biodiversity** Importance, types, mega-biodiversity; Species interaction - Extinct, endemic, endangered and rare species; Hot-spots; GM crops- Advantages and disadvantages; Terrestrial biodiversity and Aquatic biodiversity – Significance, Threats due to natural and anthropogenic activities and Conservation methods.

Module-3	**Sustaining Natural Resources and Environmental Quality** Environmental hazards – causes and solutions. Biological hazards – AIDS, Malaria, Chemical hazards- BPA, PCB, Phthalates, Mercury, Nuclear hazards- Risk and evaluation of hazards. Water footprint; virtual water, blue revolution. Water quality management and its conservation. Solid and hazardous waste – types and waste management methods.
Module-4	**Energy Resources** Renewable - Non renewable energy resources- Advantages and disadvantages - oil, Natural gas, Coal, Nuclear energy. Energy efficiency and renewable energy. Solar energy, Hydroelectric power, Ocean thermal energy, Wind and geothermal energy. Energy from biomass, solar-Hydrogen revolution.

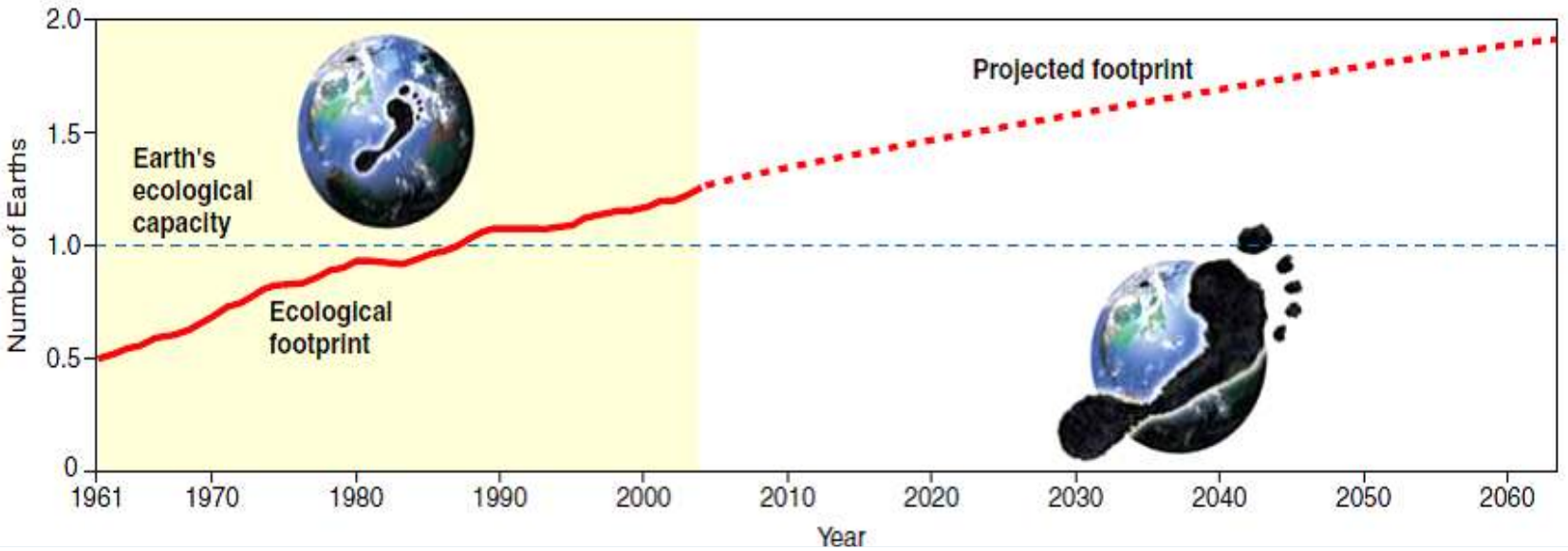
Module-5	**Environmental Impact Assessment** Introduction to environmental impact analysis. EIA guidelines, Notification of Government of India (Environmental Protection Act – Air, water, forest and wild life). Impact assessment methodologies. Public awareness. Environmental priorities in India.
Module-6	**Human Population Change and Environment** Urban environmental problems; Consumerism and waste products; Promotion of economic development – Impact of population age structure – Women and child welfare, Women empowerment. Sustaining human societies: Economics, environment, policies and education.
Module-7	**Global Climatic Change and Mitigation** Climate disruption, Green house effect, Ozone layer depletion and Acid rain. Kyoto protocol, Carbon credits, Carbon sequestration methods and Montreal Protocol. Role of Information technology in environment-Case Studies
Module-8	**Contemporary issues** - Industry Expert Lectures

Text books	1. G. Tyler Miller and Scott E. Spoolman (2013), Environmental Science, 14th Edition, Cengage learning. 2. George Tyler Miller, Jr. and Scott Spoolman (2012), Living in the Environment – Principles, Connections and Solutions, 17th Edition, Brooks/Cole, USA.
Reference books	1. David M.Hassenzahl, Mary Catherine Hager, Linda R.Berg (2011), Visualizing Environmental Science, 4thEdition, John Wiley & Sons, USA

M1- Environment and Ecosystem

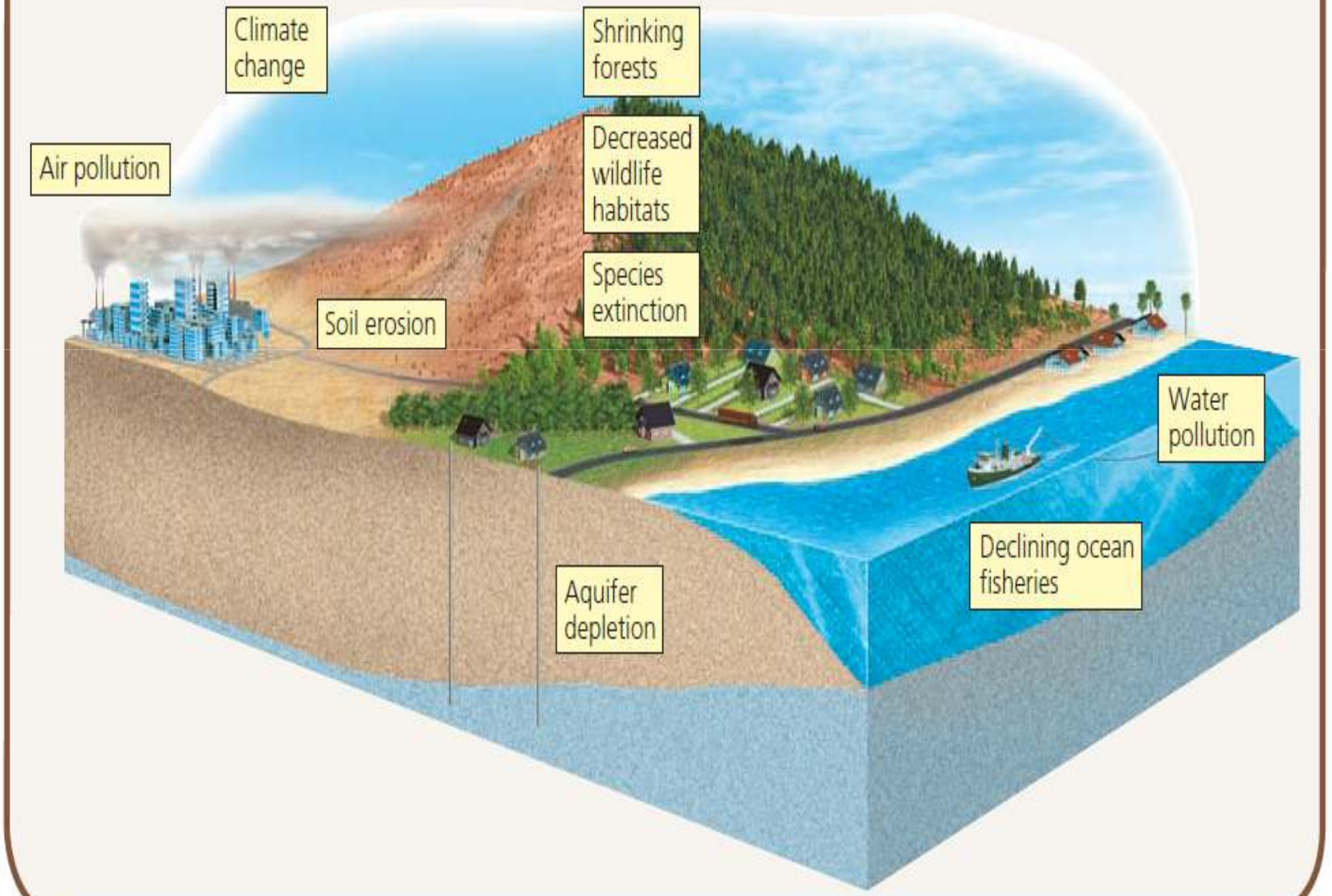
- Environmental science is a study of connections in nature
  - We are part of and not apart from rest of nature
  - Inter/multi-disciplinary
  - Goals – to know how life on earth survived and thrived, understand our interaction with environ., and find ways to deal with environmental problems and live more sustainably
- Key environmental problems
  - Unsustainability – environmental degradation
    - Climate change, pollution and biodiversity loss

- Pollution – We are polluting the environment – population increases pollution due to increase in use and consumption.
- Global climatic changes – Increase in CO_2 levels (Green house effect), deforestation etc,
- Depletion of natural resources – The sustainability of our environment is depends on the extent and ways of natural resources utilization which ultimately disrupt the natural services.
- Ecological footprint - The amount of natural resources and services used by mankind – higher the more degradation



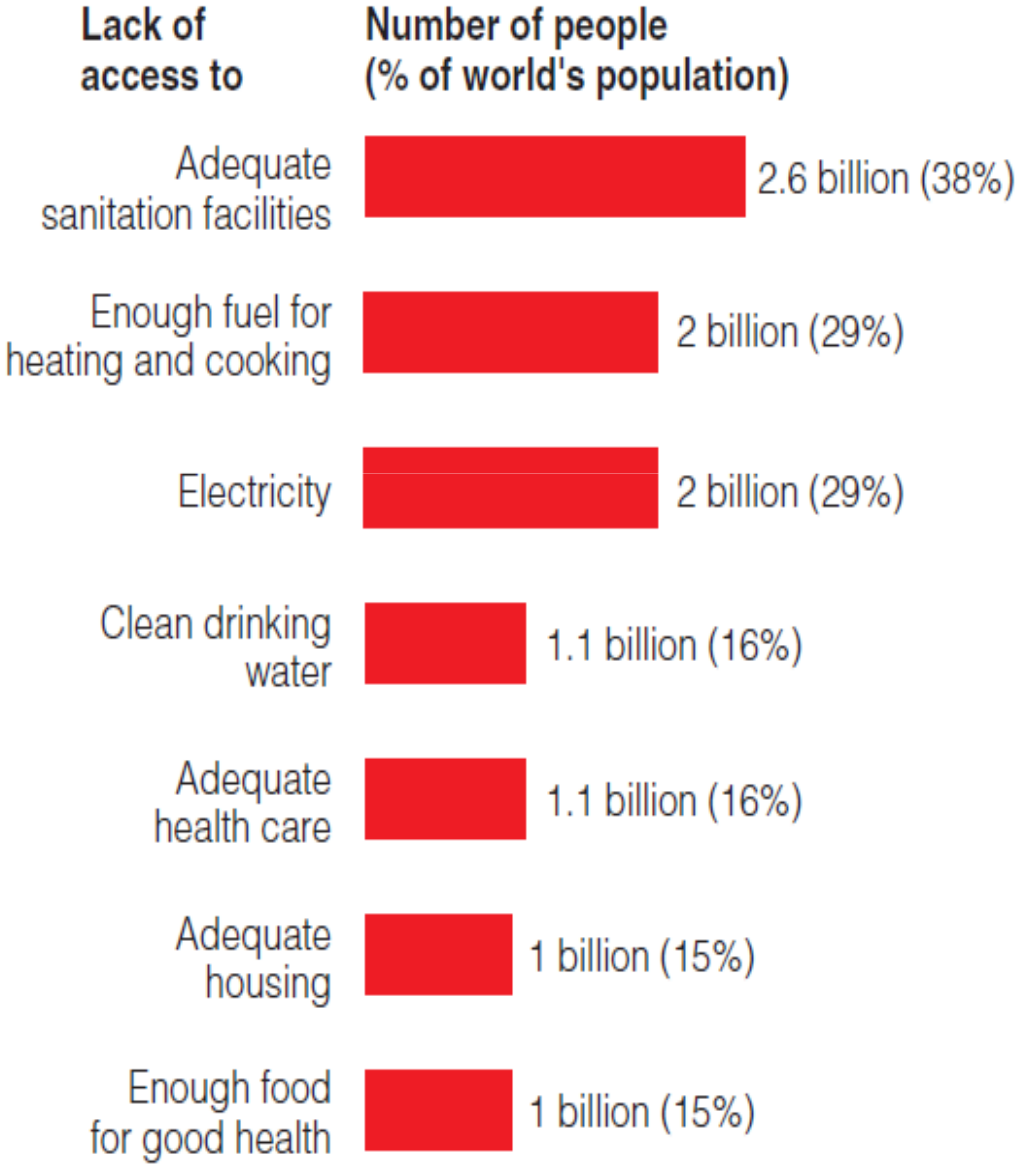
Natural Capital Degradation

Degradation of Normally Renewable Natural Resources

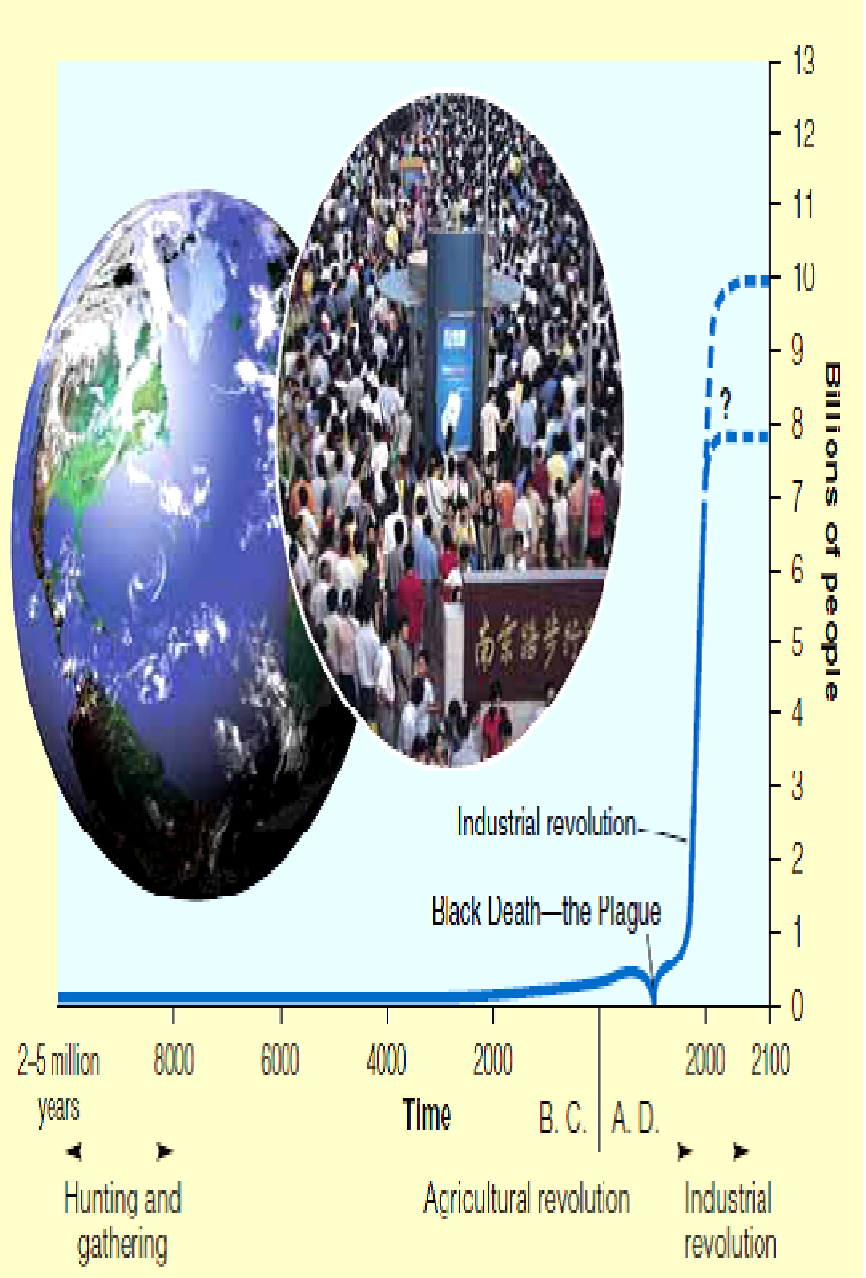


Causes for environmental problems

- Major causes
  - Population growth
  - Wasteful and unsustainable resource use – affluence
  - Poverty
  - Failure to include harmful environmental costs



- <u>Population growth:</u> Increases ecological foot print. Consumes more natural more natural capital. More industrialization for their needs that leads to pollution.
- On exponential growth of population, the magnitude for environmental problem also enhancing exponentially.



- <u>Wasteful and unsustainable resource use</u>

  If renewable resources are exploited in such a way that there is no time for regeneration, it will be converted to non-renewable.
- Colorado River: Source: Rocky Mountain, USA
- Mouth: Gulf of California
- Tamed: 14 major dams – Provides power distribution or water supplies to hottest & driest cities
- Much withdrawal: Very little reaches to the sea. Increasing population - Limited resource.

- Poverty - Poverty occurs when people are unable to meet their basic needs for adequate food, water, shelter, health, and education.

- Desperate for short-term survival, some of these people deplete and degrade forests, soil, grasslands, fisheries, and wildlife, at an ever-increasing rate - not have the luxury of worrying about long-term environmental quality or sustainability

- Poverty affects population growth. To many poor people, having more children is a matter of survival.

- Pollution and environmental degradation have a severe impact on the poor and can increase poverty. Poor becomes poorer.

- Affluence - The lifestyles of many affluent consumers in developed and in rapidly developing countries (e.g. India and China) which are built upon high levels of consumption and unnecessary waste of resources.
- Such affluence is based mostly on the assumption—induced by mass advertising that buying more and more things will bring happiness.

Excluding environmental costs from market prices

When companies use resources to create goods and services for consumers, they are not required to pay the environmental costs of such resource used.

- For example, fishing companies pay the costs of catching fish but do not pay for the depletion of fish stocks
- Timber companies pay for clear-cutting forests but not for the resulting environmental degradation and loss of wildlife habitat.
- The primary goal of these companies is to maximize their profits, so they do not voluntarily pay these harmful environmental costs or even try to assess them,
- Hence, the prices of goods and services do not include their harmful environmental costs.

Three principles of sustainability

- Reliance on solar energy
  - Used by plants produce nutrients
- Biodiveristy
  - Different organisms exist together and interact
- Chemical cycling
  - Circulation of chemicals from environment through organisms and back to environment.

❖ Natural capital = natural resources + natural services

- ❖ Natural resources – materials and energy in nature that are essential or useful to humans
- ❖ Natural services – processes that support life and human economies.
- ❖ Key components of sustainability – natural resource, human effect, solutions

Sustainable solutions

Follow nature's principles of sustainability

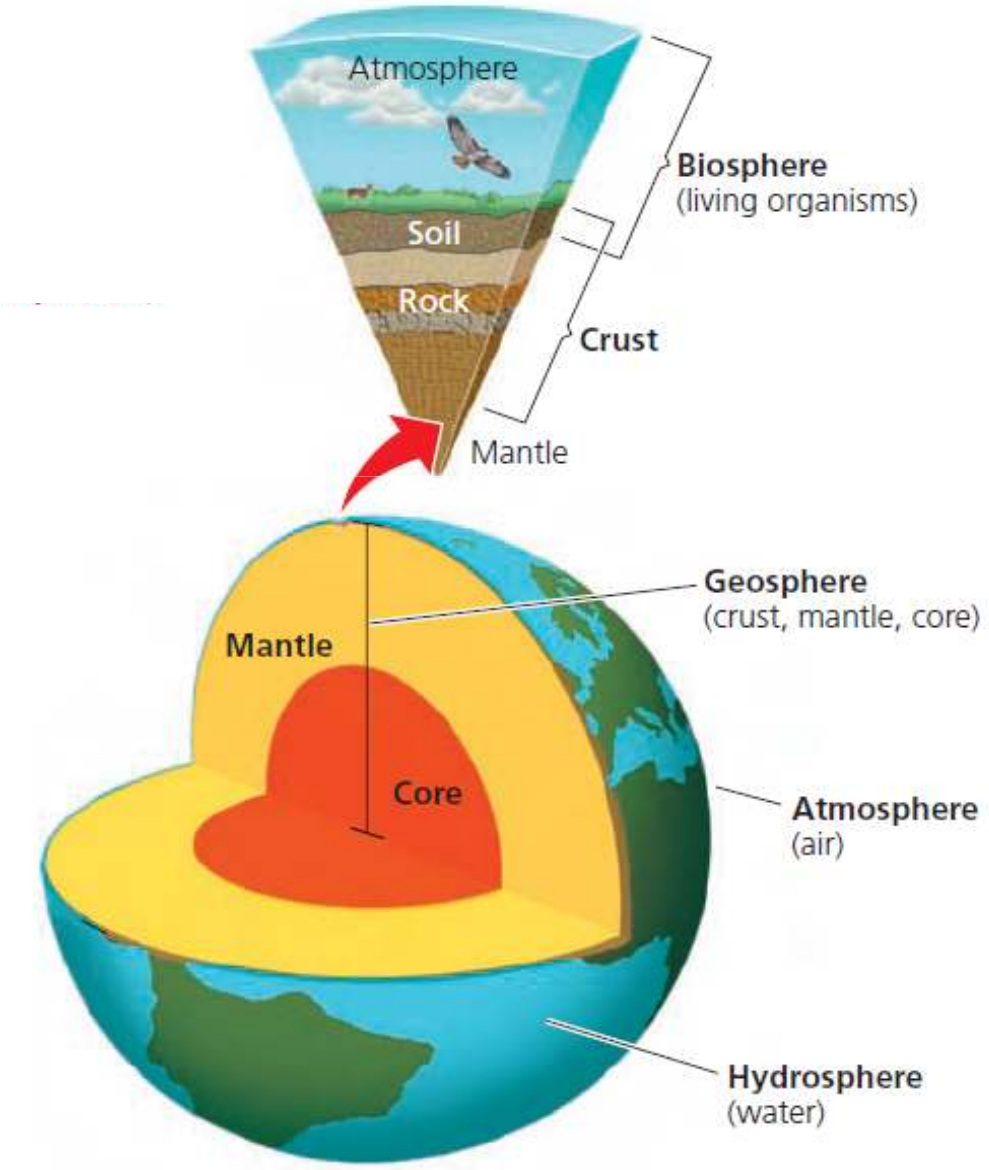
- Reliance on solar energy – use renewable energy resources - powers indirect forms of solar energy such as wind and flowing water, which we can use to produce electricity

- Biodiversity – conserve it by laws and leigslations, creating awareness, optimal use of resources etc., as it provides countless ways for life to adapt to changing environmental conditions

- Chemical cycling – Do not disrupt the earth's natural chemical cycles by overloading them with harmful chemicals or by removing natural chemicals faster than the cycles can replace them – requires relying more on pollution prevention and reducing the wasteful use of resources - 3R principle - Learn from nature and try to recycle and reuse chemicals wherever and whenever possible

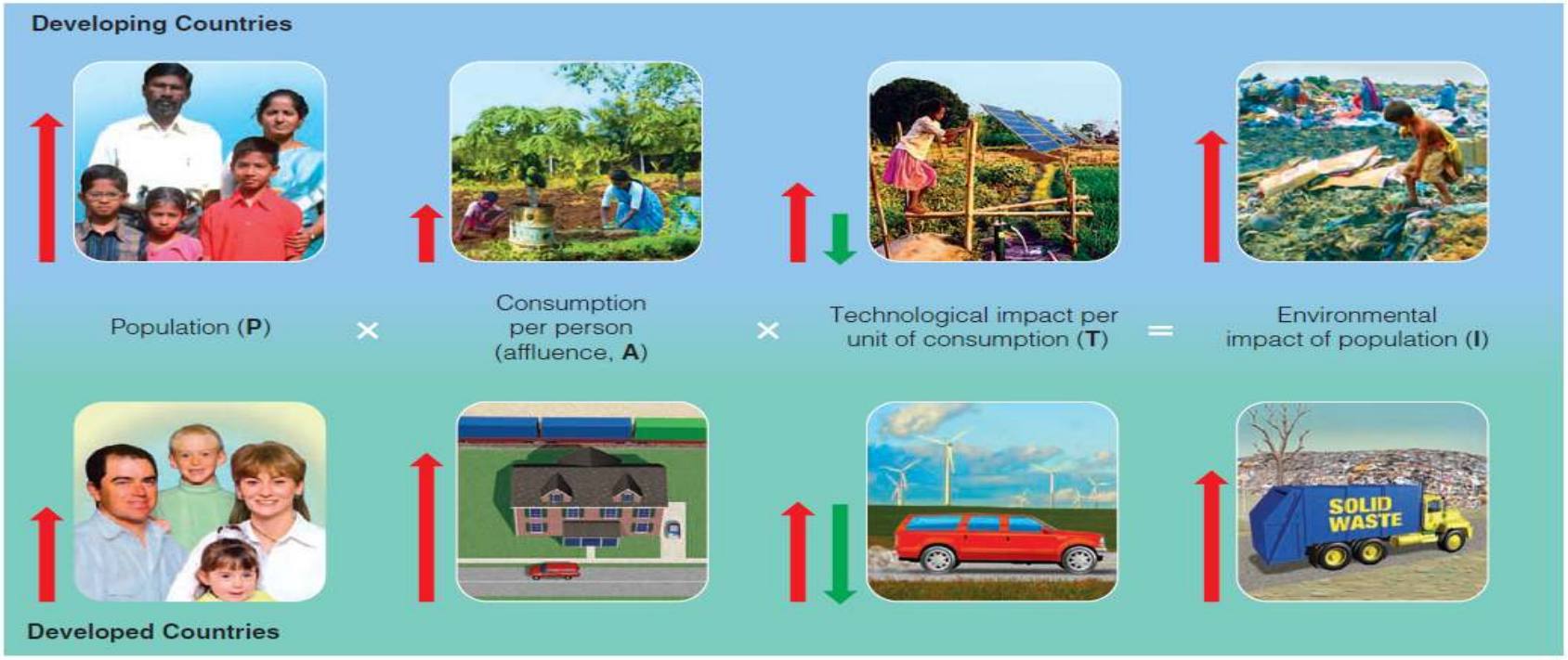
Earth – life support system

- Earth's life – support system
  - Atmosphere
    - Troposphere, Stratosphere
  - Hydrosphere
    - Vapour, liquid, ice
  - Geosphere
    - Hot core, thick rock mantle
  - Biosphere
    - Above spheres with life



IPAT Equation

- Paul Ehrlich and John Holdren in early 1970s
- I = P x A x T.
- Simple model showing how population size (P), affluence or resource consumption per person (A), and the beneficial and harmful environmental effects of technologies (T)



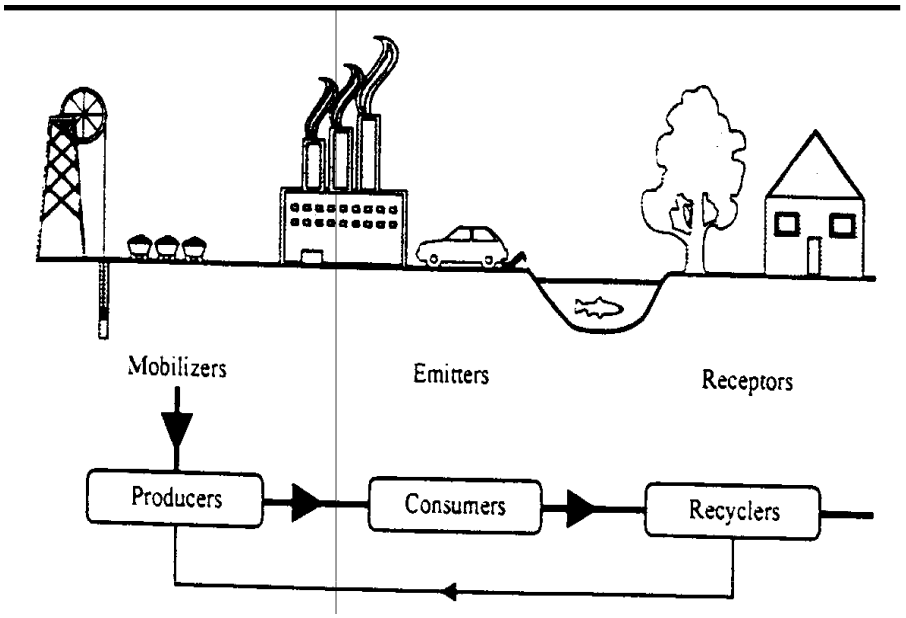
Ecosystem

- Self-regulating group of biotic communities of species interacting with one another and with their non-living environment exchanging energy and matter
  - Open – free exchange of energy and matter from outside - anthroposystem
  - Closed – isolated

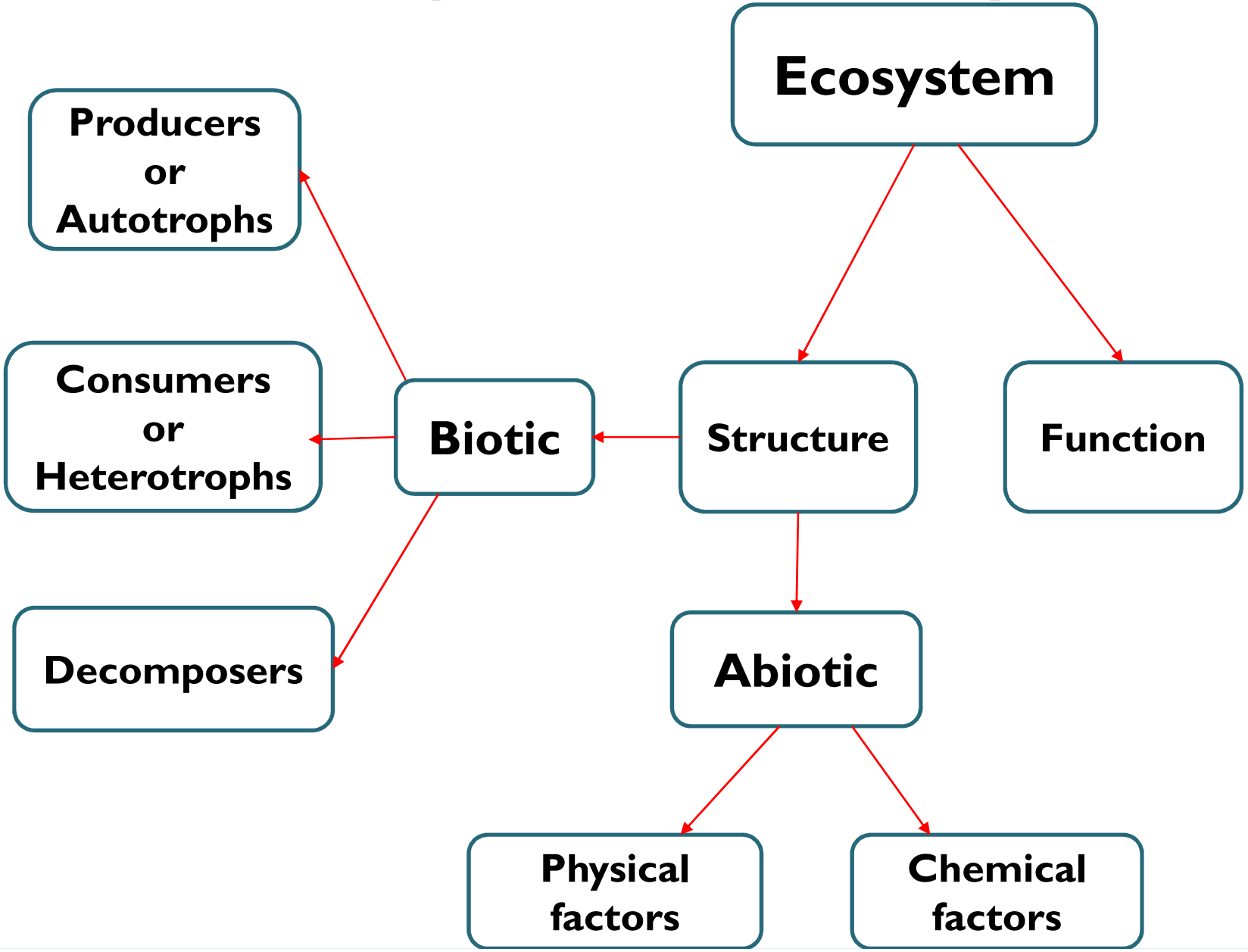
- Ecology – study of ecosystem

  'The first law of ecology is that everything is related to everything else'

  - *Barry Commoner*

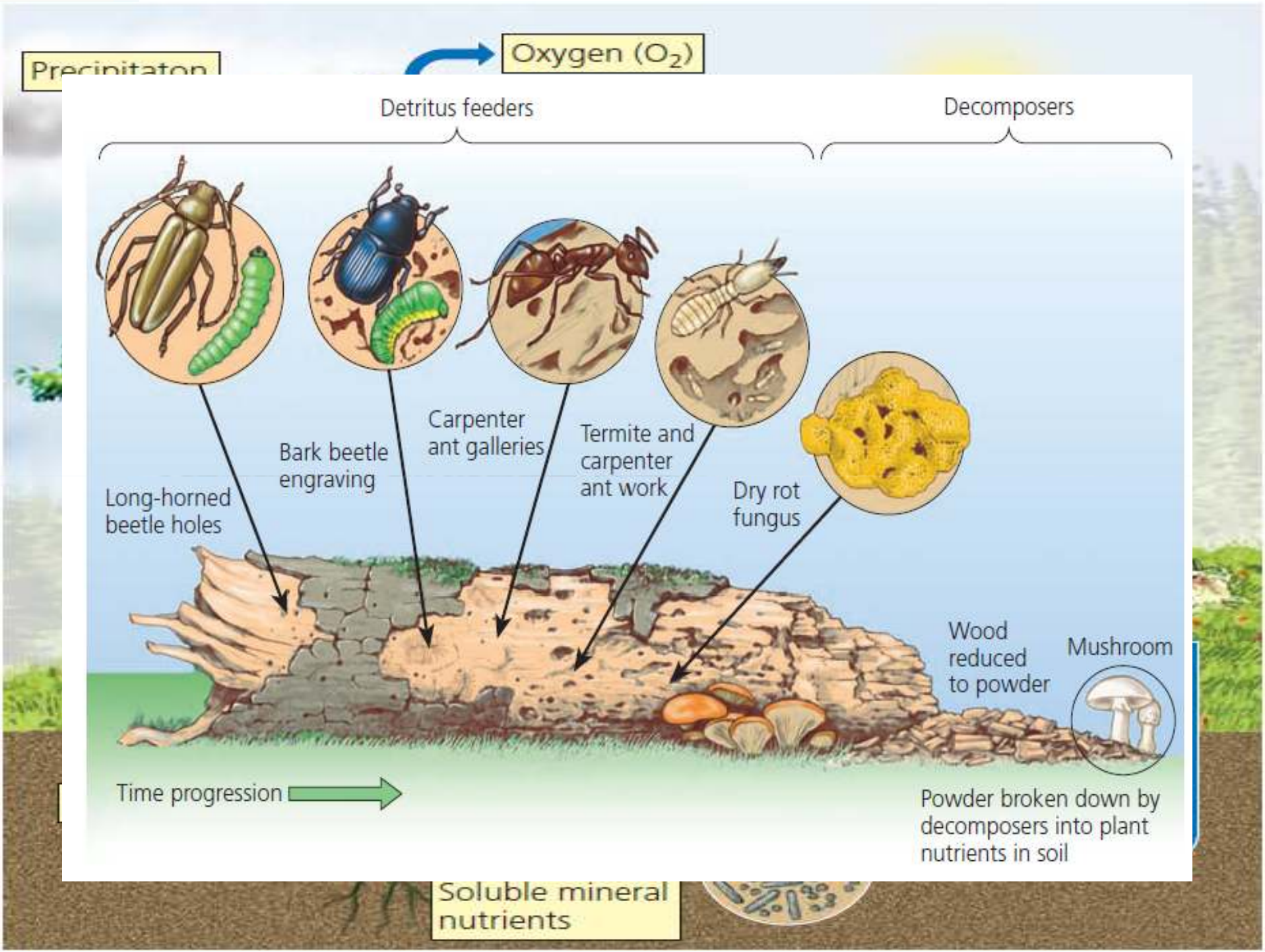


Major components of ecosystem



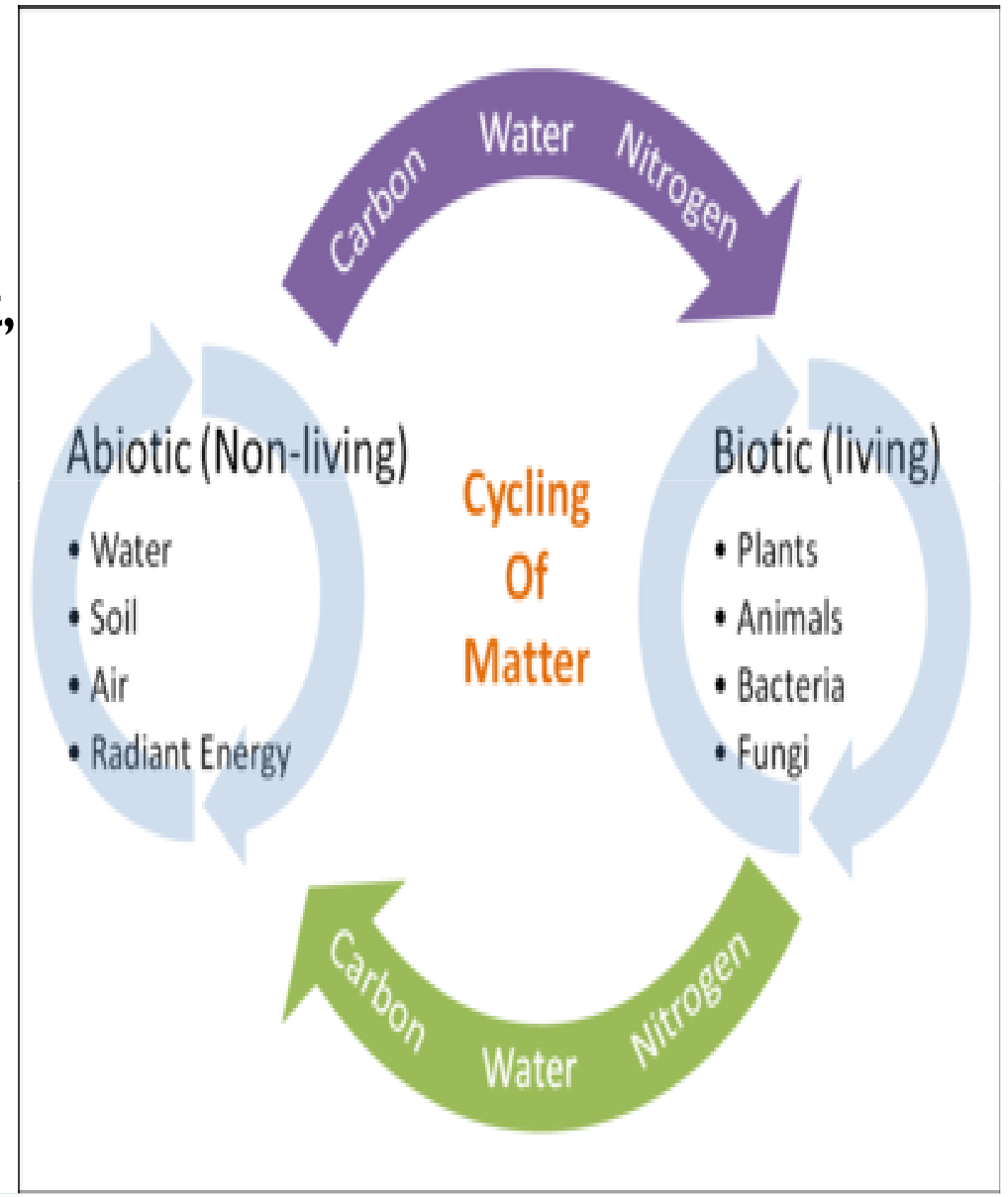
Biotic Structure

- Producers – mainly green plants – self dependent – photosynthesis
  - Photo autotrophs – making food using light
  - Chemo-autotrophs – oxidize certain chemicals in the absence of light
- Consumers – feed on other organisms
  - Herbivores – feed directly on producers – primary consumers. eg. Rabbit, insect, man
  - Carnivores – feed on other consumers
    - Secondary consumers (Herbivores) – e.g. frog
    - Tertiary consumers (Carnivores)– e.g. snake, big fish etc.
  - Omnivores – feed on both plants and animals e.g. human, rat, fox etc.
  - Detritivores – feed on parts of dead animals e.g. beetles, termite, ant, earthworms etc.
- Decomposers – break down complex organic molecules to simpler – bacteria and fungi

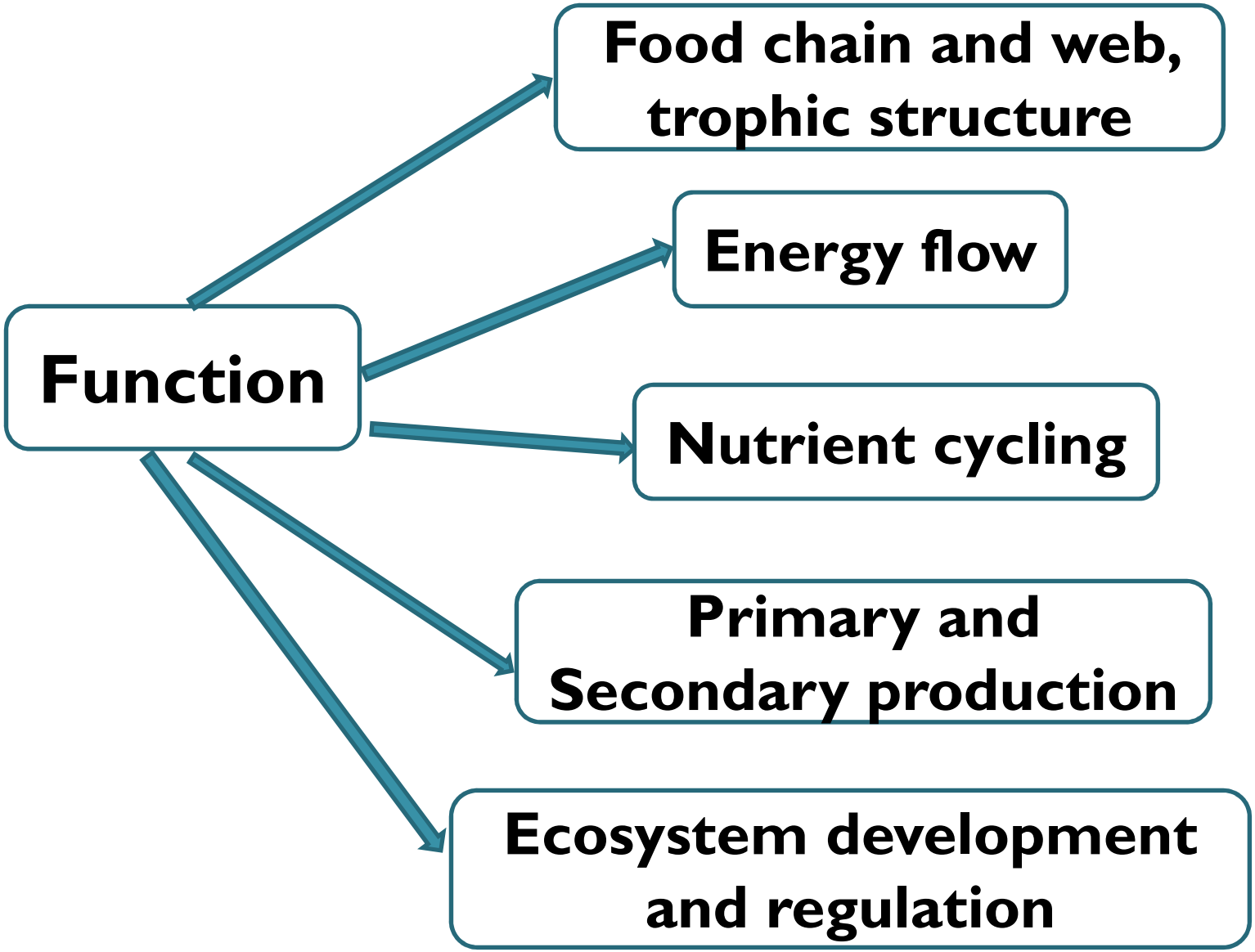

Precipitaton
Oxygen (O_2)
Detritus feeders
Decomposers
Long-horned beetle holes
Bark beetle engraving
Carpenter ant galleries
Termite and carpenter ant work
Dry rot fungus
Wood reduced to powder
Mushroom
Time progression
Powder broken down by decomposers into plant nutrients in soil
Soluble mineral nutrients

Abiotic structure

- Physical factors – Climatic, edaphic, geographical
  - Intensity and duration of sun light, avg. temp., annual rainfall, wind, soil type, water availability, water currents
- Chemical factors – energy, nutrients, toxic substances
  - C, N, P, K, H, O, S, level of toxic substances, salts (salinity)

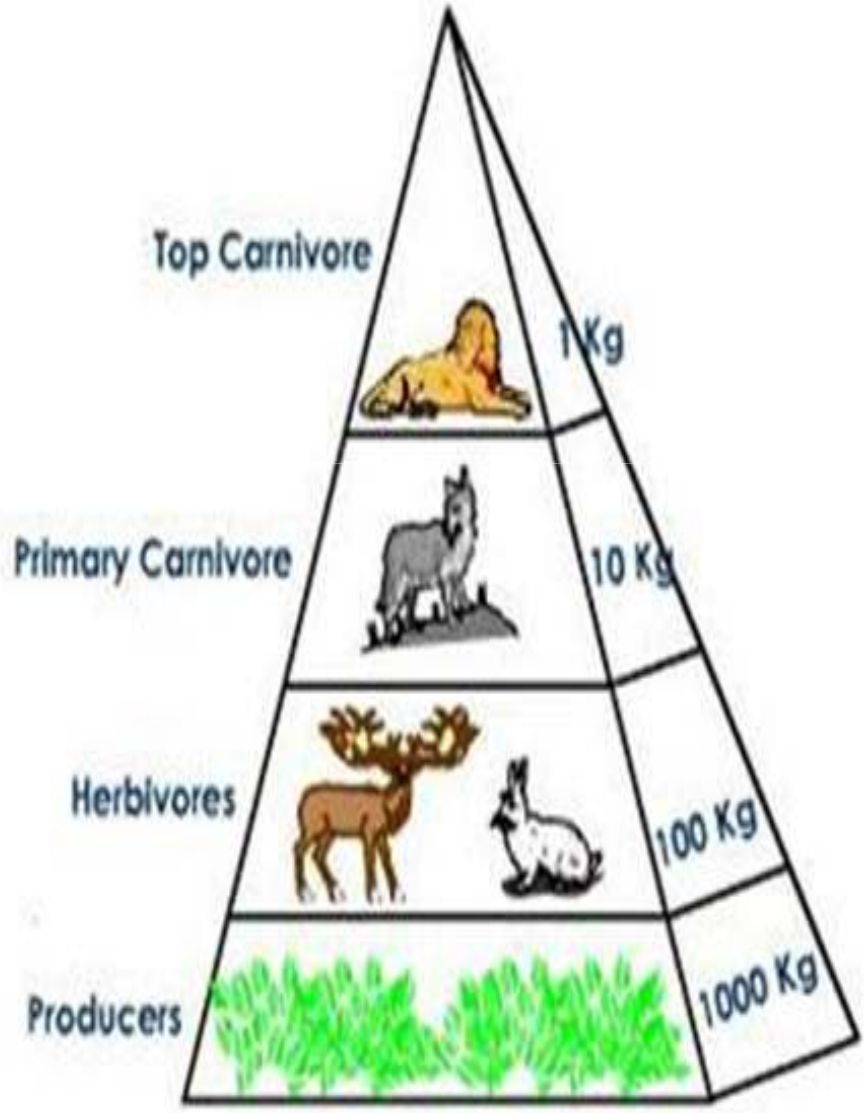


Functional attributes



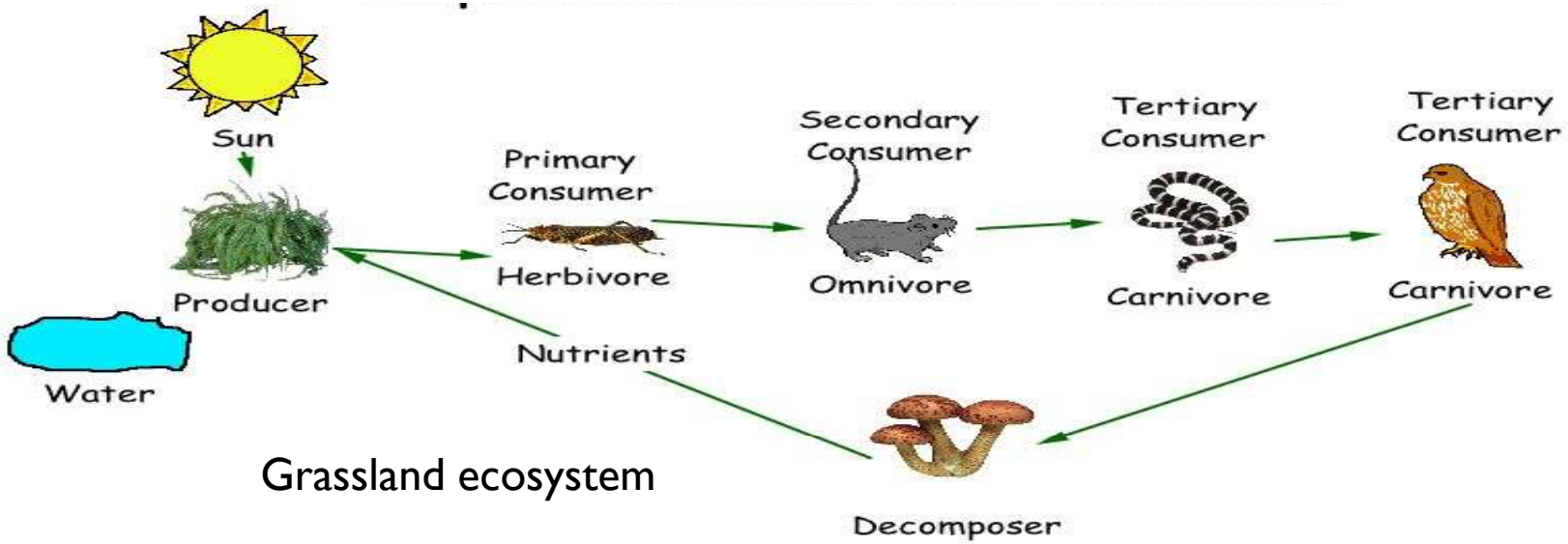
Trophic Structure

- Definite arrangement of producer and consumer in ecosystem and their interaction along with population size
- Each food level in food chain – **trophic level**
- **Standing biomass** – amount of living matter in each trophic level at a given time.

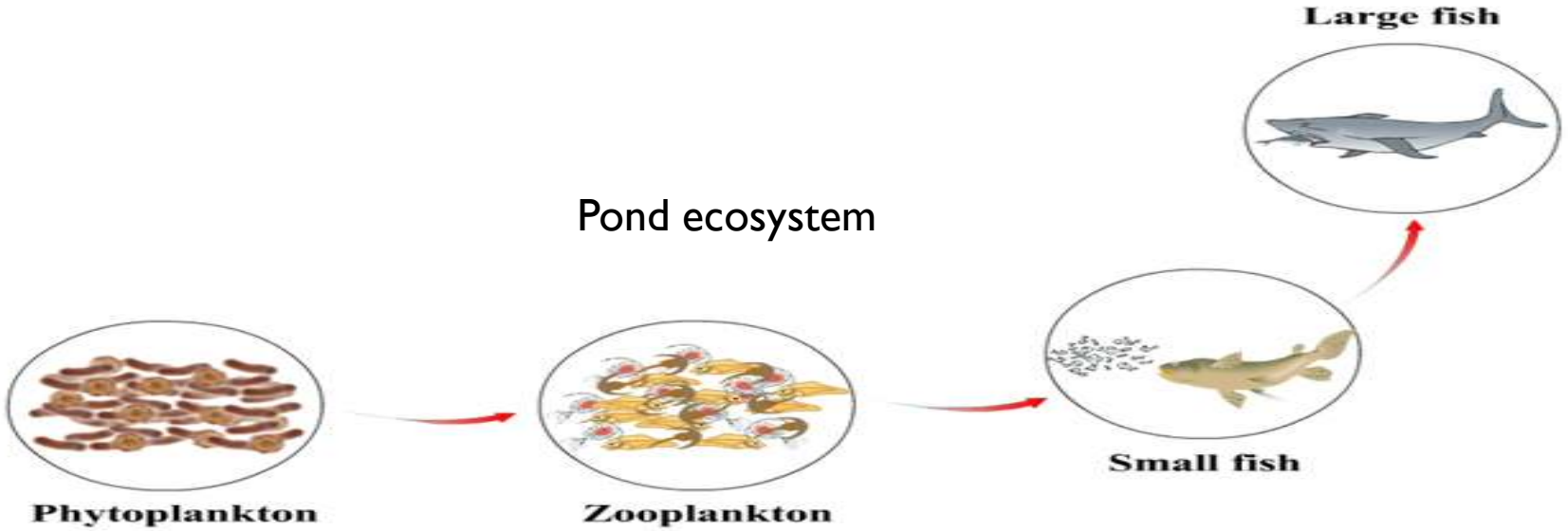


Food Chain

- It's a sequence of eating and being eaten – no waste process



Grassland ecosystem

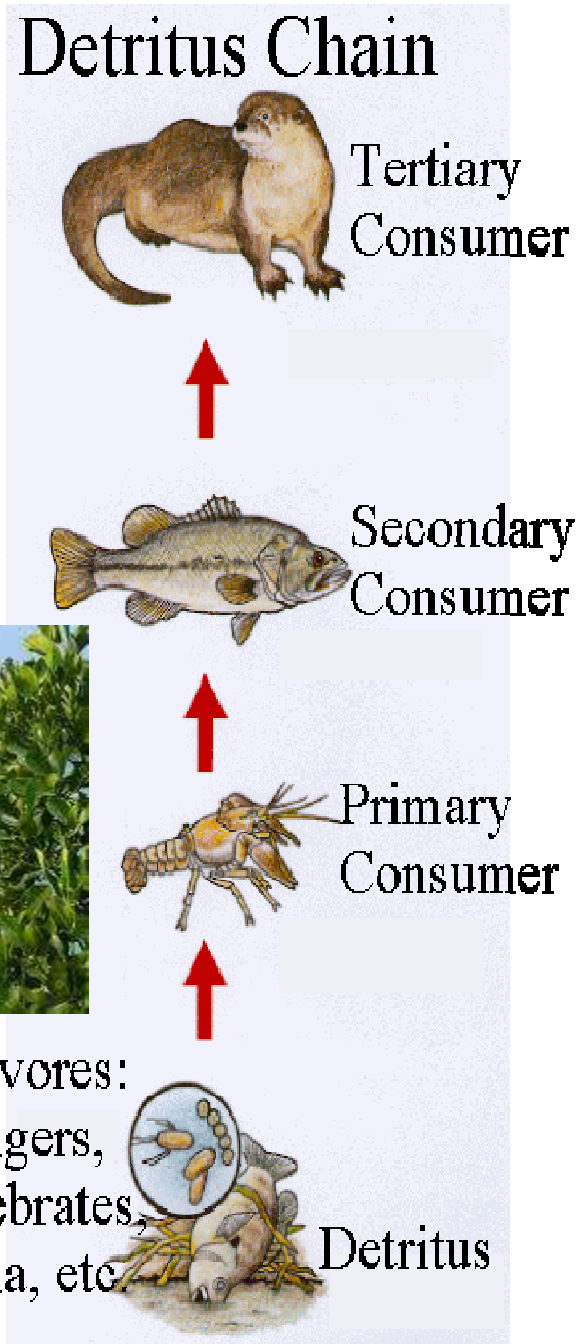


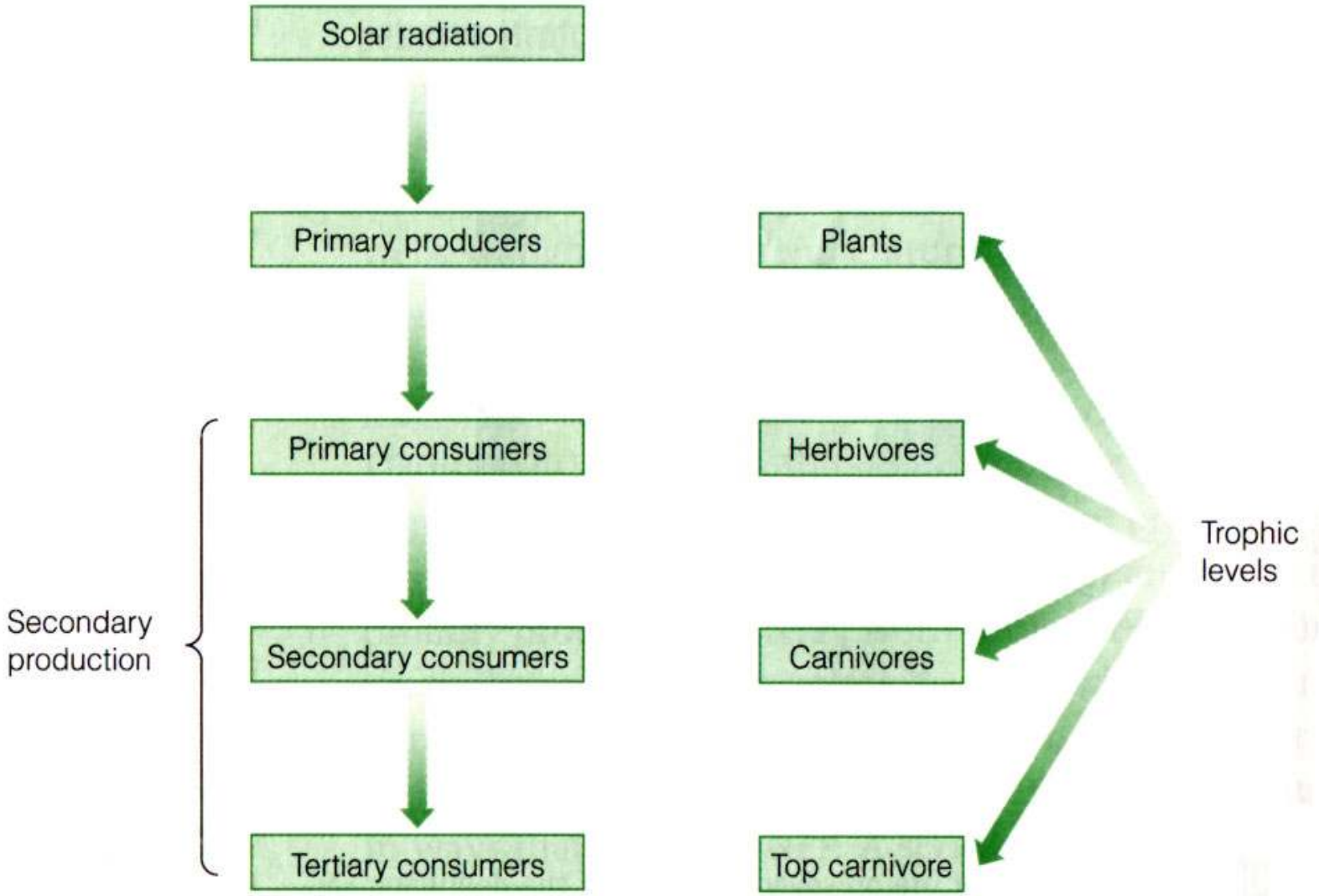
Pond ecosystem

Types

- Grazing food chain – Green plants are primary producers – more common

- Detritus food chain – dead organic matter are starting point- Derive energy from plant biomass
  - Ex:- Leaf litter → algae→crabs→small carnivorous fish→large carnivorous fish (mangrove ecosystem)
  - Dead organic matter→fungi→bacteria (forest ecosystem)

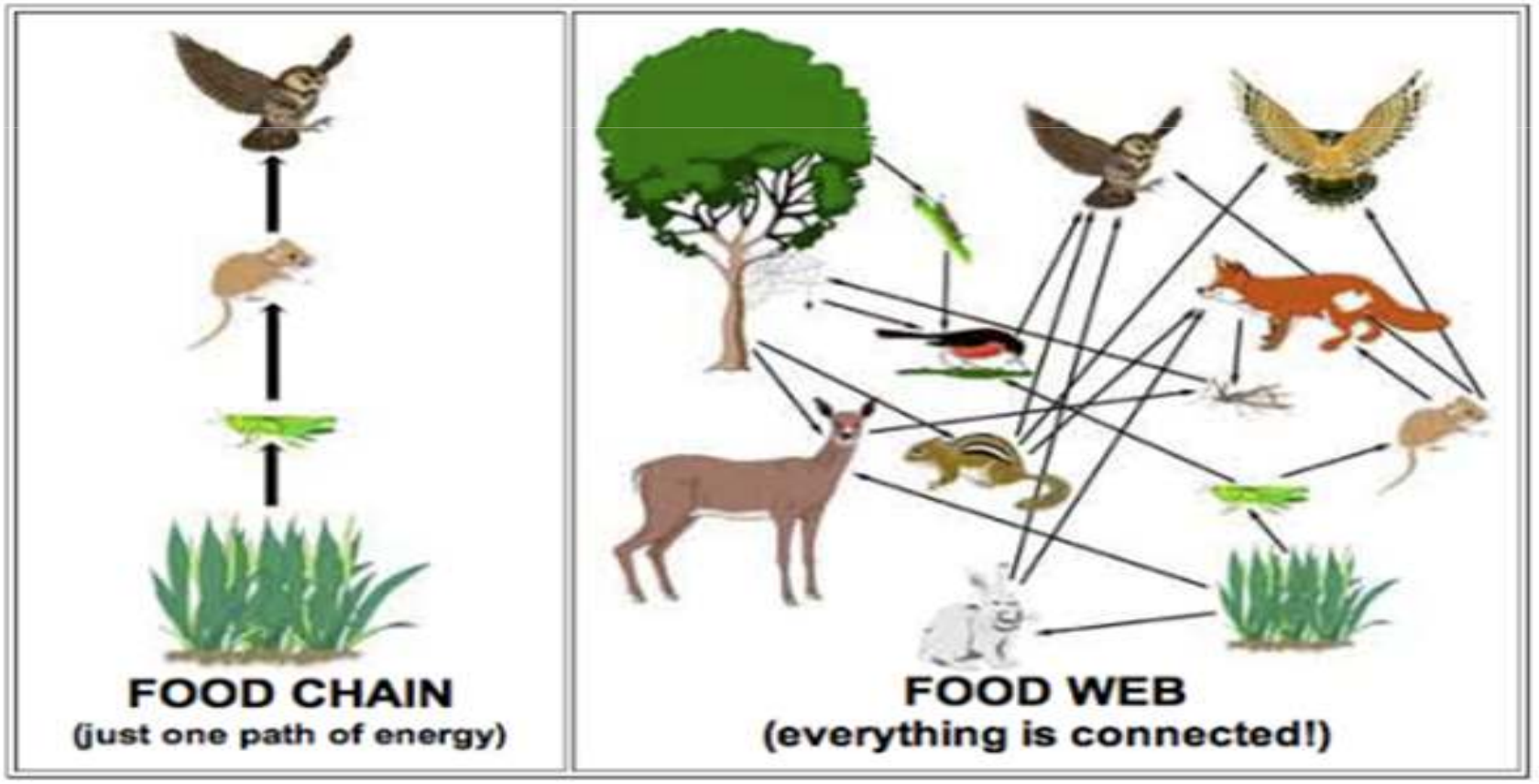


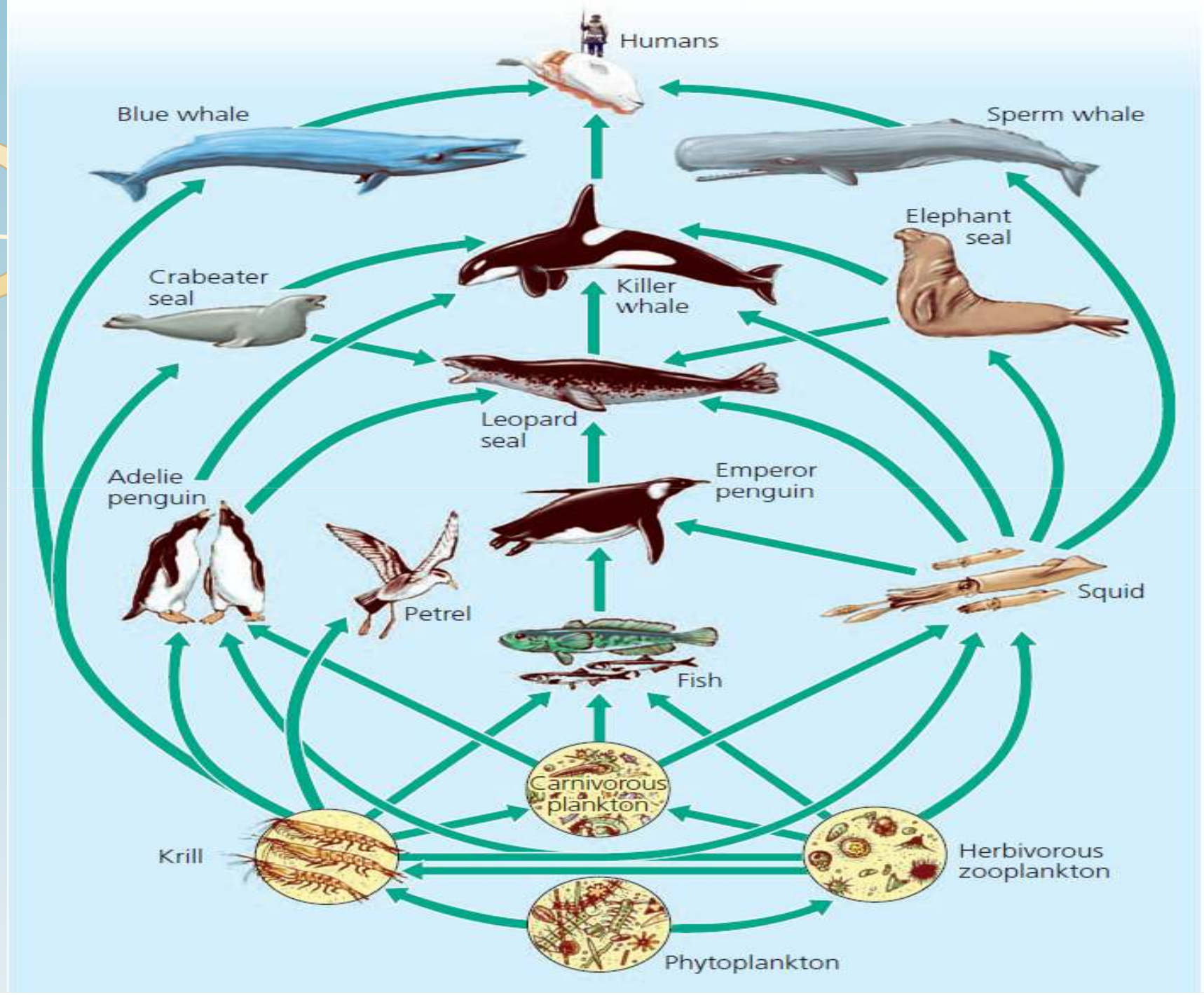


The schematic structure of a food chain. Each trophic level may contain many species.

Food web

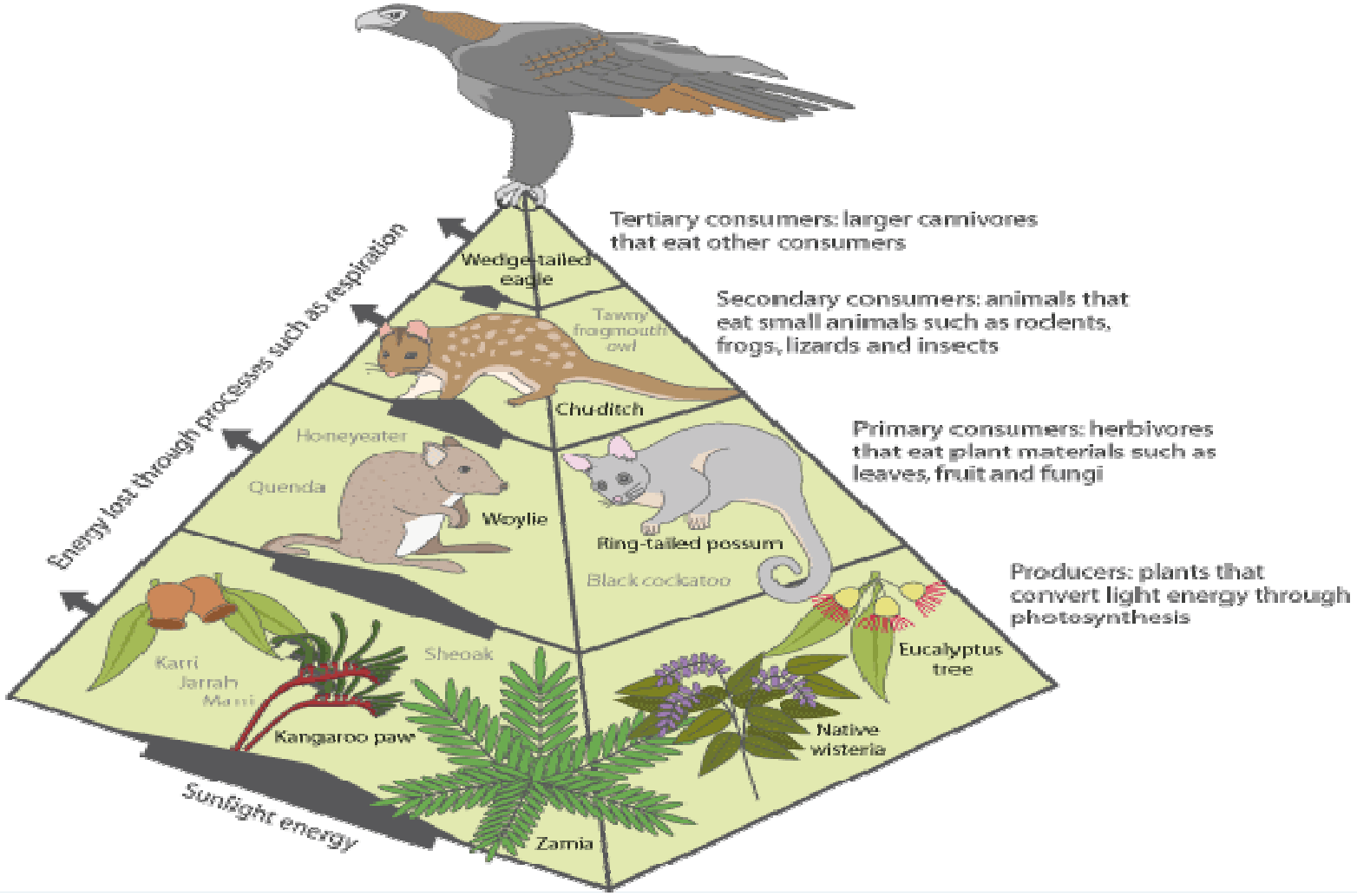
- Network of food chains – increase options of eating and being eaten – greater stability to ecosystem
- Significance
  - Energy flow and nutrient cycling
  - Ecological balance – maintenance and regulates population size
  - Biological magnification – Decline of Osprey due to DDT




Humans
Blue whale
Sperm whale
Elephant seal
Crabeater seal
Killer whale
Leopard seal
Adelie penguin
Emperor penguin
Petrel
Squid
Fish
Carnivorous plankton
Krill
Herbivorous zooplankton
Phytoplankton

Ecological pyramids

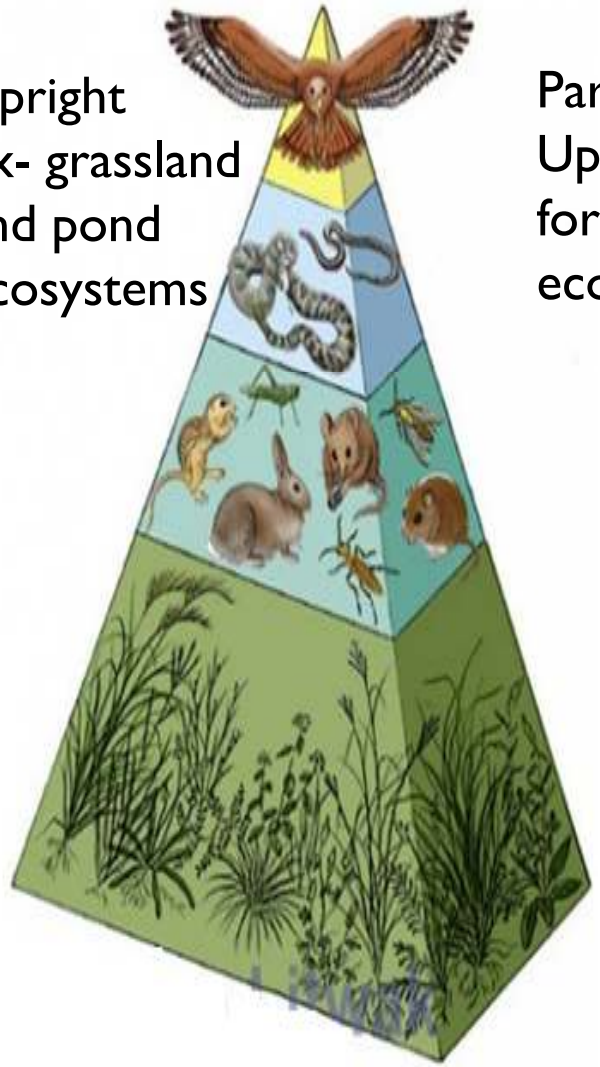
- Graphic representation of trophic structure and function of an ecosystem.
- Starts with producers



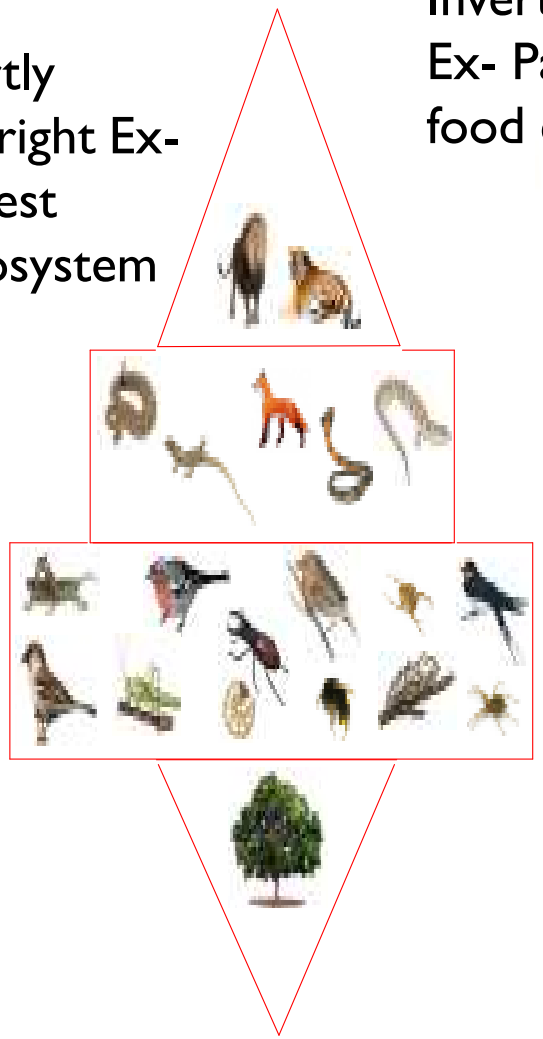
Types

- Pyramid of numbers – no. of organisms at each level

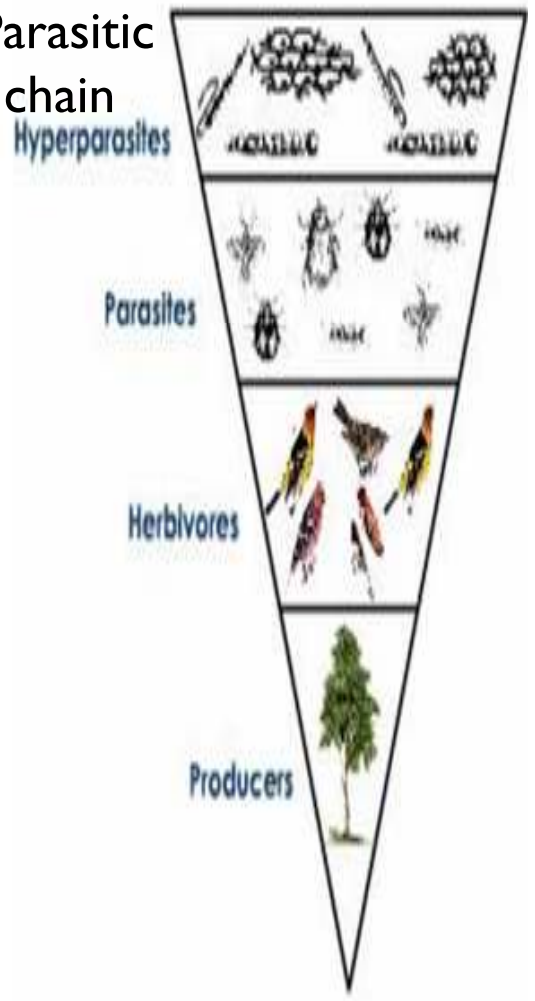
Upright
Ex- grassland and pond ecosystems



Partly Upright Ex- forest ecosystem

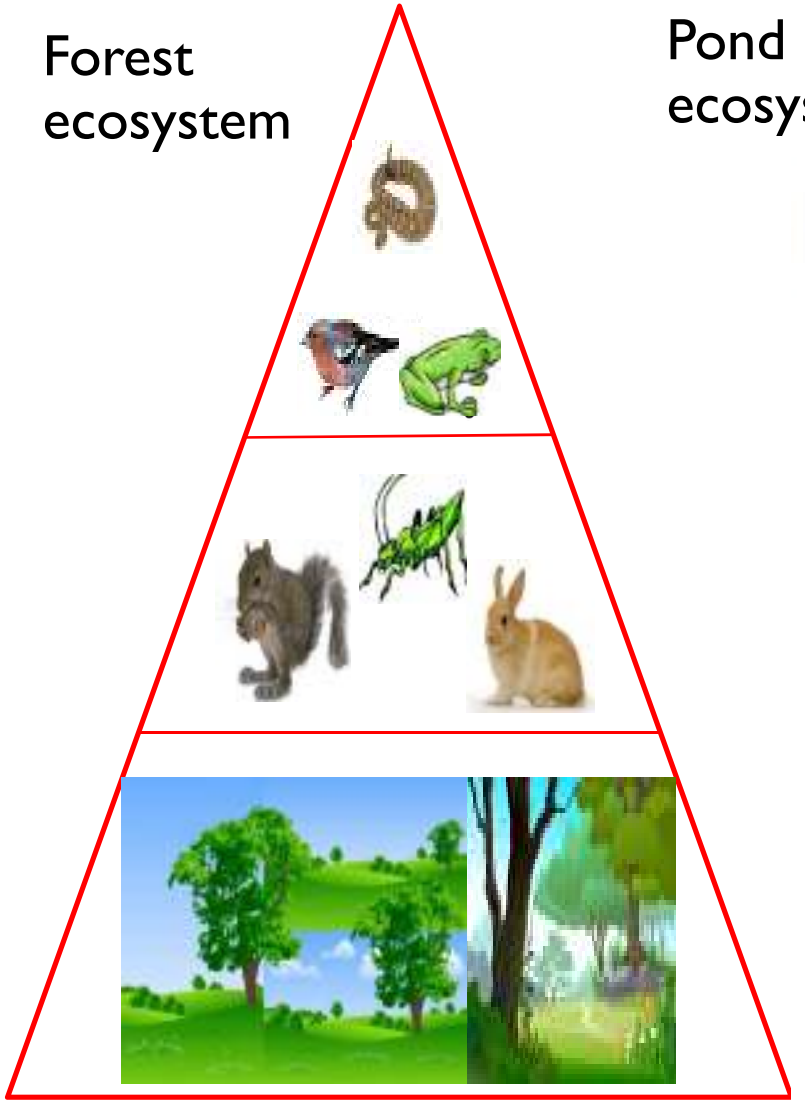


Inverted
Ex- Parasitic food chain

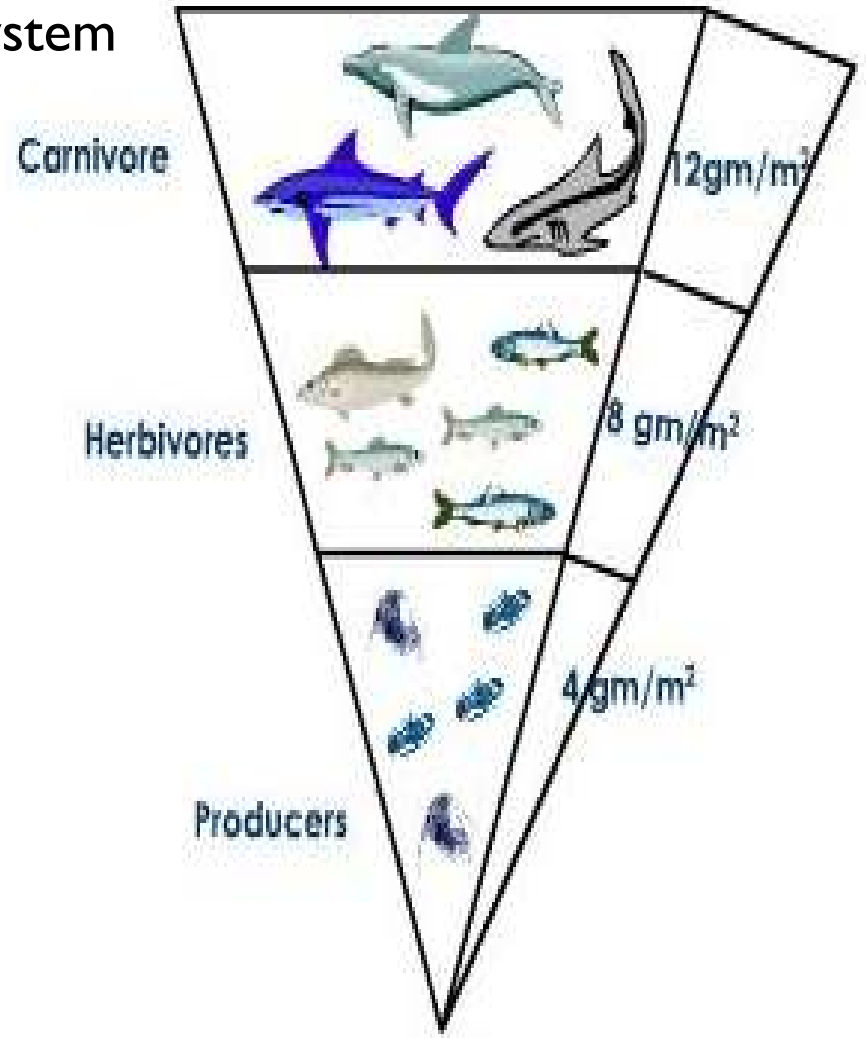


- Pyramid of biomass - total biomass at each level

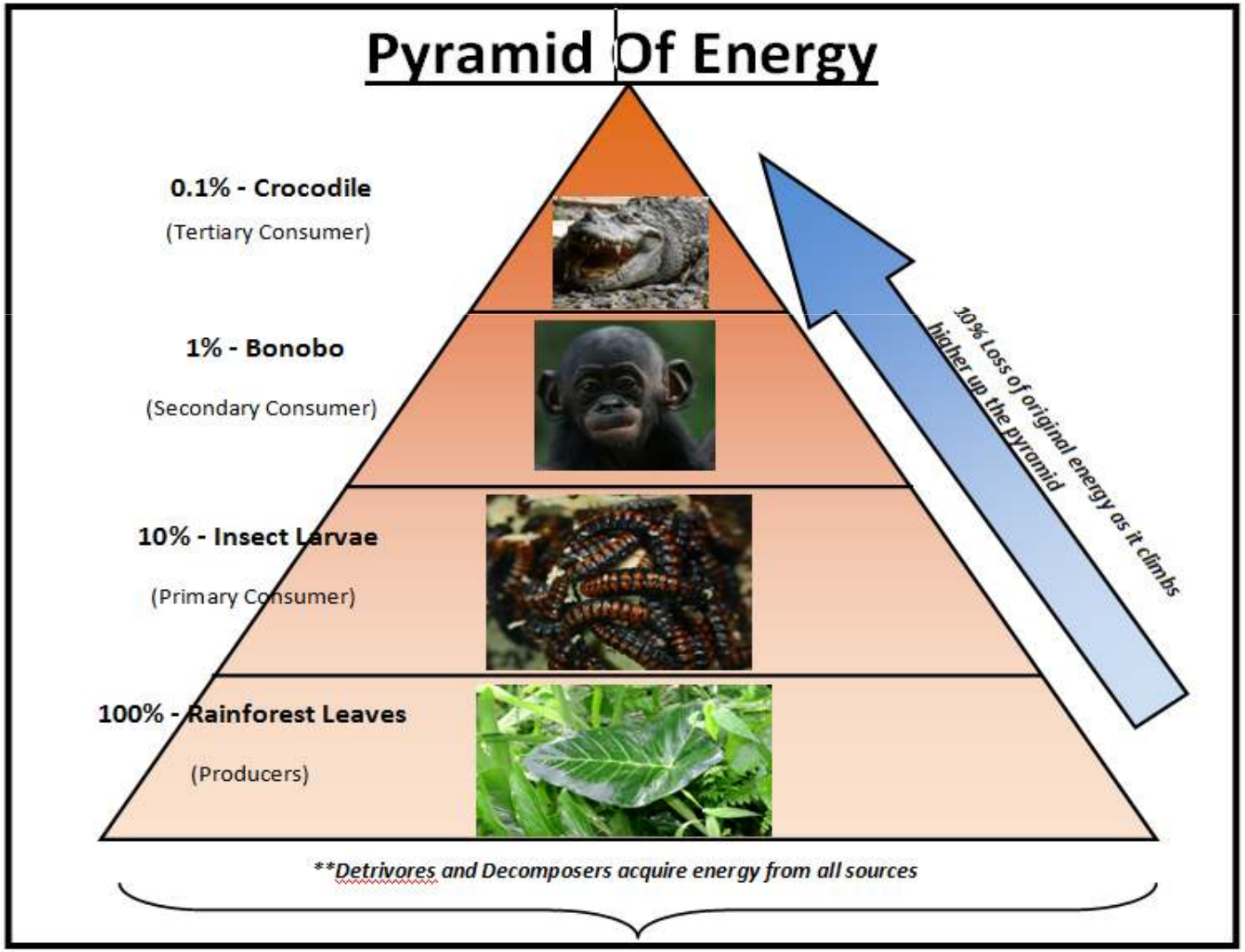
Forest ecosystem



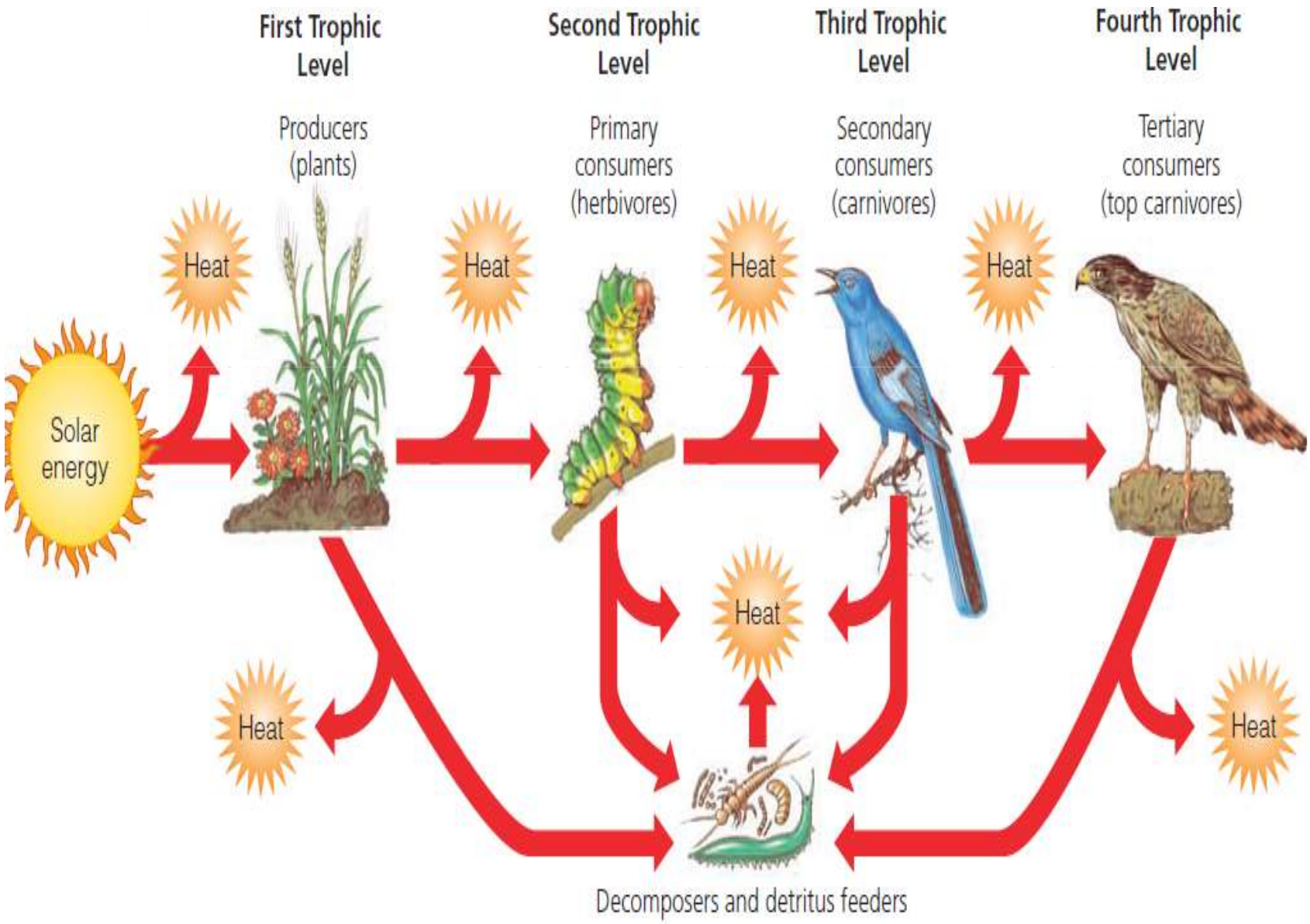
Pond ecosystem



- Pyramid of energy – amount of energy at each level – always upright



What happens to Energy?



Energy flow in ecosystem

- Unidirectional flow – follow laws of thermodynamics
  - I law – In plants solar energy to biochemical energy - consumers
  - II law – dissipation of energy at various levels (respiration, locomotion, hunting etc.) – only 10% energy transferred.
- Energy flow models
  - Universal energy flow model – E. P. Odum

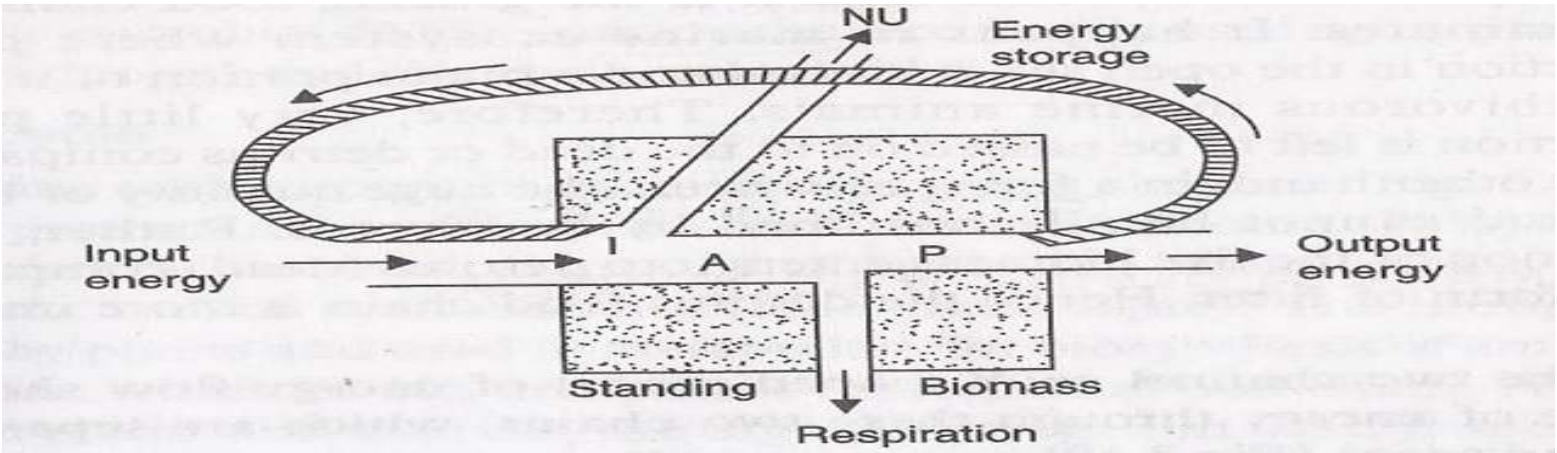
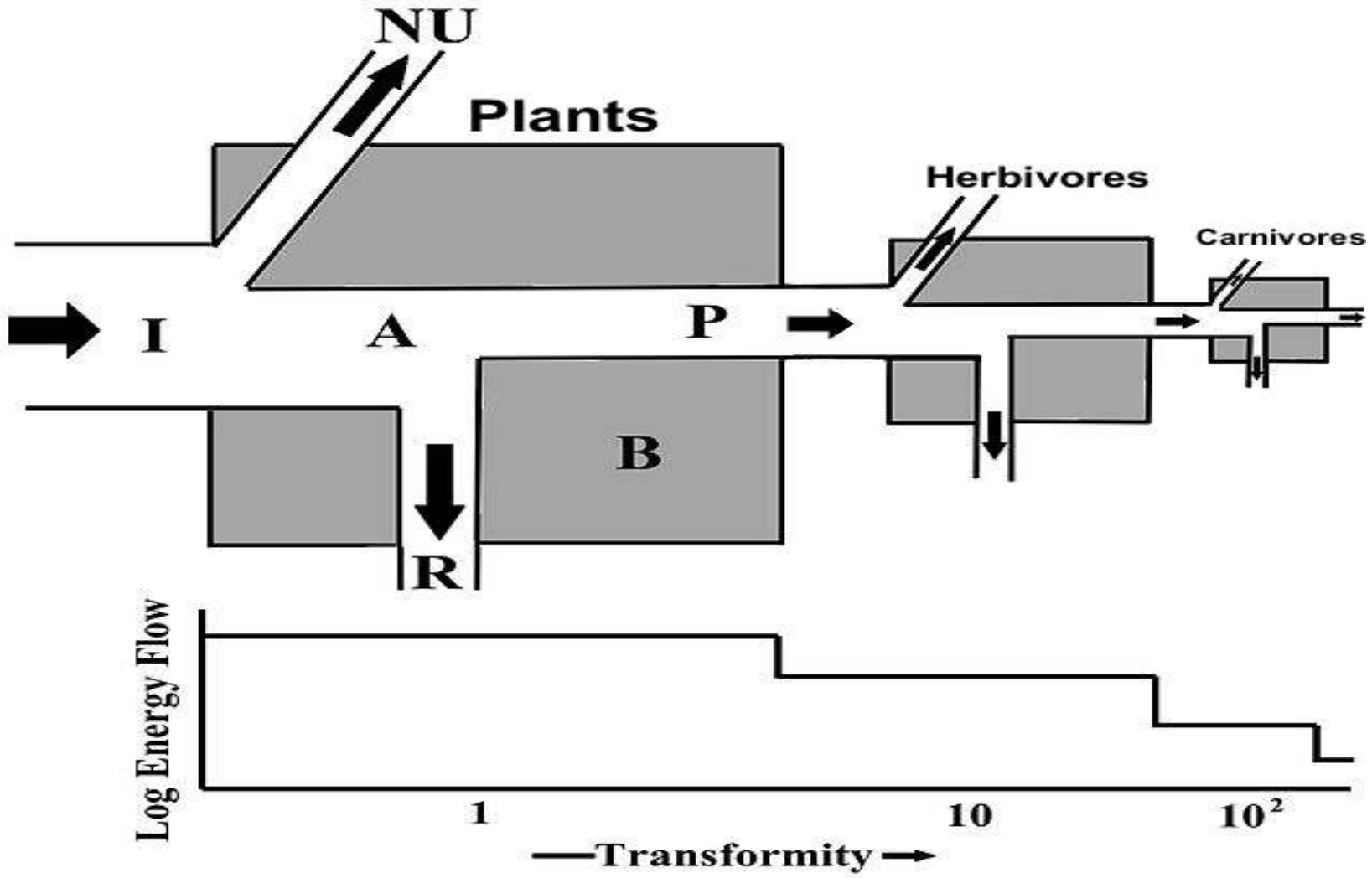


Fig. 3.8. Universal energy flow model applicable to all living components (I = Energy input; A : assimilated energy ; P = Production ; NU = Energy not used.

- Single channel energy flow model – unidirectional through single channel



- Double channel or Y-shaped energy flow model - passage of energy through forest ecosystem.

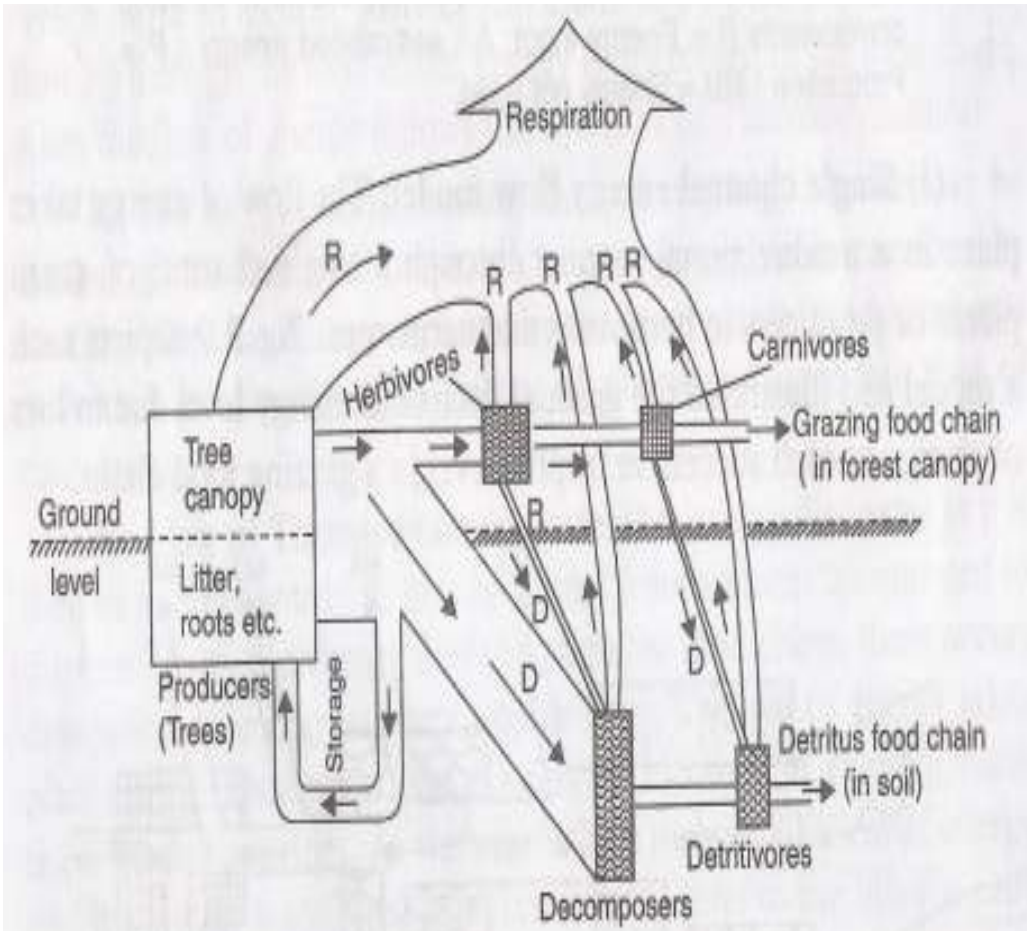
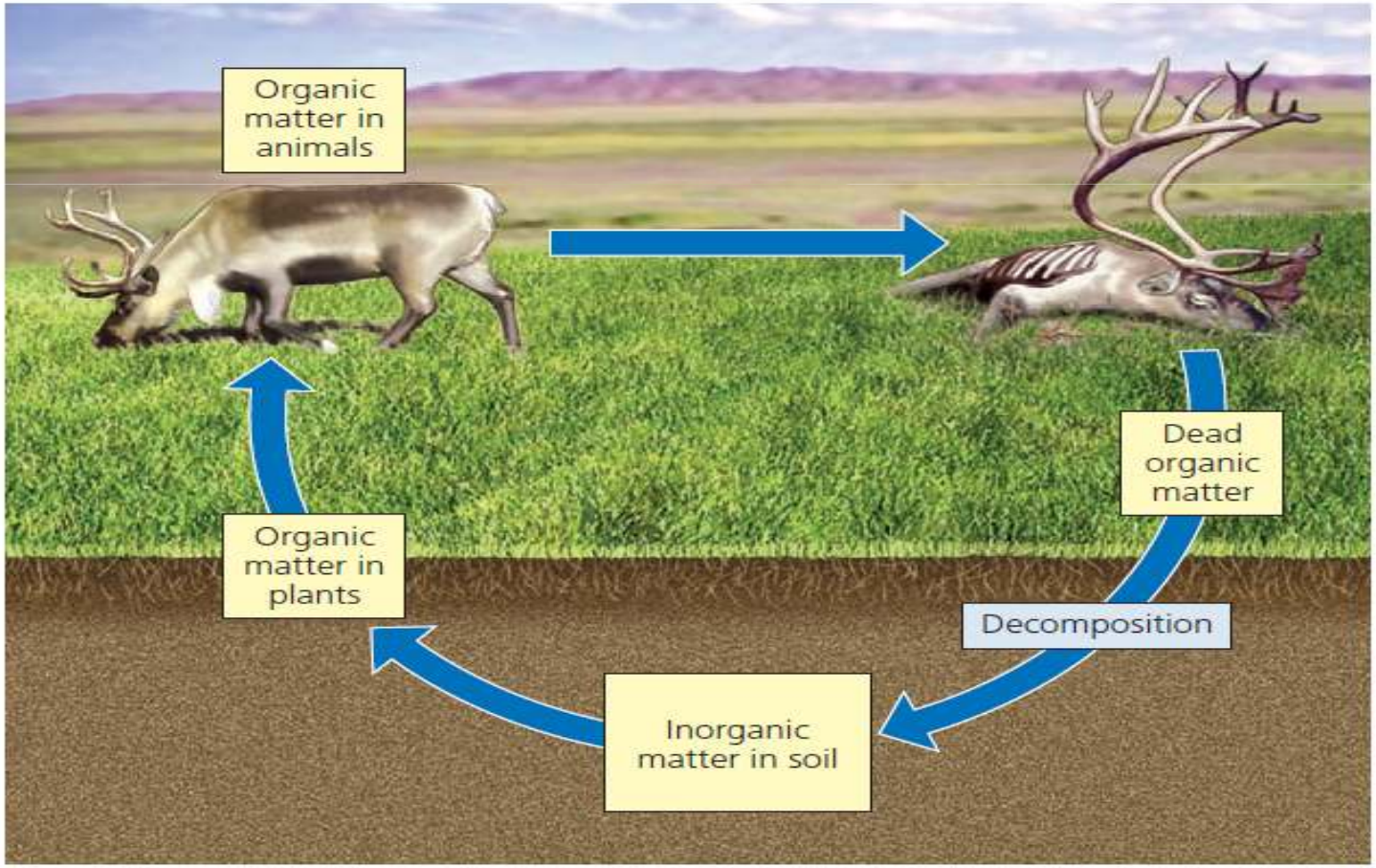


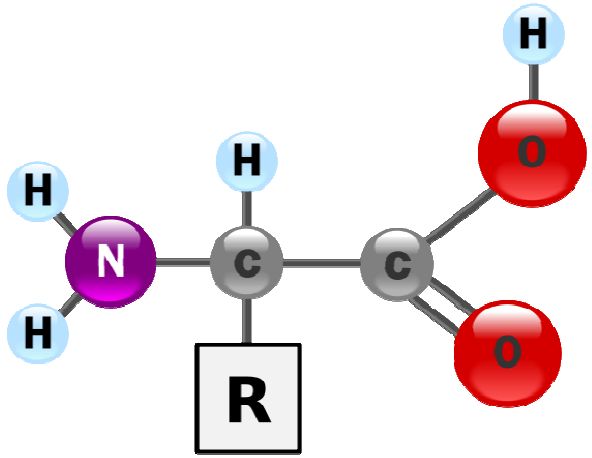
Fig. 3.10. Y-shaped or 2-channel energy flow model showing energy flow through the grazing food chain and the detritus food chain (R = Respiration, D = Detritus or dead matter).

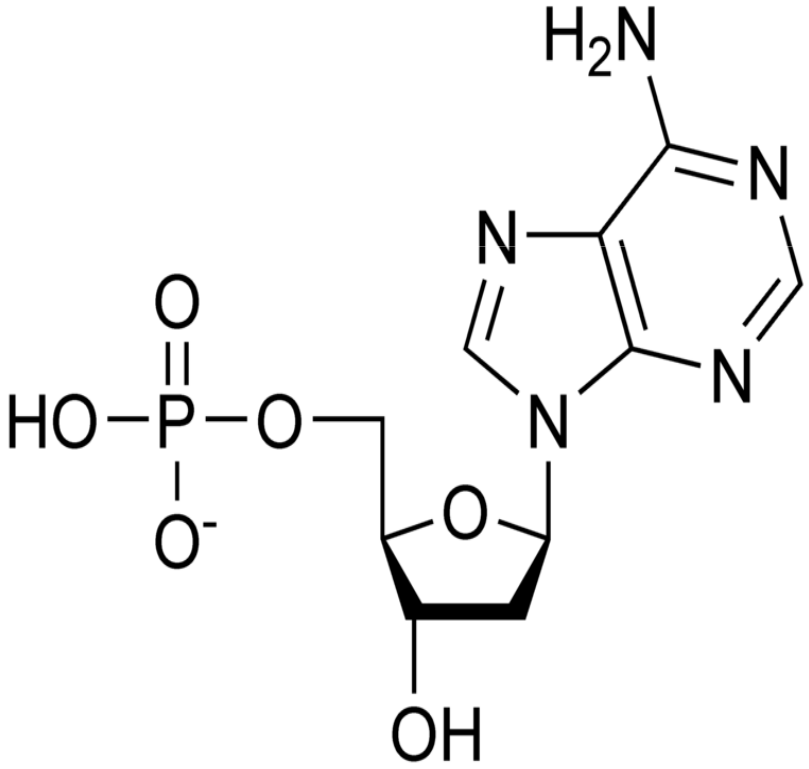
Nutrient cycling

- Nutrient – Inorganic or organic elements or compounds needed for survival and growth ex:- C, N, P, O, S etc.
- Biogeochemical cycles – move in circular paths through biotic and abiotic components



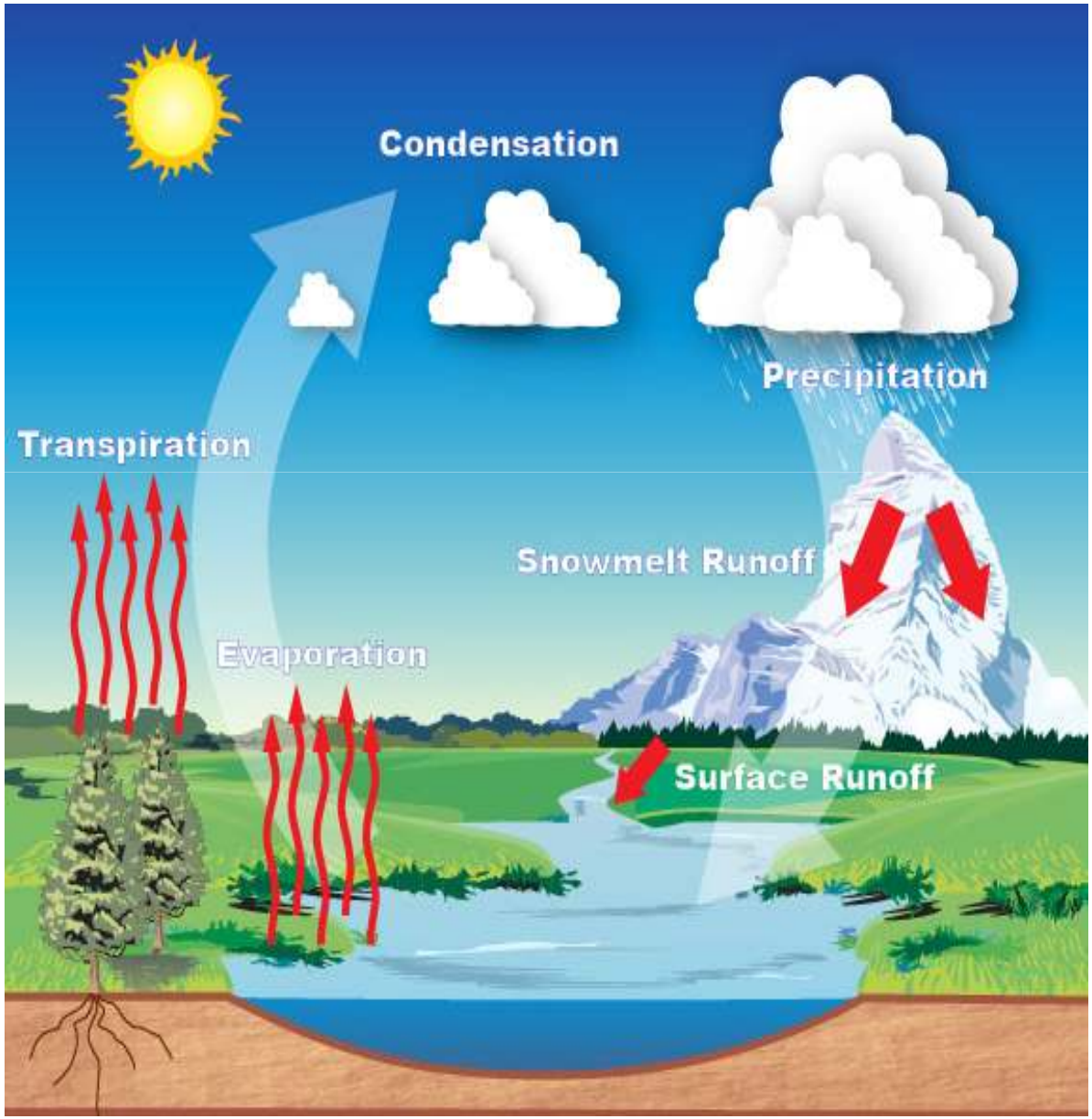
- Importance – Proteins, ATP, DNA, RNA, bones etc.





$Ca_5(PO_4)_3(OH)$

Water cycle



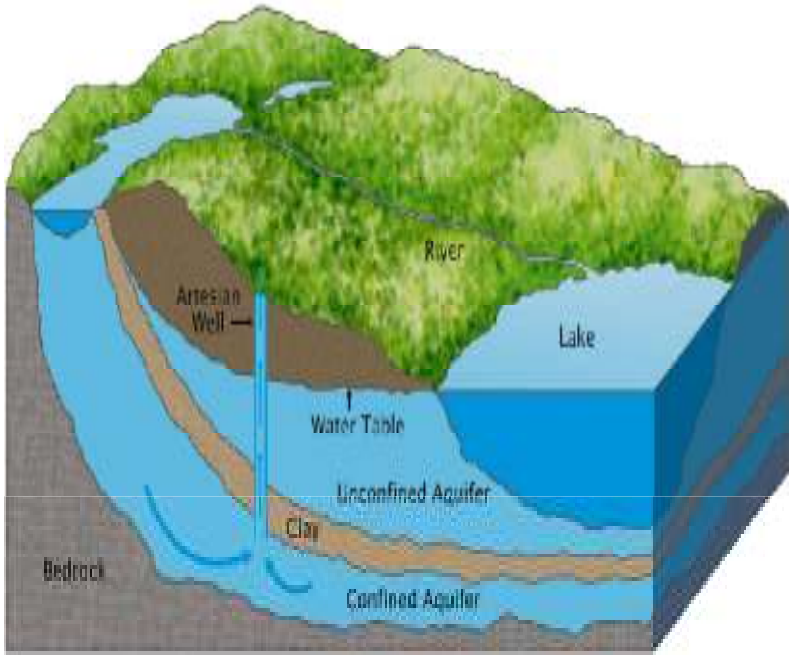
Natural renewal of water quality powered by energy from sun

1. Evaporation
2. Precipitation
3. Transpiration

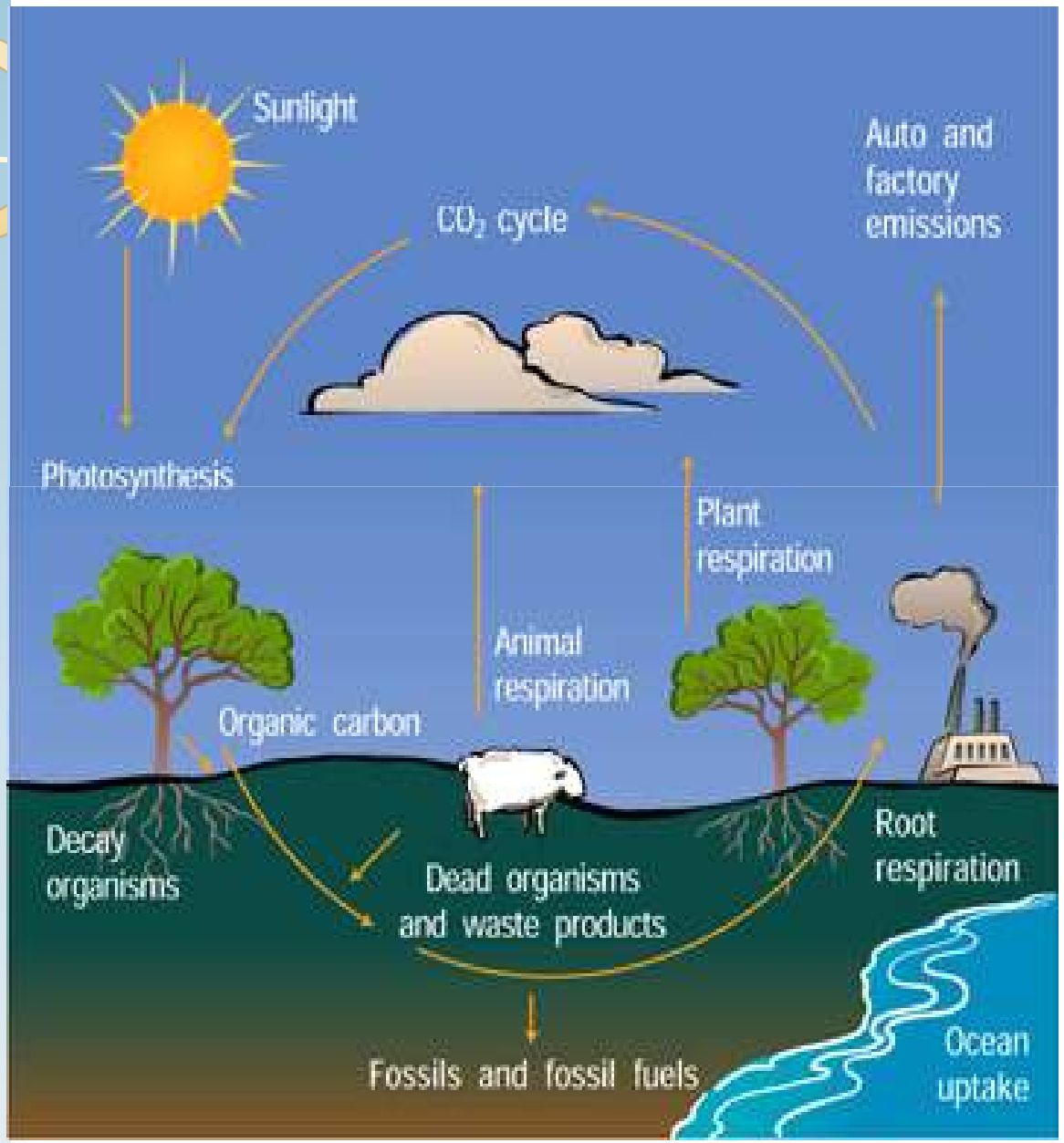
Only 0.024% is readily available

How we affect water cycle

- Large quantities of water withdrawal from various sources - aquifers
- Clearing vegetation from land for various activities
- Filling up wetlands for urbanization



C-cycle



Based on carbon dioxide (CO_2) gas – 0.038% of the volume of the atm.

As insoluble carbonates in water

As fossil fuels in earth's crust.

We alter the cycle by adding more CO_2 to the atm. – green house effect

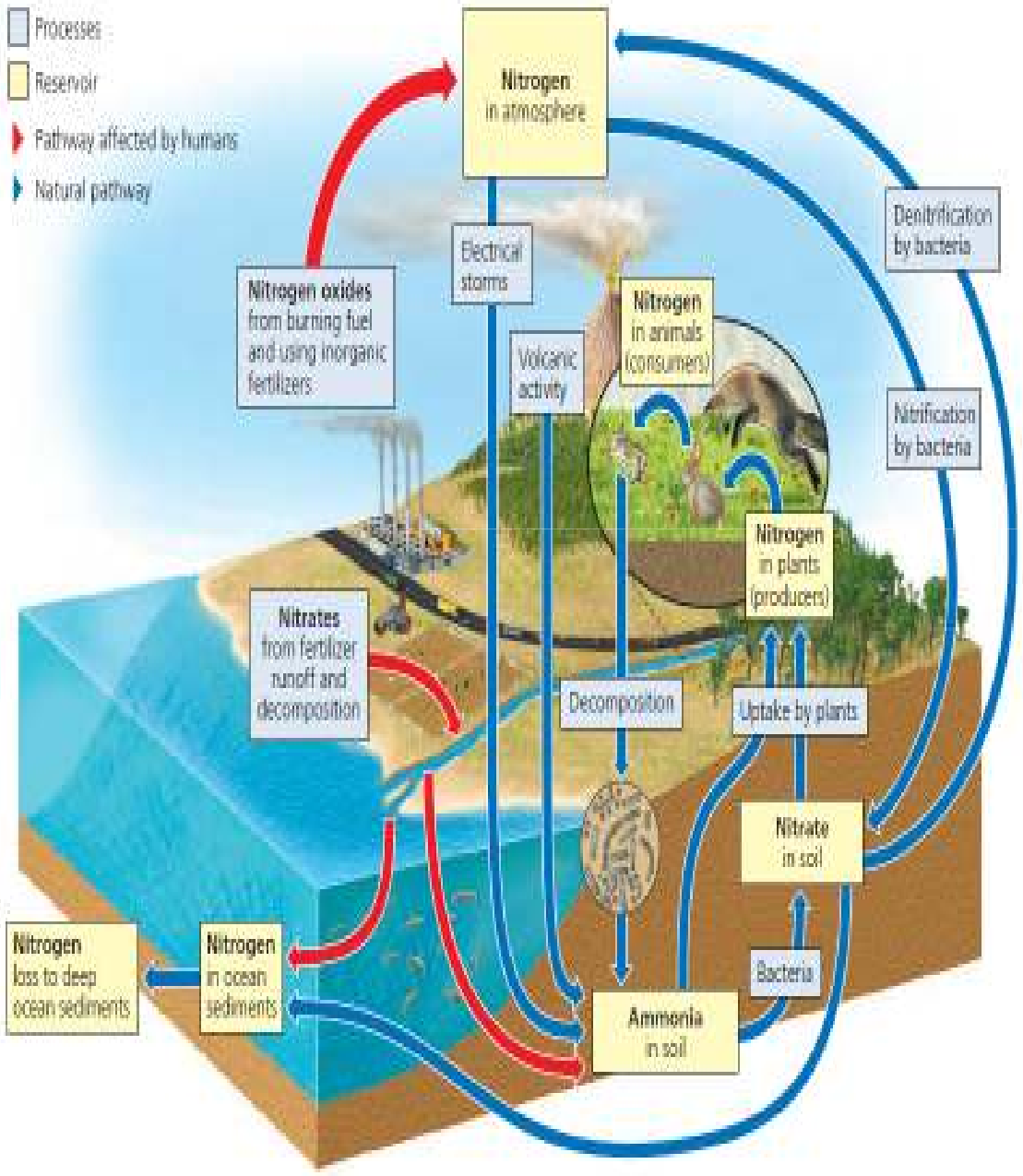
Every organic molecule contains the element carbon.

Carbon and oxygen form carbon dioxide gas (CO_2), an important component of the atmosphere - taken in by plants during photosynthesis and is given off by plants and animals during cellular respiration.

Four main types of processes move carbon through its cycle:

- Biological processes, such as photosynthesis, cellular respiration and decomposition, take up and release carbon and oxygen.
- Geochemical processes, such as erosion and volcanic activity, release carbon dioxide into the atmosphere and oceans.
- Mixed biogeochemical processes, such as the burial and decomposition of dead organisms and their conversion under pressure into coal and petroleum (fossil fuels), store carbon underground.
- Human activities, such as mining, cutting and burning forests, and burning fossil fuels, release carbon dioxide into the atmosphere.

N_2 cycle



1) Nitrogen fixation - bacteria – Rhizobium, cyanobacteria.

2) Nitrogen assimilation – conversion of nitrates to organic nitrogen

3) Ammonification– conversion of organic nitrogen to ammonia

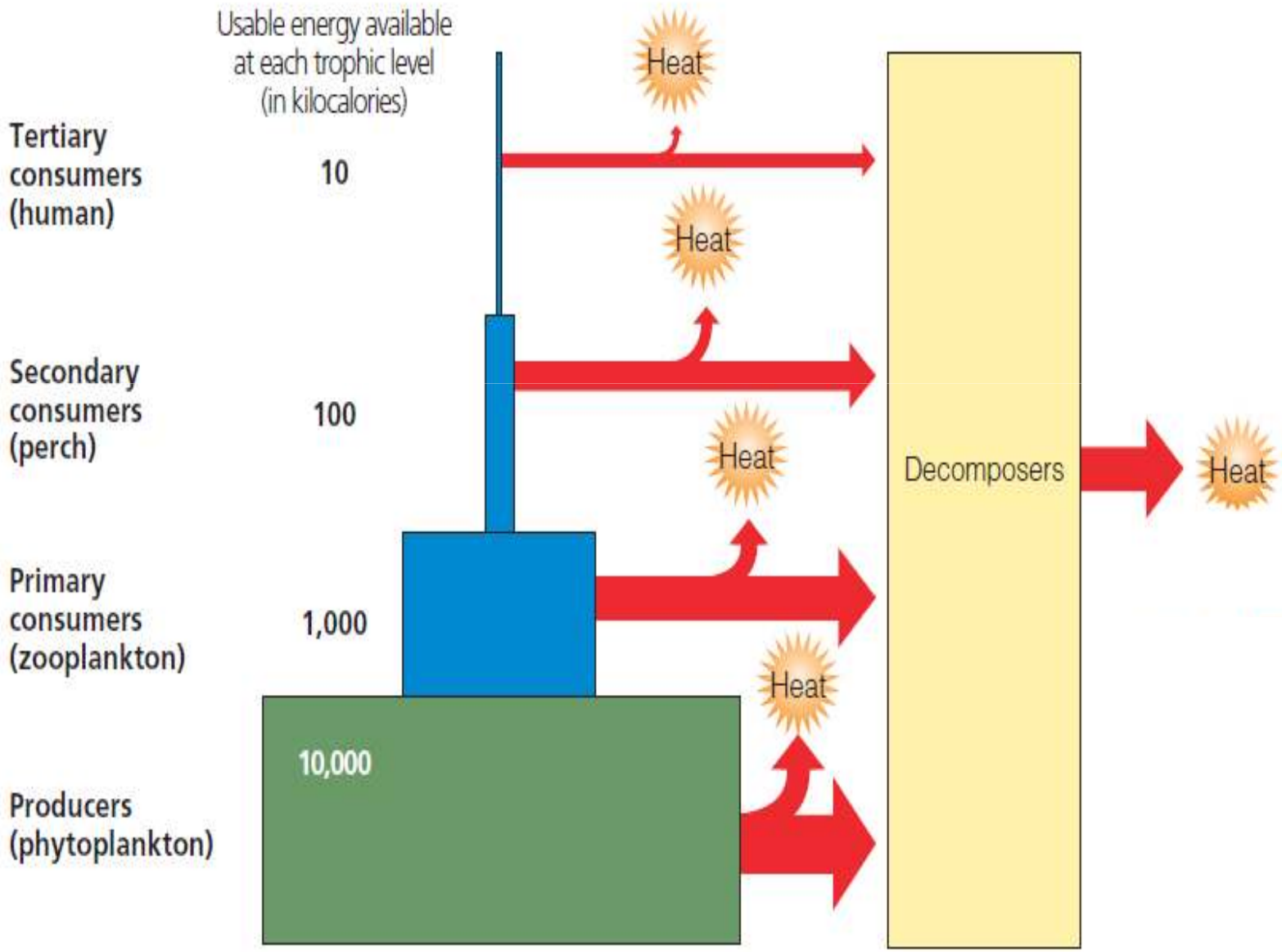
4) Nitrification – conversion of ammonia to nitrates - Nitrosomonas

5) Denitrification – reduction of oxides to molecular N_2

Our effect on N_2 cycle

- *Adding large* amounts of nitric oxide (NO) into the atmosphere when N_2 and O_2 combine as we burn any fuel at high temperatures, such as in car, truck, and jet engines - converted to nitrogen dioxide gas (NO_2) and nitric acid vapor (HNO_3), which can return to the earth's surface as damaging *acid deposition,* commonly called *acid rain.*
- *Adding nitrous oxide (N_2O) to the atmosphere* through the action of anaerobic bacteria on commercial inorganic fertilizer or organic animal manure applied to the soil. This greenhouse gas can warm the atmosphere
- *Releasing large quantities of nitrogen stored* in soils and plants as gaseous compounds into the atmosphere through destruction of forests.
- Adding excess nitrates (NO_3^-) to bodies of water through agricultural runoff of fertilizers and animal manure and through discharges from municipal sewage systems. This can cause excess growth of algae – Eutrophication.
- *Removing nitrogen from topsoil when* we harvest nitrogen-rich crops, irrigate crops and burn or clear grasslands and forests before planting crops.

Production


Usable energy available at each trophic level (in kilocalories)
Tertiary consumers (human)
10
Secondary consumers (perch)
100
Primary consumers (zooplankton)
1,000
Producers (phytoplankton)
10,000
Heat
Heat
Heat
Heat
Decomposers
Heat

- Primary – Total amount of organic matter produced using solar energy, nutrients and water.
- Available organic matter is always little less than produced due to respiration.

NPP = GPP – R

NPP = Net Primary production
GPP = Gross Primary Production
R = Respiratory loss

- Herbivores consume producers to built up organic matter – in turn is used up by carnivores.
- Secondary – Amount of organic matter or energy stored at consumer level for use at next tropic level

Net productivity

- Net primary productivity is the energy that producers can make available to a community at any one time.
- Net productivity determines how much life an ecosystem supports.
- Productivity can be measured in calories (units of energy) or biomass (amount of organic material)
- Primary productivity depends on solar radiations, availability of water, nutrients and upon the type of plants and chlorophyll content.

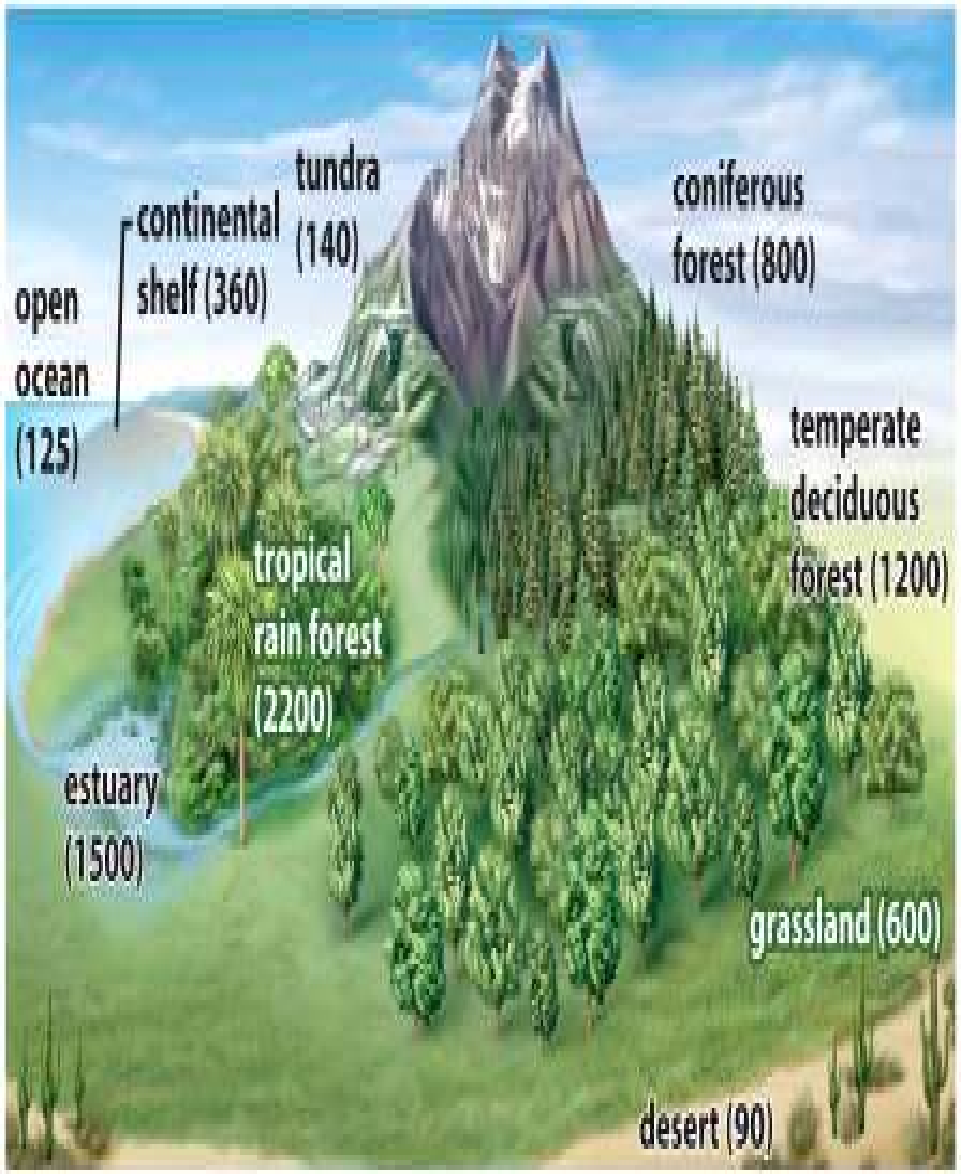
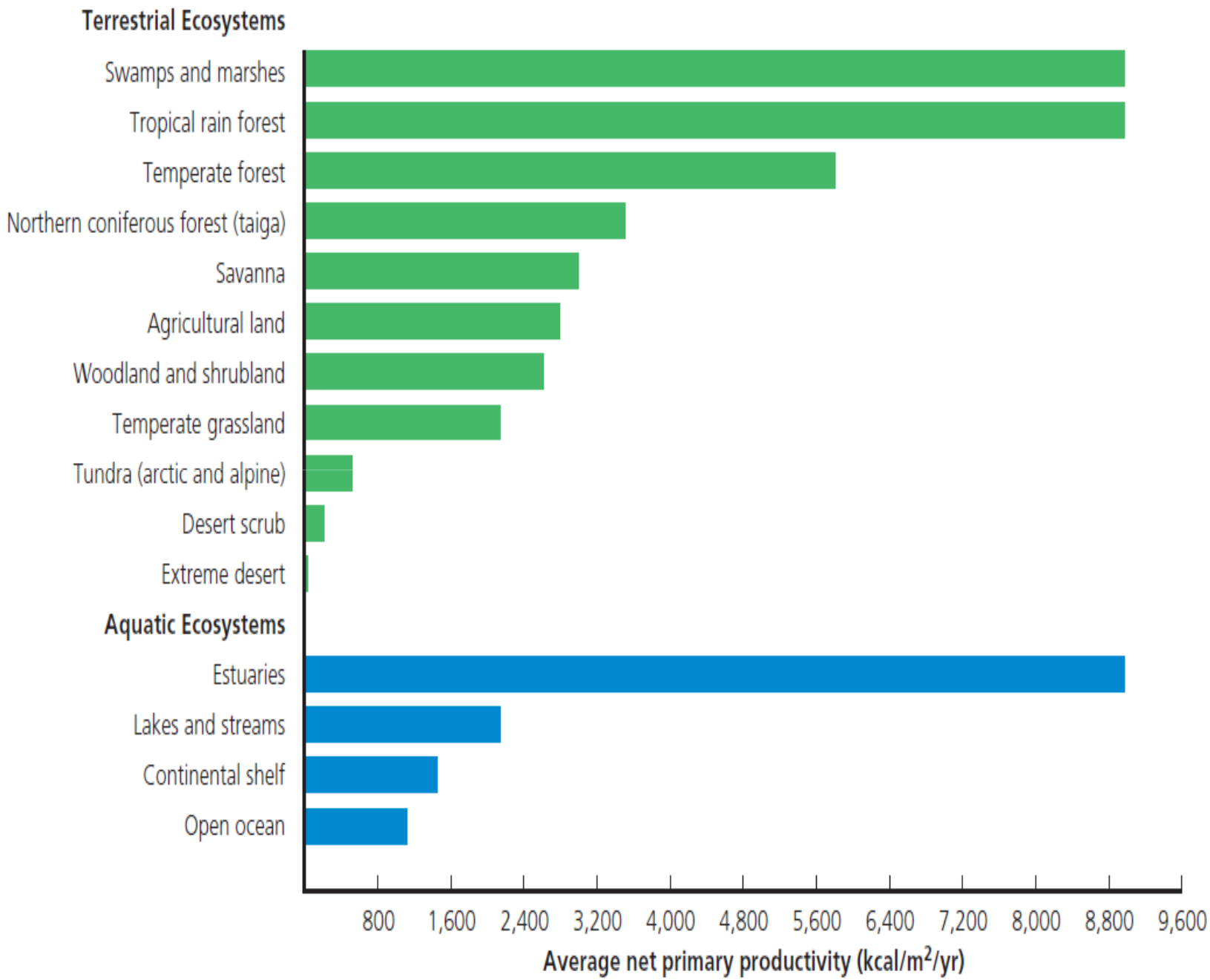
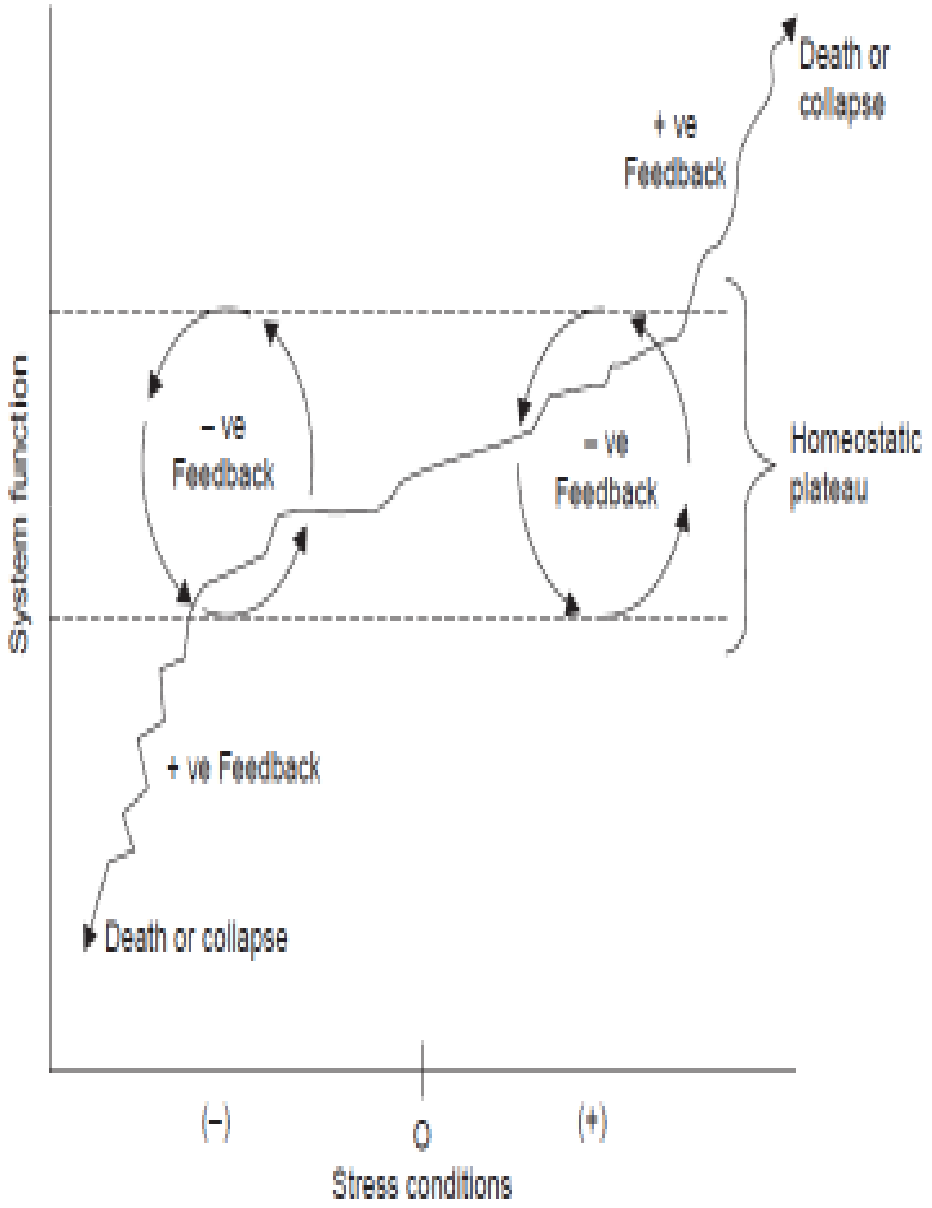


Figure 28-3 Biology: Life on Earth, 8/e
© 2008 Pearson Prentice Hall, Inc.


Terrestrial Ecosystems
Swamps and marshes
Tropical rain forest
Temperate forest
Northern coniferous forest (taiga)
Savanna
Agricultural land
Woodland and shrubland
Temperate grassland
Tundra (arctic and alpine)
Desert scrub
Extreme desert
Aquatic Ecosystems
Estuaries
Lakes and streams
Continental shelf
Open ocean
800
1,600
2,400
3,200
4,000
4,800
5,600
6,400
7,200
8,000
8,800
9,600
Average net primary productivity (kcal/m2/yr)

Ecosystem regulation

- All ecosystems function under a set of environmental condition.
- Any environmental stress disturbs it equilibrium, it tries to nullify -homeostasis.
- Range of tolerance is known as homeostatic plateau.
- Stress within this range allows ecosystem to return to its equilibrium - negative feedback mechanisms.
- Beyond this range ecosystem collapses by positive feedback mechanisms



Ecological succession

- Ecosystem is dynamic in nature
- The structure and species composition of communities and ecosystems change in response to changing environmental conditions through a process called ecological succession
- Orderly process of changes in community structure and function through physical environment modifications ending in stabilized ecosystem (climax)
- Primary – life from no life like conditions – no soil, no bottom sediment – long time
- Secondary – life from life like conditions - begins in an area where ecosystem is disturbed, removed, or destroyed, but some soil or bottom sediment remains

- Pioneer community/species – first established community
- Seral stages – transitory phases

- Types - based on starting types or areas
  - Hydrarch or hydrosere – pond, swamp, bog
  - Mesarch – adequate moisture
  - Xerarch or xerosere – dry area
    - Lithosere – bare rock
    - Psammosere – sand and
    - Halosere – saline soil

Process

- Nudation – development of a bare area devoid of any life form
  - Topographic, climatic and biotic
- Invasion – successful establishment of one or more species through dispersal followed by establishment.
  - Migration, ecesis and aggregation
- Competition and coaction – increased no. of individuals lead to competition (intra and inter)
- Reaction – species use nutrients, water etc. influence environment – several seral communities
- Stabilization – stable community in equilibrium with environment(climax) – max. biomass and symbiotic linkages between organisms

Hydrosere

Hydrosere succession –
starts in a water body like pond

Phytoplanktons (algae, pioneer species).

Rooted submerged plants (invasion).

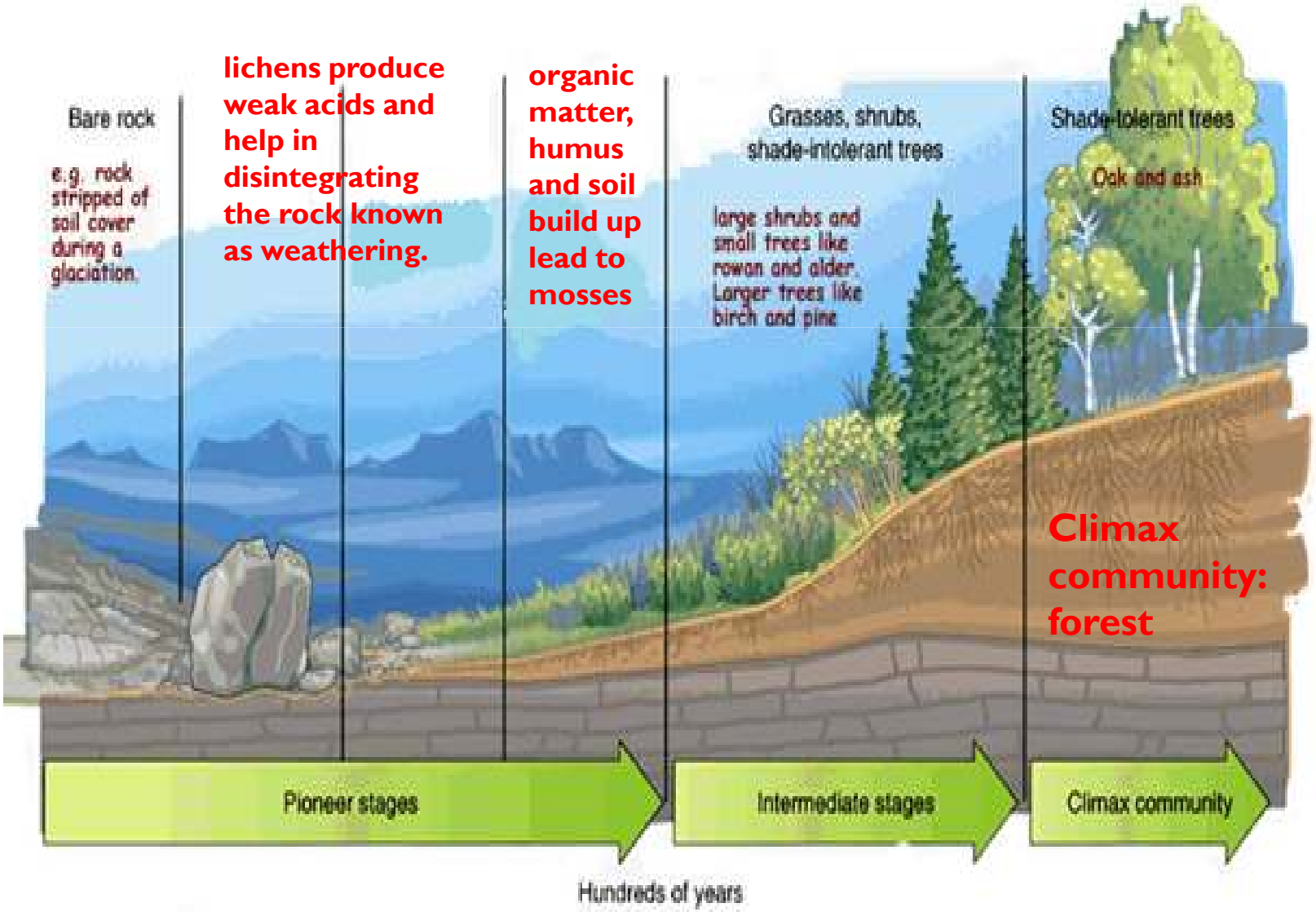
Rooted floating plants
(competition and coaction).

Reed swamp, layer of solid builds up, plants are partly in water and partly on land sedge-meadow stage of grass(reaction).

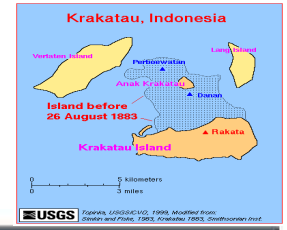
Shrubs and trees and finally forest
(climax community).

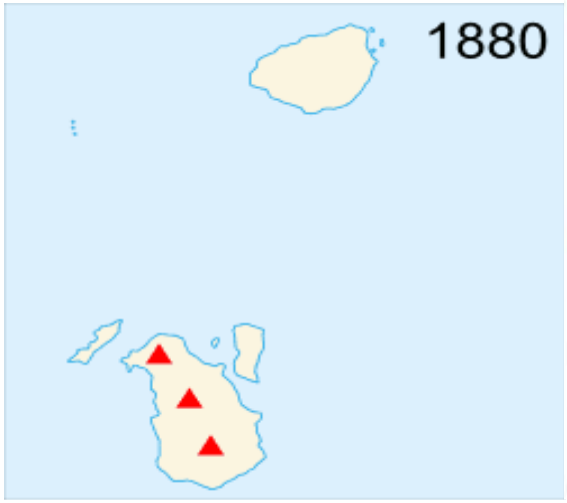
Xerosere

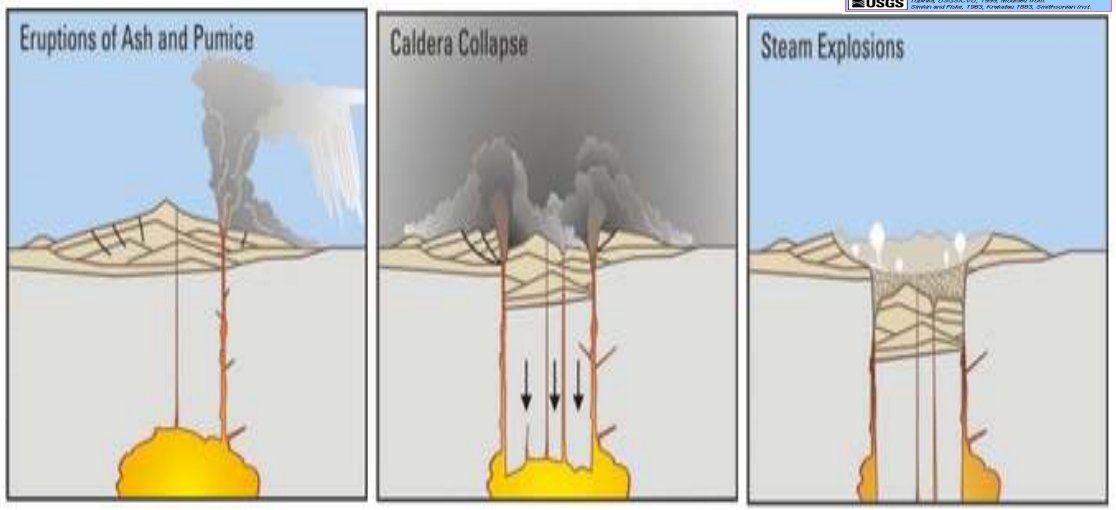
Originates on bare rocks which lacks water and organic matter.
Climax community is a forest !



Case study – Krakatoa islands







- 0 years – only molten lava was found on the island soon after the eruption.
- 1-2 years – barren solidified lava was found
- 5-10 years – lichens were found
- 15-20 years – moss was found
- 50 years – forest was found

End of Module 1