Energy &
Environmental Engineering

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Module 1:

OVERVIEW OF PRESENTATION

- Introduction
- Ecology
- Components of ecosystem and interdependency- Case studies
- System Concept of Ecosystem
- Ecosystem services and function- Case studies
- Food chains, food webs, ecological pyramids
- Energy flow in ecosystem- Concepts of thermodynamics
- Ecological efficiency and methods of quantification
- Material flow in ecosystem
- Human Impact of technology on environment- Ecological footprint, Carbon footprint

Introduction

(David Orr,1991)- If today is the typical day on planet earth

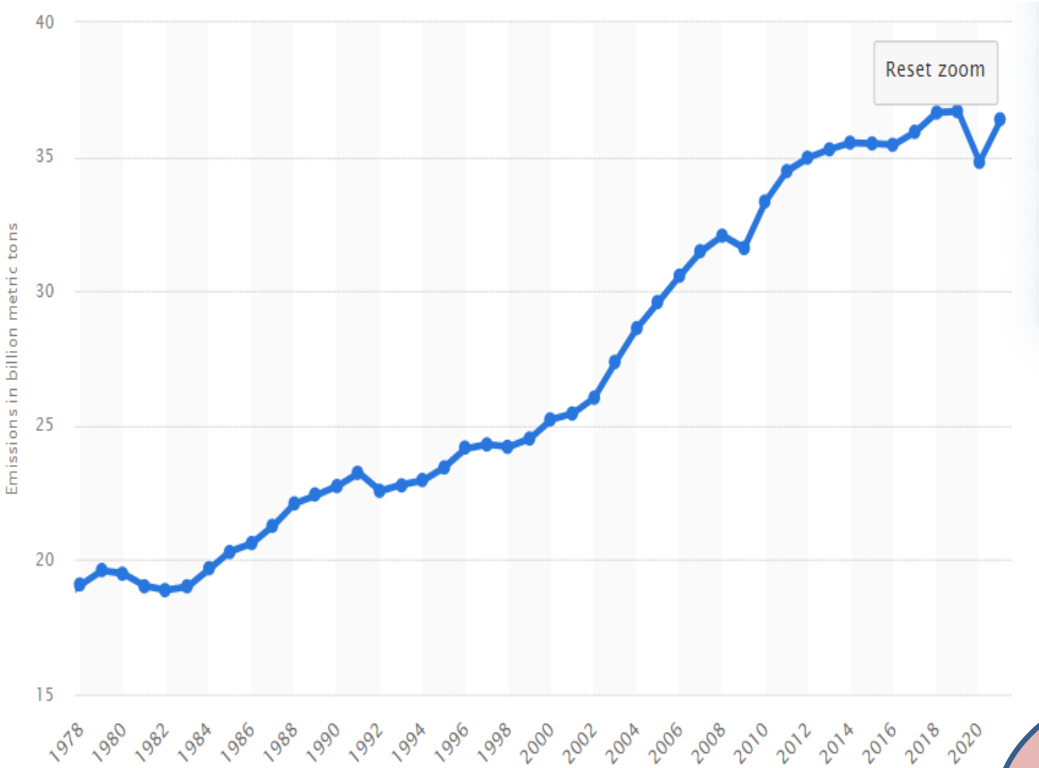
We will lose 116 square miles of rainforest or about an acre a second

We will lose 72 square miles of land to encroaching deserts

We may lose 40 to 100 species, this is we are talking about a typical day on planet

Introduction

- ❑And tonight, the earth will be little hotter
- ❑Global warming
- ❑We still have lot of carbon being added to the atmosphere

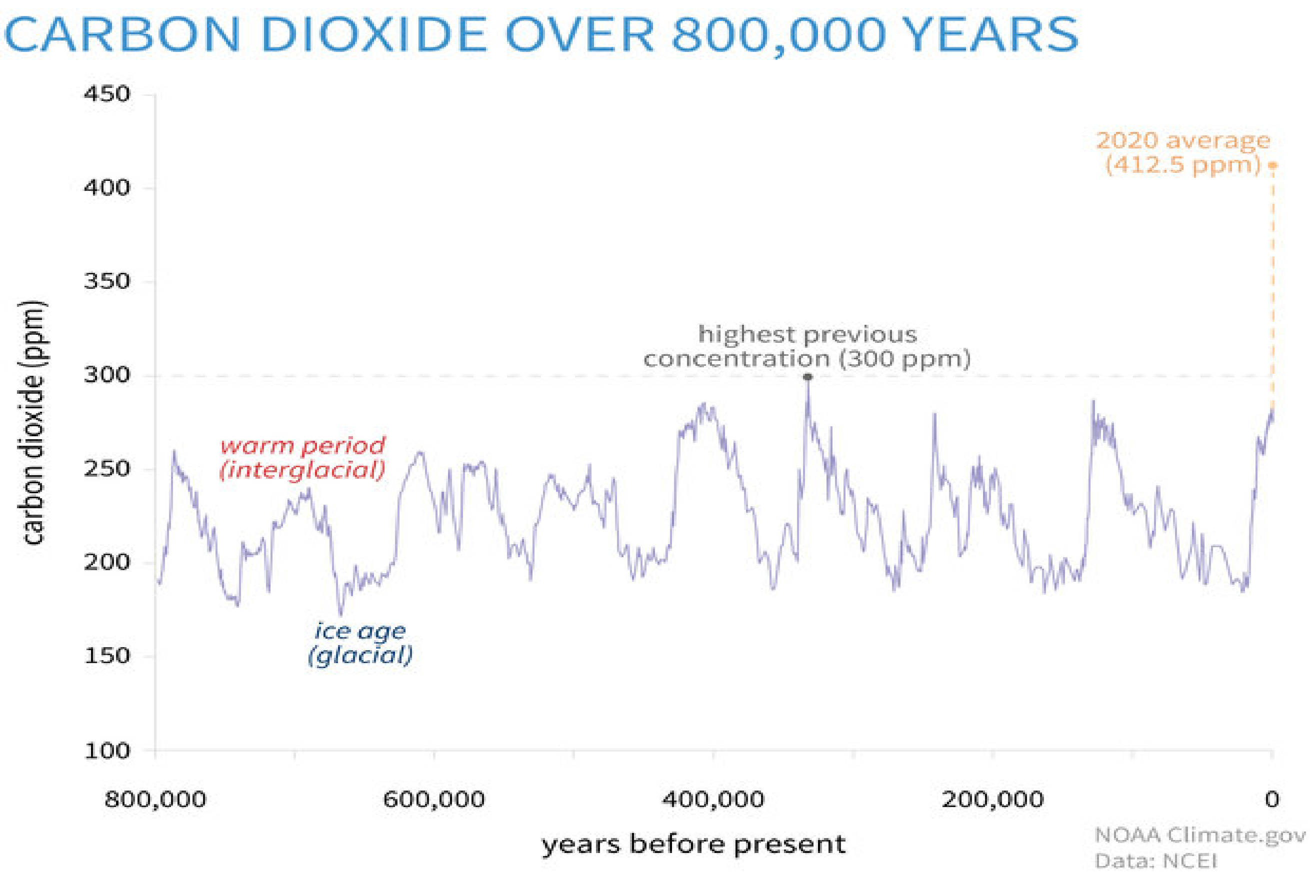


NOAA Climate.gov

Waters more acidic
putting more and more carbon dioxide,
nitrous oxide,
sulphur oxides into the atmosphere,
this comes back as rain and the water is becoming more and more acidic.

As engineers we need to know how the planet earth works and we need to understand ecology.

Introduction



Global atmospheric carbon dioxide concentrations (CO_2) in parts per million (ppm) for the past 800,000 years. The peaks and valleys track ice ages (low CO_2) and warmer interglacials (higher CO_2). During these cycles, CO_2 was never higher than 300 ppm. On the geologic time scale, the increase (orange dashed line) looks virtually instantaneous. Graph by NOAA Climate.gov based on data from Lüthi, et al., 2008, via NOAA NCEI Paleoclimatology Program. *[Correction: August 20, 2020. An earlier version of this image had an error in the time scaling on the X axis. This affected the apparent duration and timing of the most recent ice ages, but did not affect the modern or paleoclimate carbon dioxide values.]*

Ecology

Definition:

- it is defined as the scientific study of the processes influencing the **distribution and abundance of organisms, the interactions among organisms and the interactions between organisms and the transformation and flux of energy and matter** - Ernst Haeckel (1866)

- It emphasizes both **living and non-living components** of the natural world.

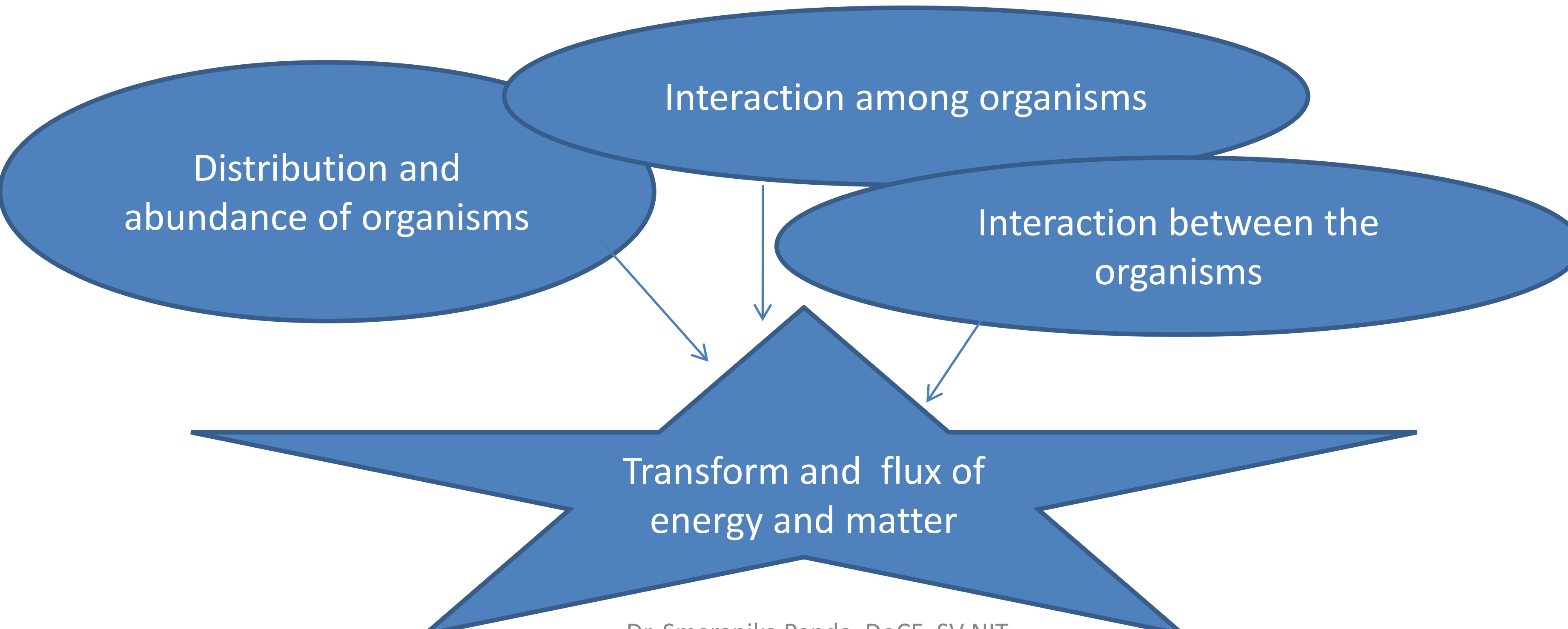
•it is called the **study of distribution of organisms**- Andrewartha and Birch (1954)

•so which reinforces the focus on organism as the core of ecology.

Evelyn Hutchinson defined ecology as the sc**ience of the universe**.

Ecology

ecology is a study of **the processes**,
it could be chemical process, it could be physical process,



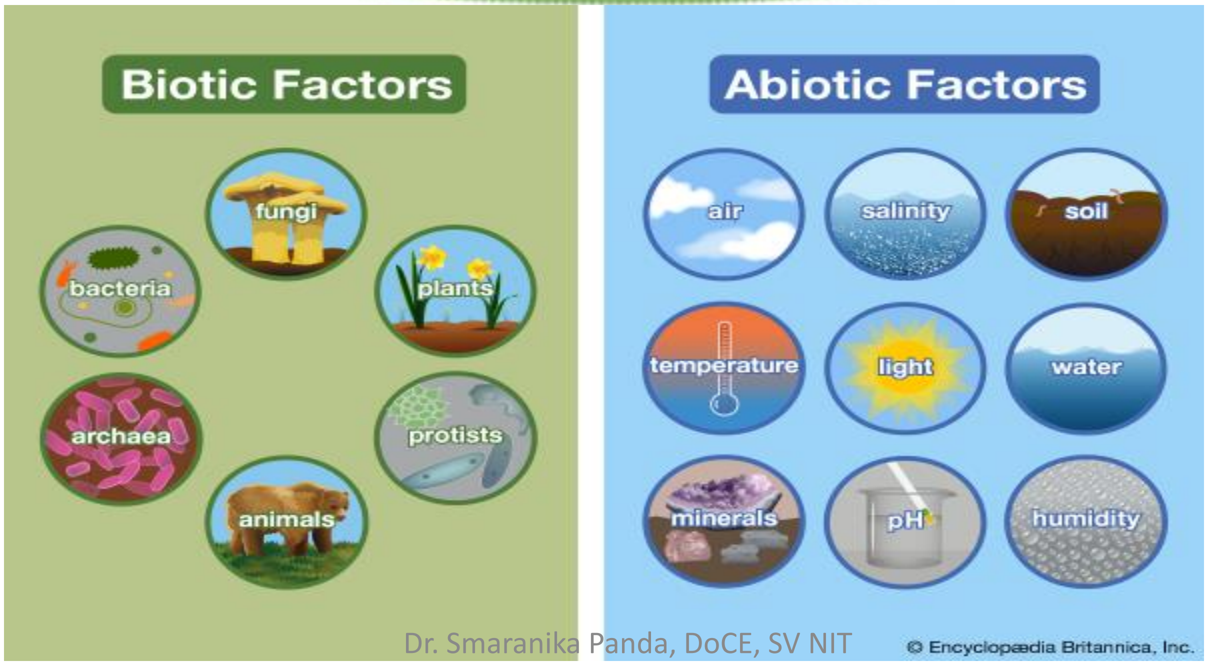
Ecosystem

<u>Boundary of ecosystem:</u>

- **Ecosystem is a region in which the organisms and the physical environment** form an **interacting unit**. Within an ecosystem there is a complex network of interrelationships.
- E.g tree, pond --- simple ecosystems. Forest ecosystem

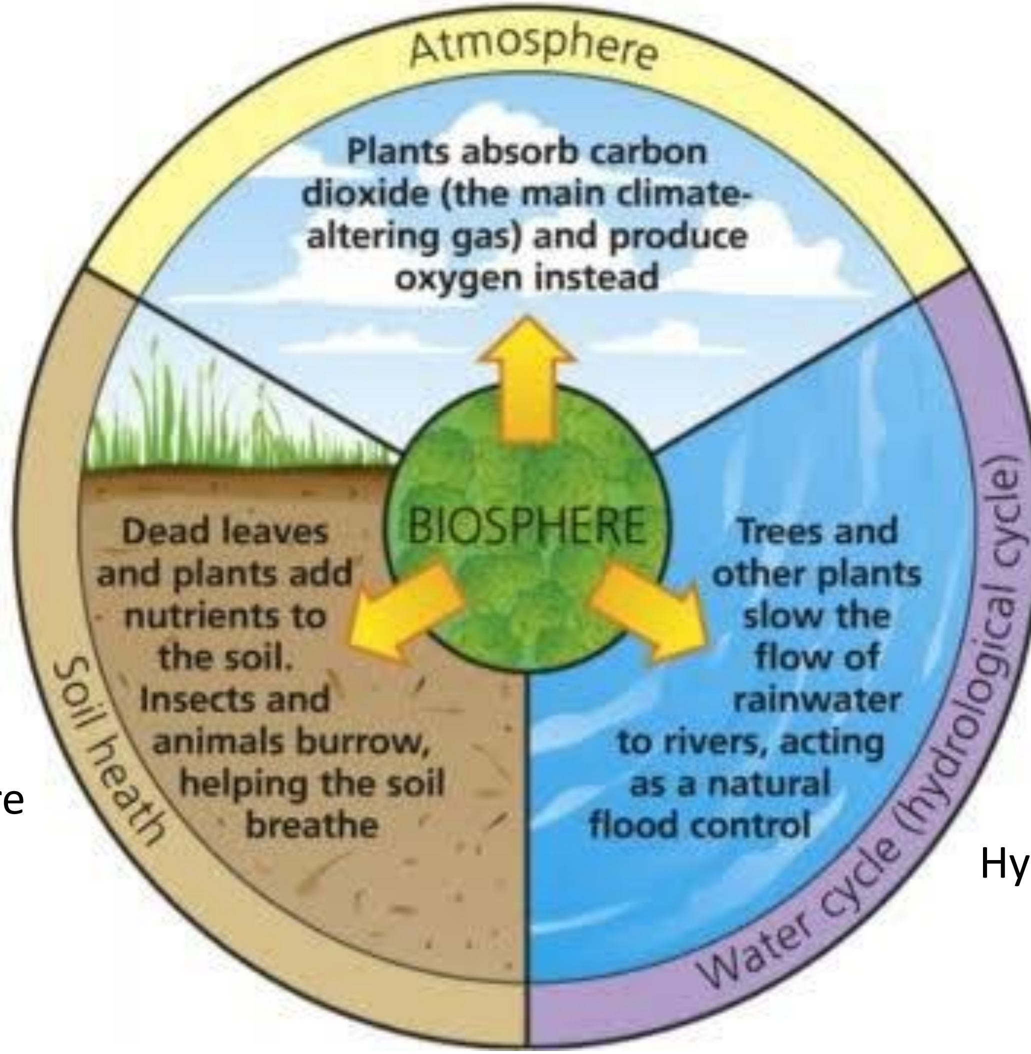
Ecosystem

- Plants
- Animals
- Micro-organisms
Environment
Biotic (living)
Interactions
Physical and Chemical
Abiotic (non-living)
Energy and matter flow/transform



Biotic Factors
fungi
bacteria
plants
archaea
protists
animals
Abiotic Factors
air
salinity
soil
temperature
light
water
minerals
pH
humidity
© Encyclopædia Britannica, Inc.

Ecosystem

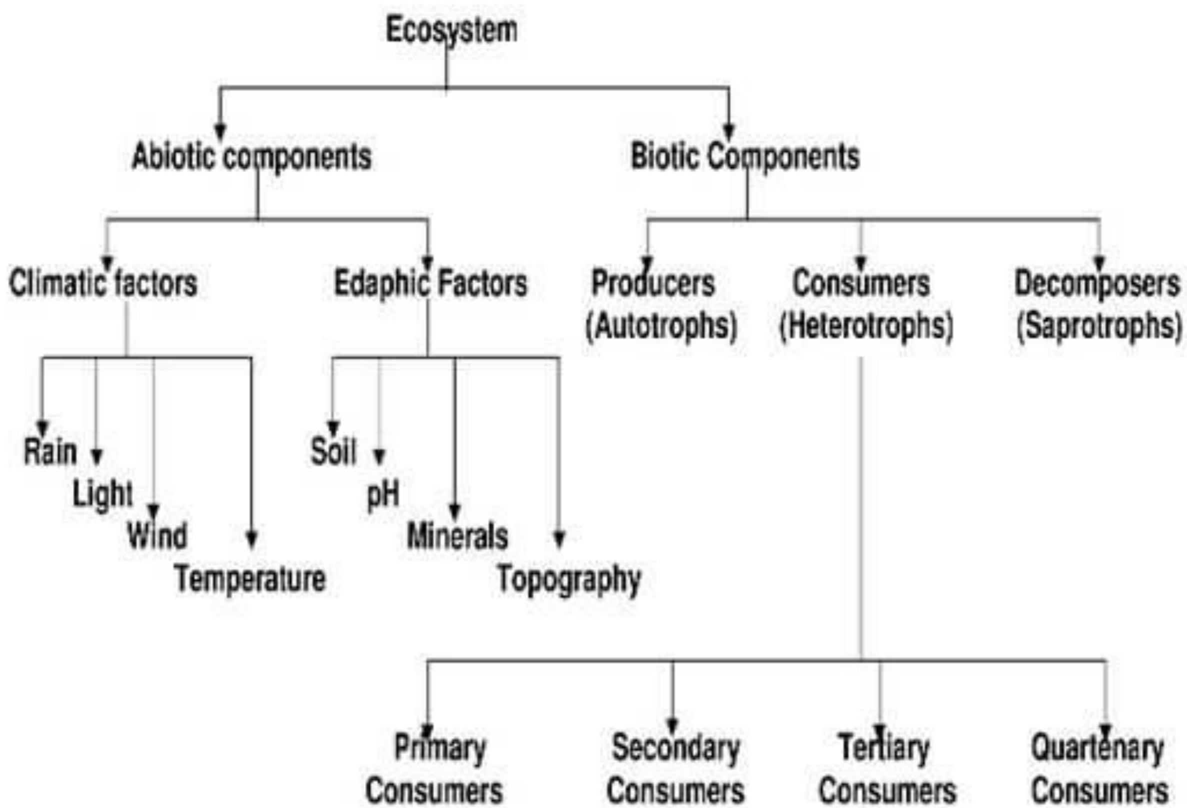


Lithosphere

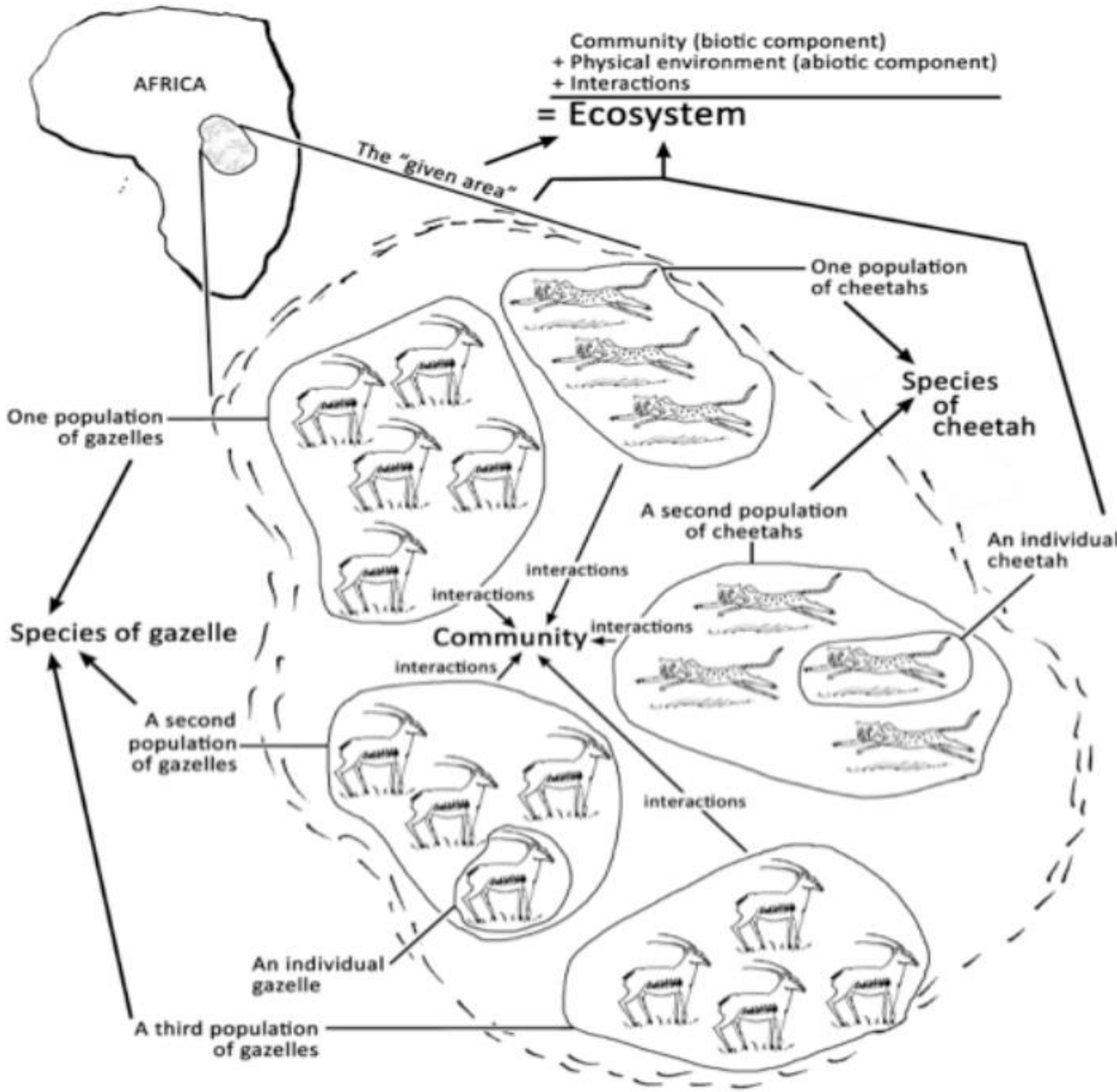
Hydrosphere

Ecosystem

Components of Ecosystem

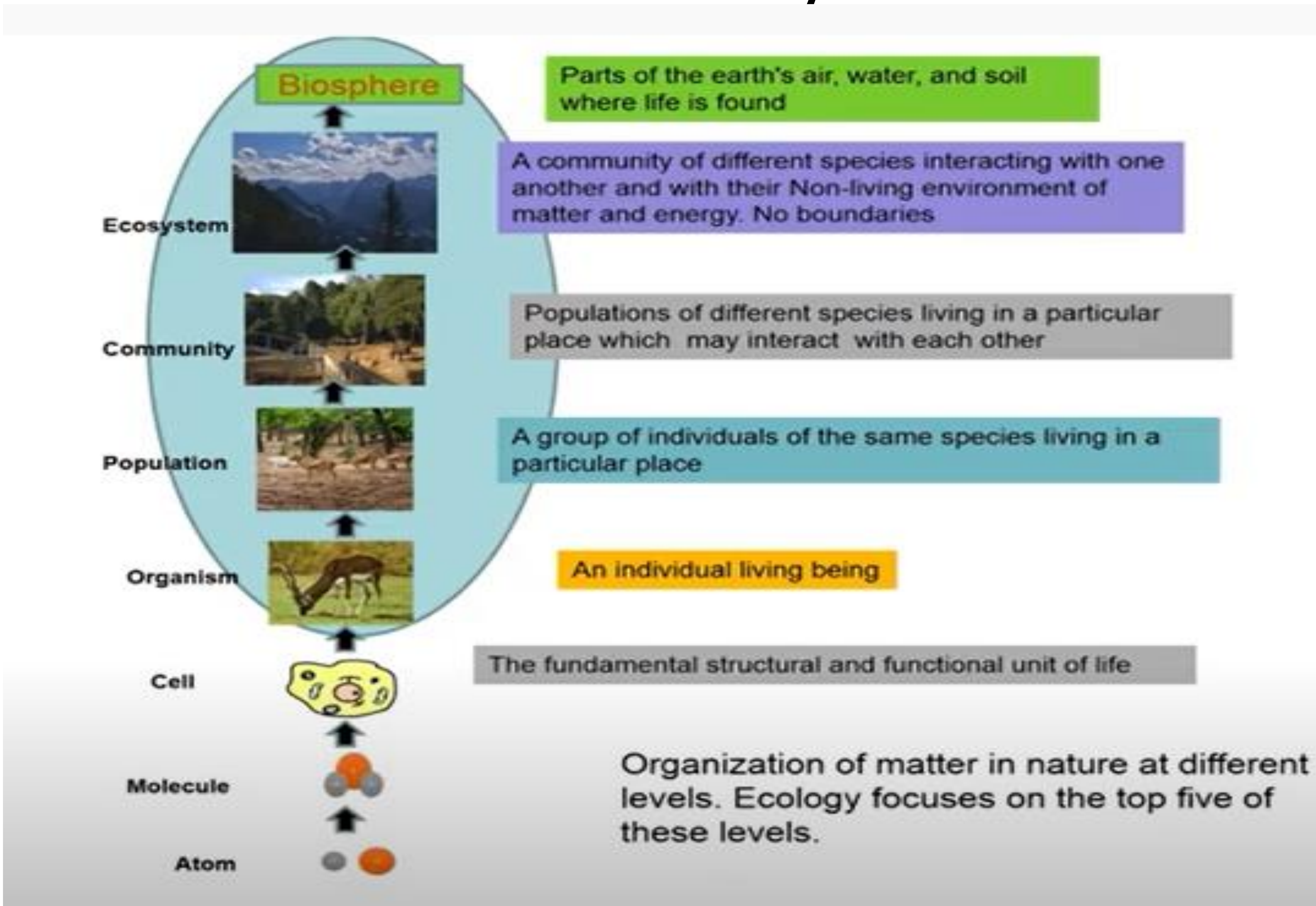


Levels of ecosystem



- •Individual
- •Population
- • species
- •community
- •ecosystem

Levels of ecosystem



Ecosystem

- A complex ecosystem
- For example,
  - Weather affects plants,
  - Plants use minerals in the soil and are food for animals,
  - Animals spread plant seeds
  - Plants secure the soil, and
  - Plants evaporate water, which affects weather

Case Study

Inter-relations in Ecosystem- Case study

Keoladeo was declared a national park

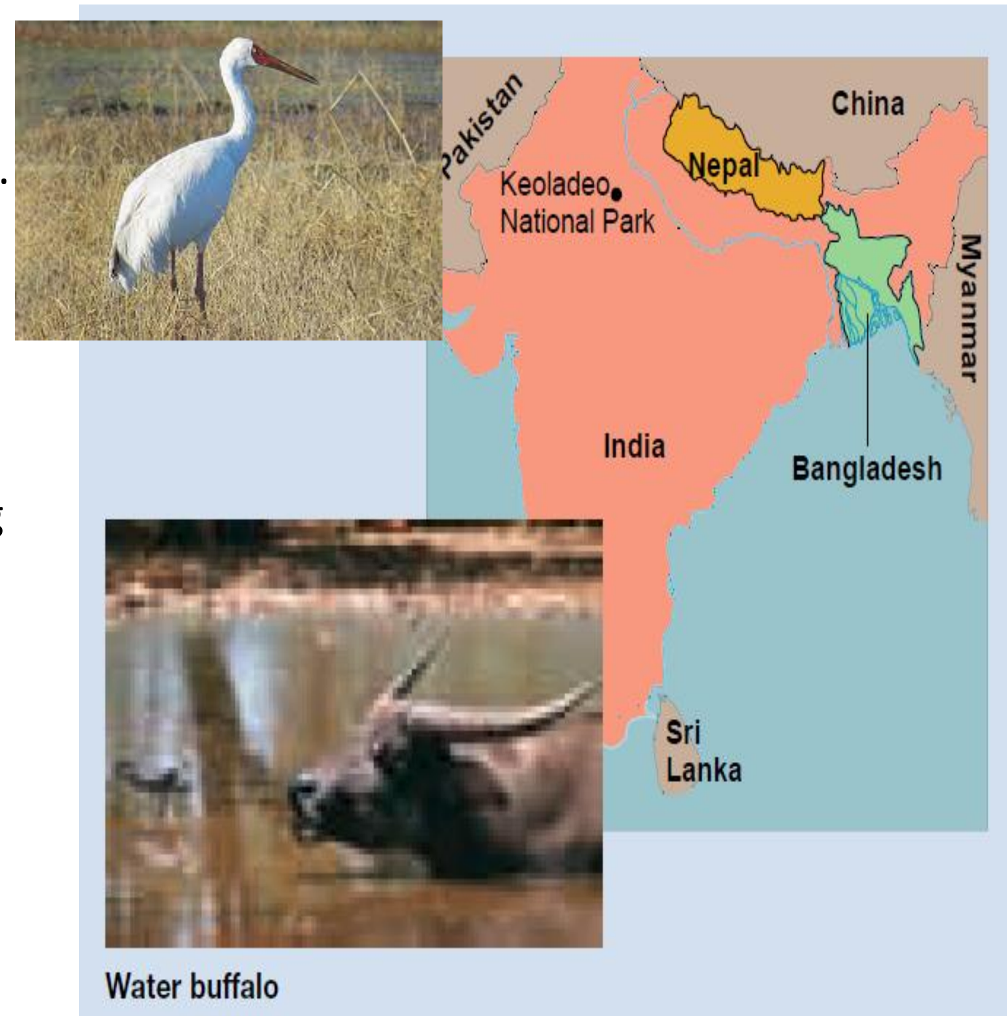
- In 1982, Keoladeo was declared a national park and was designated as a World Heritage Site by the UNESCO in 1985.

- **Water buffalo, certain aquatic plants, and the Siberian crane coexisted in a three-way relationship**.

- Local villagers were prohibited from using the land to graze their cattle and water buffalo

- Cranes to dig up rhizomes and tubers of the aquatic plants for food.

- the weeds grew to their full height and in solid masses that created a physical barrier for crane



Enger and Smith, 2010

How ecology is studied?

- **Organism Level:**
  - Individual of a particular species
  - Population of a species

- **Habitat based studies:**
  - Terrestrial (forest, desert, grassland etc)
  - Aquatic (marine, estuarine, freshwater)

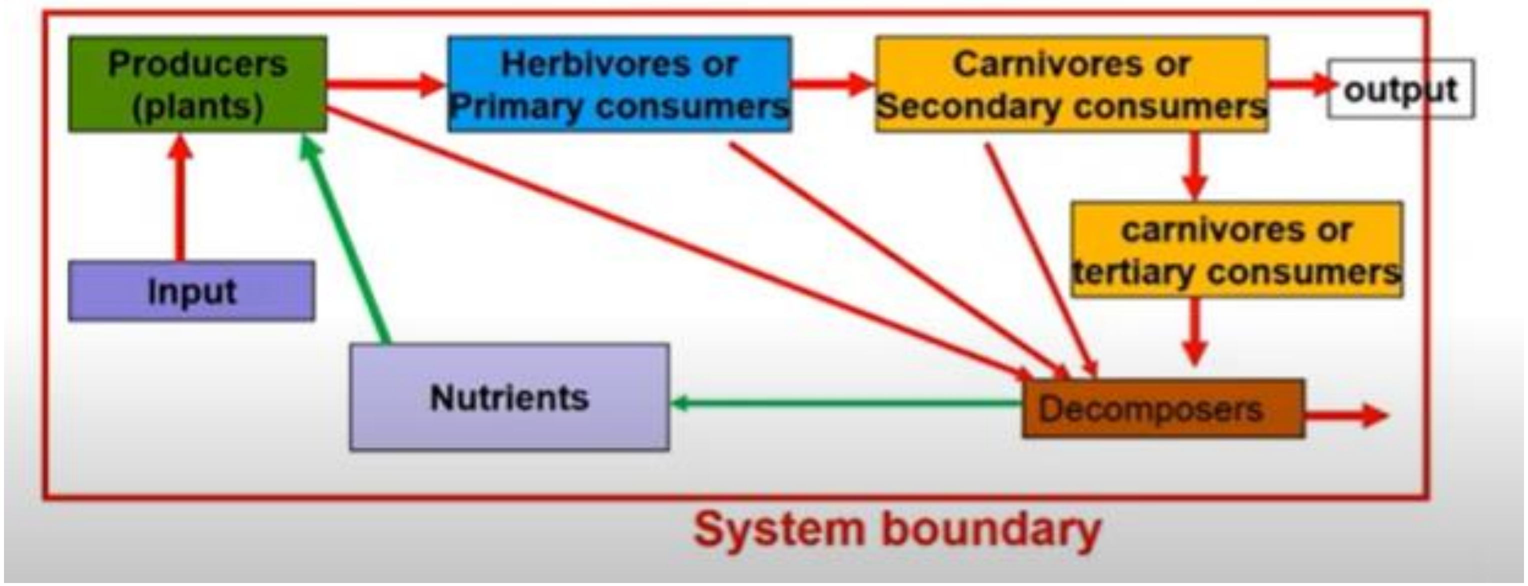
System Concept in ECology

A group of interacting, interrelated, or interdependent parts made up of matter and energy that form a complex whole.

Anything that uses matter and energy to organize, maintain, or change itself (e.g., the sun, a glass of water, a frog, a city)

- Isolated (no exchange of energy or matter with the environment)
- closed (exchanges energy but not matter and attain true thermodynamic equilibrium with the environment)
- open systems (exchange of energy and matter. Thermodynamically they are not in true equilibrium but are in dynamic steady state)

The living organisms (biotic community) of a habitat and their non-living environment function together as one unit called the ecological system or ecosystem

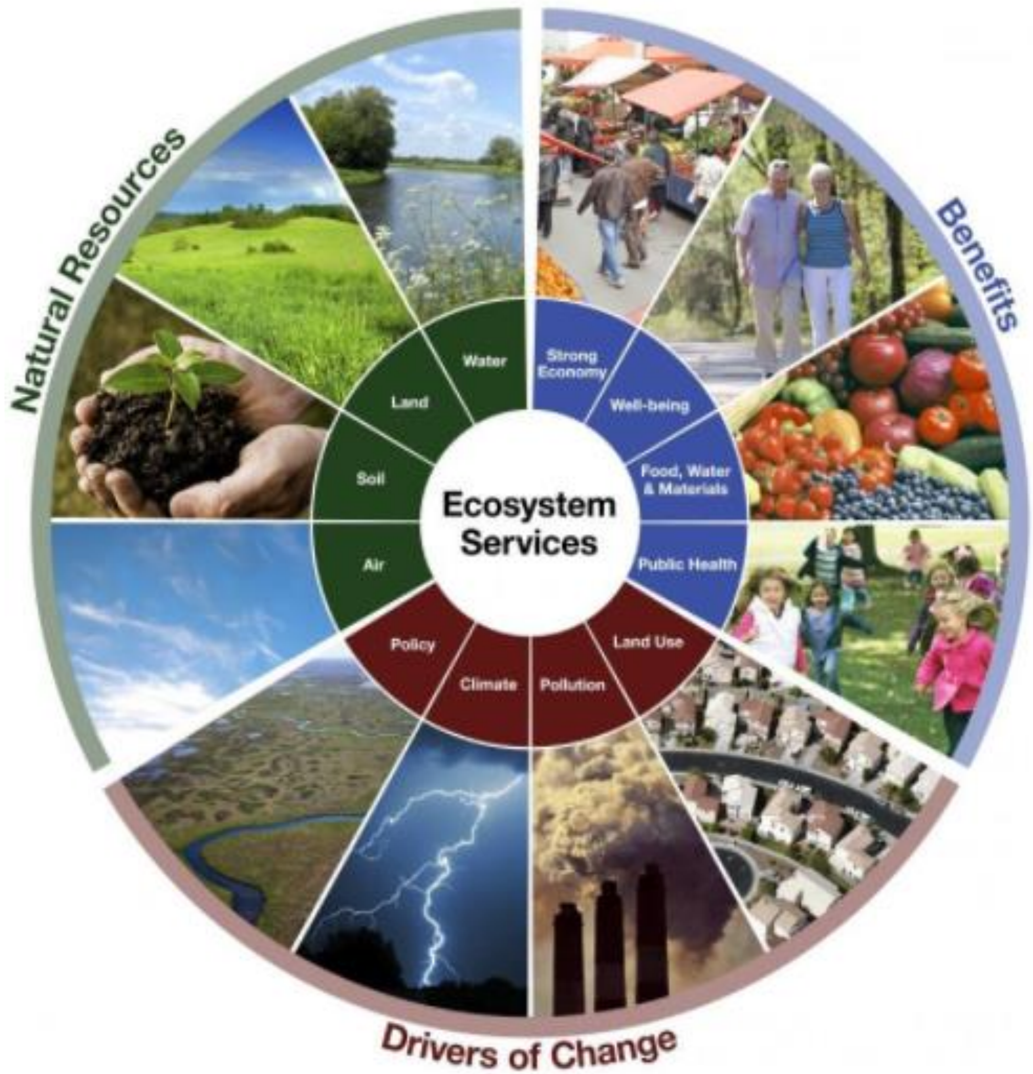


Ecosystem services

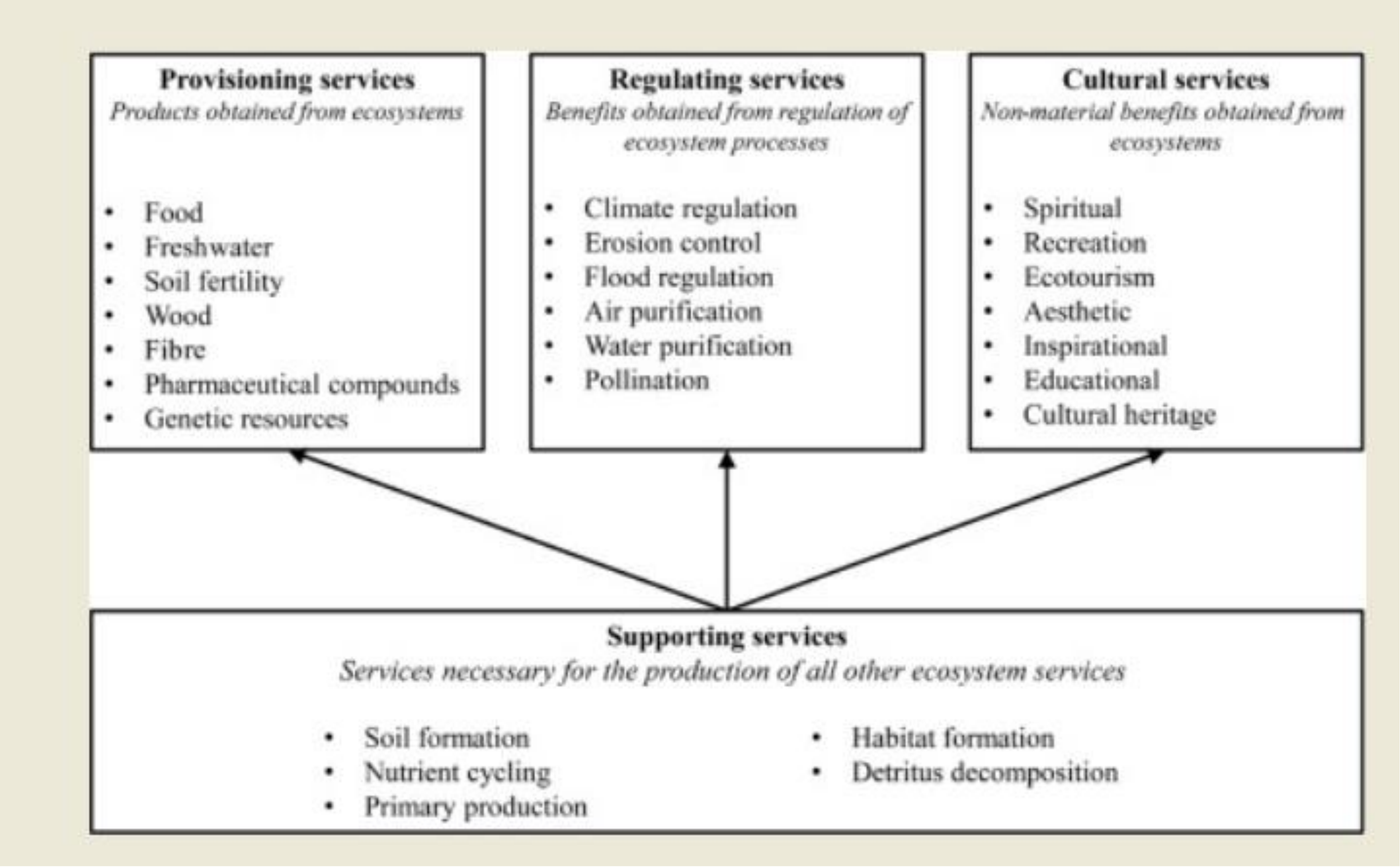
- Ecosystem services
  - **Supporting life**
    - Produce natural capital (fuel, fibre and O_2, air, water, food- sustain life)
  - **Regulation of climate**
    - Primitive time-starting of evolution – reductive
    - Oxidation and reduction
    - Plants- releasing O_2 and taking CO_2
    - Temperature maintenance – Current average temp if increased - 2^0 C– result in catastrophic effects

Ecosystem services

- **Biochemical cycles-** CO_2, H_20, Nitrogen, Phosphorus, sulphur cycle etc. – reaction between living organisms and surrounding
- Water filtration-
    - Self purification capacity
- Soil formation- microbes –
    - decaying, health living soil mass mass with nutrients that can provide
- Erosion control
- Flood protection



Ecosystem services



Ecosystem services

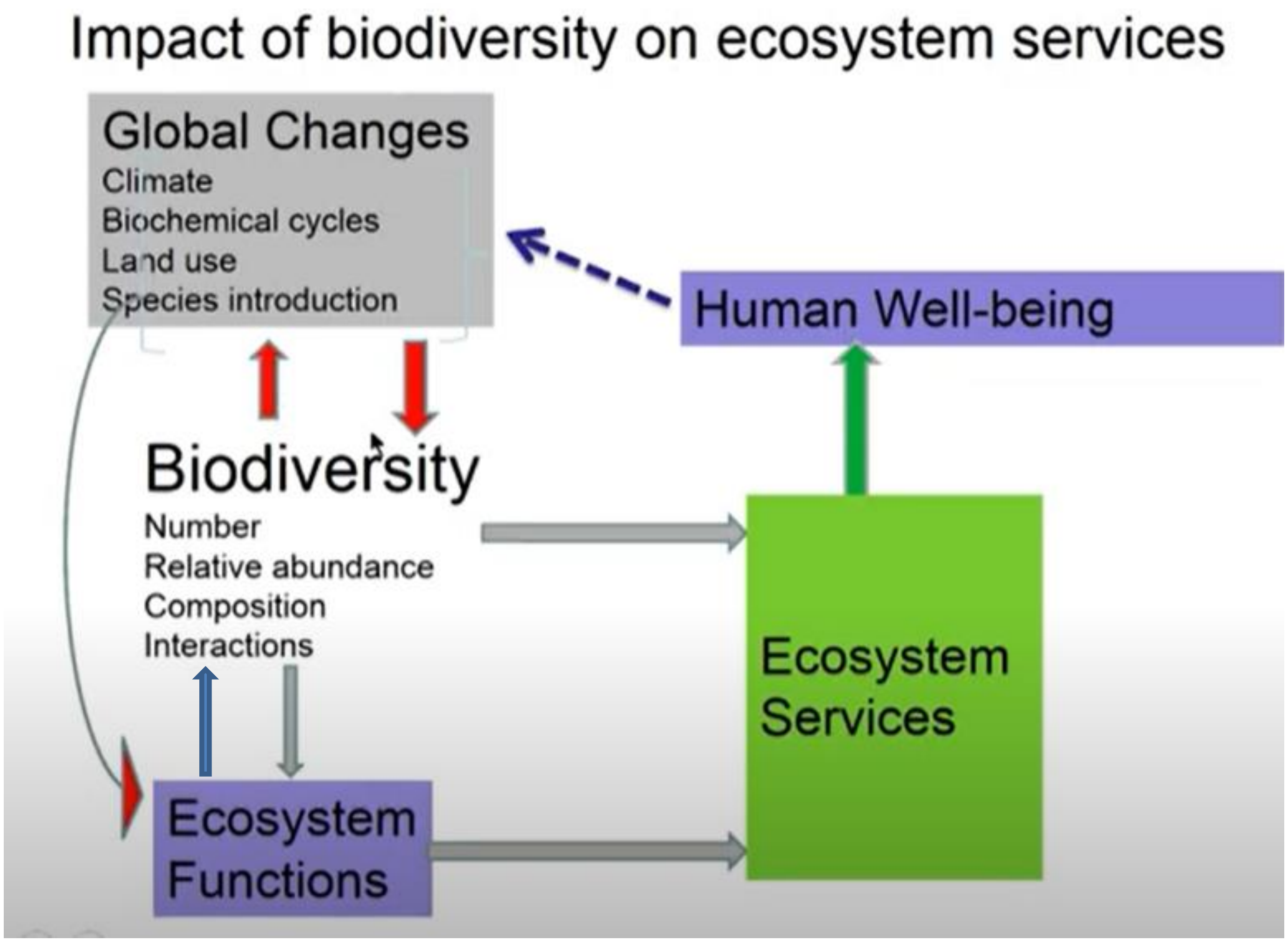
Millennium Ecosystem Assessment

- 2001-2005 by UN
- More than 1500 scientists – How to put the ecosystem services into economics !

Whether we and our politicians know it or not, Nature is party to all our deals and decisions, and she has more votes, a longer memory, and a sterner sense of justice than we do. – Wendell Berry

Ecosystem function

- Ecosystem services are output of its function

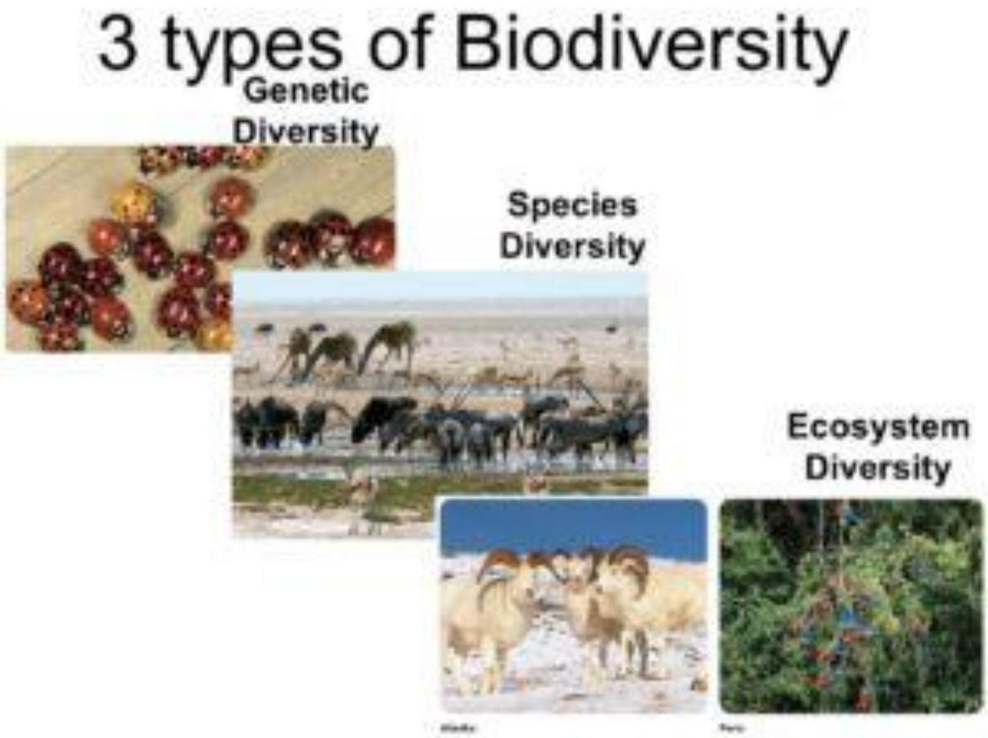


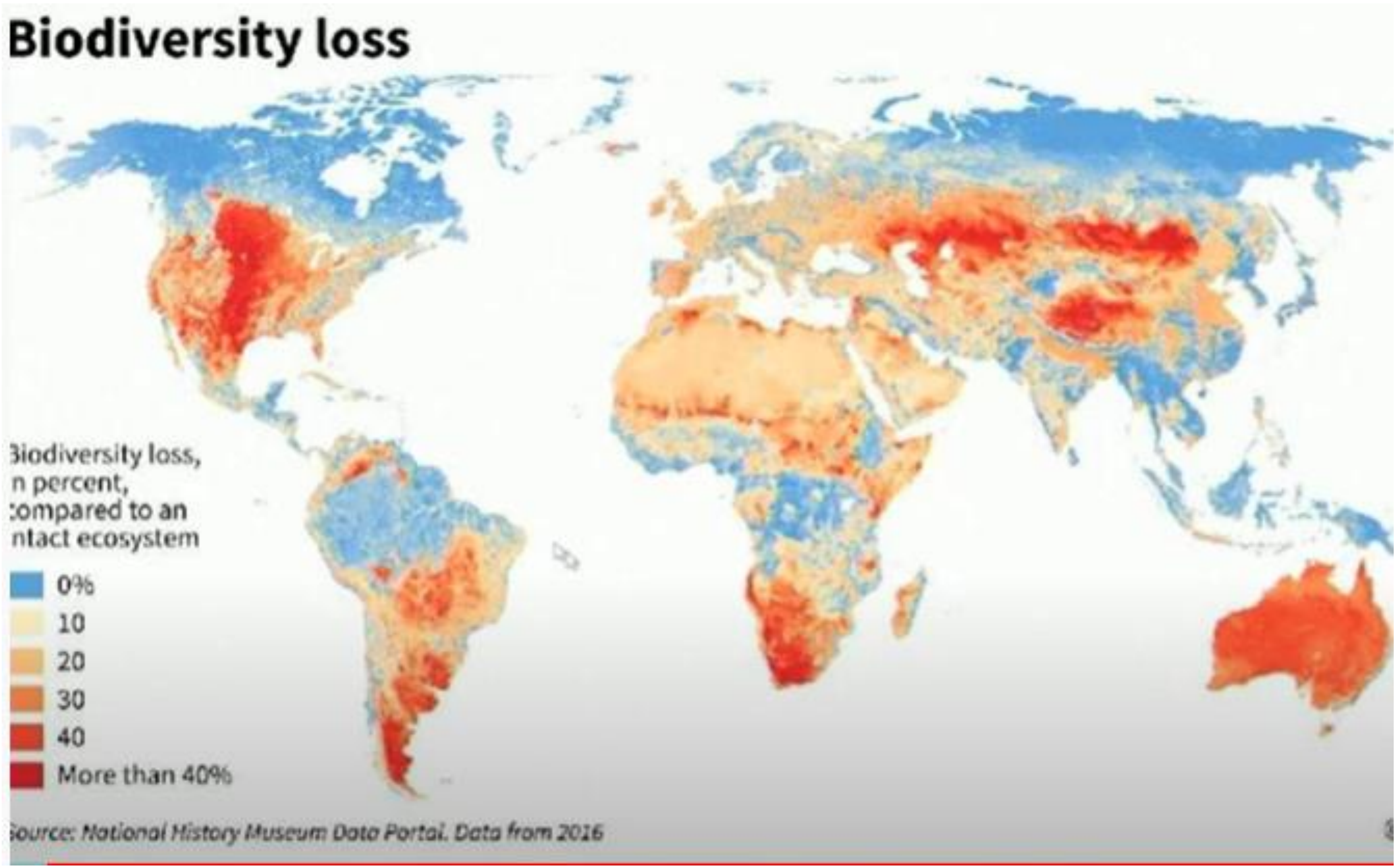
Biodiversity

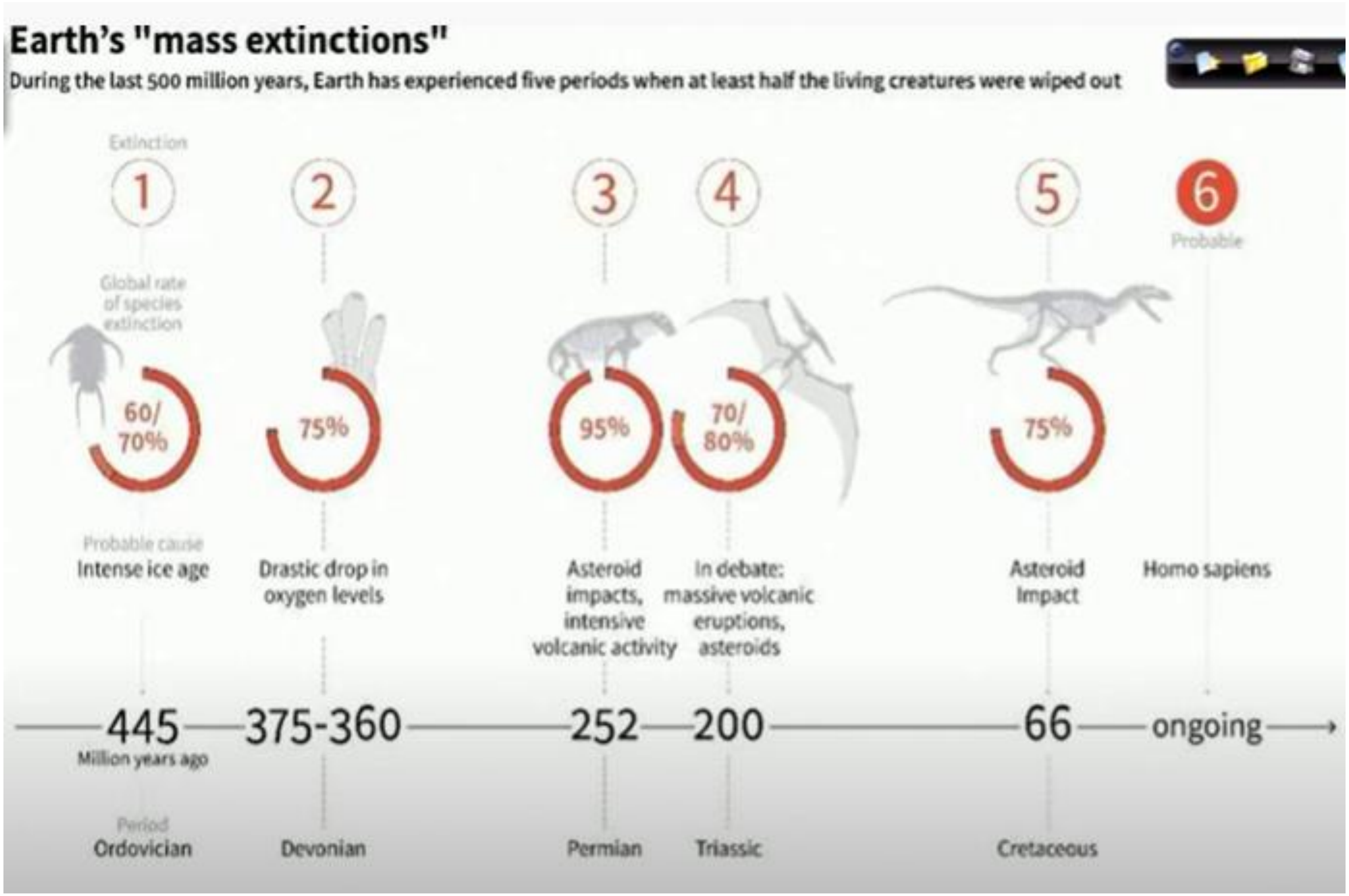
Each human being is very different from all others. This genetic variability is essential for a healthy breeding population of a species.

The number of species of plants and animals that are present in a region constitutes its species diversity.

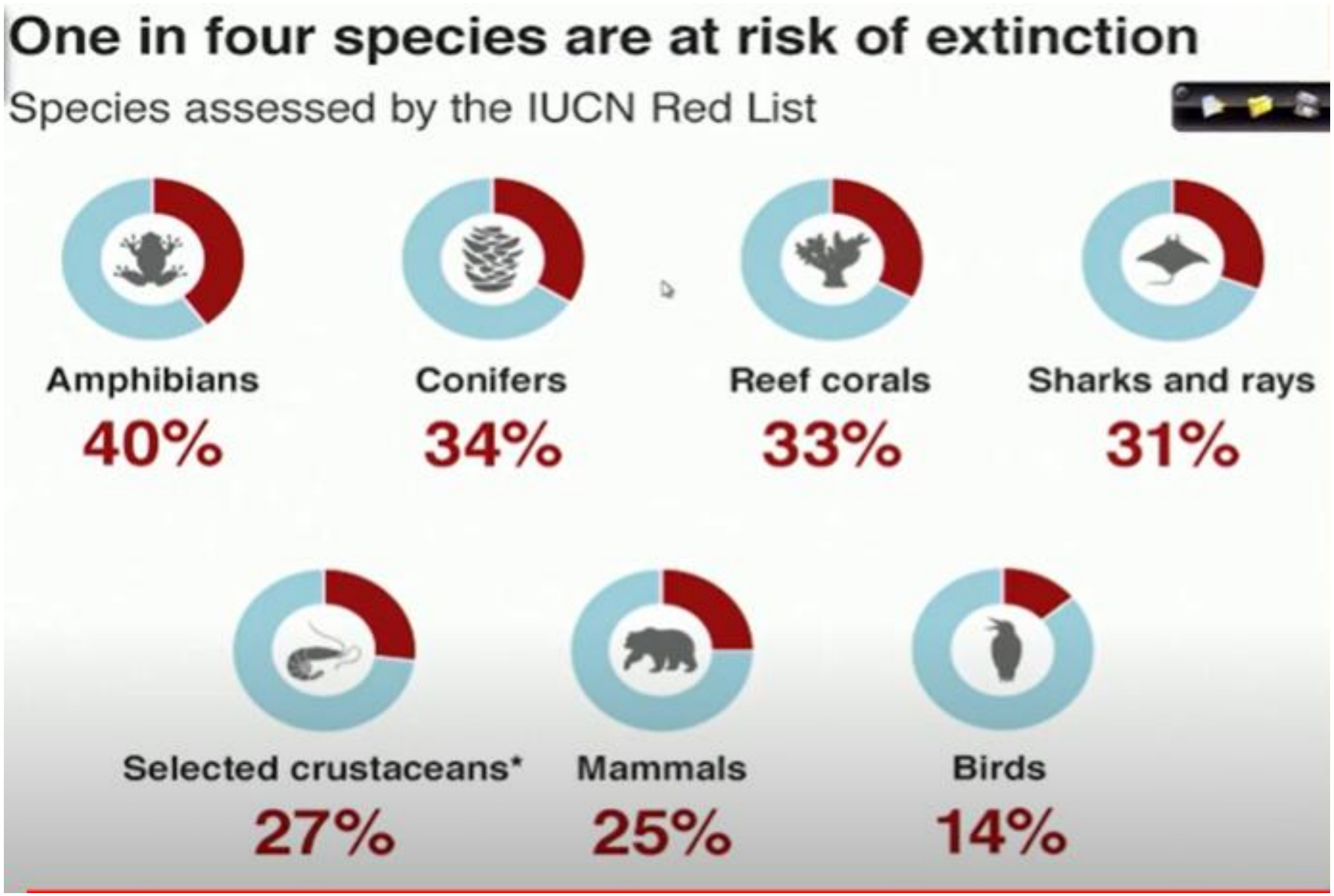
There is a large variety of different ecosystems on earth, which have their own complement of distinctive interlinked species based on the differences in the habitat.




Biodiversity loss
3iodiversity loss,
n percent,
:ompared to an
ntact ecosystem
0%
10
20
30
40
More than 40%
Source: National History Museum Data Portal. Data from 2016



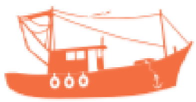
Earth's "mass extinctions"
During the last 500 million years, Earth has experienced five periods when at least half the living creatures were wiped out
Extinction
1
2
3
4
5
6
Probable
Global rate of species extinction
60/ 70%
75%
95%
70/ 80%
75%
Probable cause
Intense ice age
Drastic drop in oxygen levels
Asteroid impacts, intensive volcanic activity
In debate: massive volcanic eruptions, asteroids
Asteroid Impact
Homo sapiens
445
Million years ago
375-360
252
200
66
ongoing
Period
Ordovician
Devonian
Permian
Triassic
Cretaceous


One in four species are at risk of extinction
Species assessed by the IUCN Red List
Amphibians
40%
Conifers
34%
Reef corals
33%
Sharks and rays
31%
Selected crustaceans*
27%
Mammals
25%
Birds
14%

Changes in land and sea use, including habitat loss and degradation

This refers to the modification of the environment where a species lives, by complete removal, fragmentation or reduction in quality of key habitat. Common changes in use are caused by unsustainable agriculture, logging, transportation, residential or commercial development, energy production and mining. For freshwater habitats, fragmentation of rivers and streams and abstraction of water are common threats.

Species overexploitation



There are both direct and indirect forms of overexploitation. Direct overexploitation refers to unsustainable hunting and poaching or harvesting, whether for subsistence or for trade. Indirect overexploitation occurs when non-target species are killed unintentionally, for example as bycatch in fisheries.

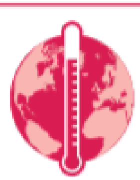
Invasive species and disease

Invasive species can compete with native species for space, food and other resources, can turn out to be a predator for native species, or spread diseases that were not previously present in the environment. Humans also transport new diseases from one area of the globe to another.

Pollution

Pollution can directly affect a species by making the environment unsuitable for its survival (this is what happens, for example, in the case of an oil spill). It can also affect a species indirectly, by affecting food availability or reproductive performance, thus reducing population numbers over time.

Climate change



As temperatures change, some species will need to adapt by shifting their range to track a suitable climate. The effects of climate change on species are often indirect. Changes in temperature can confound the signals that trigger seasonal events such as migration and reproduction, causing these events to happen at the wrong time (for example misaligning reproduction and the period of greater food availability in a specific habitat).

Figure 4: Different threat types in the Living Planet Database
Descriptions of the major threat categories used in the *Living Planet Database. This classification reflects the direct drivers with the largest global impact as identified* ***by IPBES [1]; it is also followed by the IUCN Red List and is*** *based on the original classification by Salafsky, N. et al.* ***(2010) [10]. Source WWF/ZSL (2020) [107].***

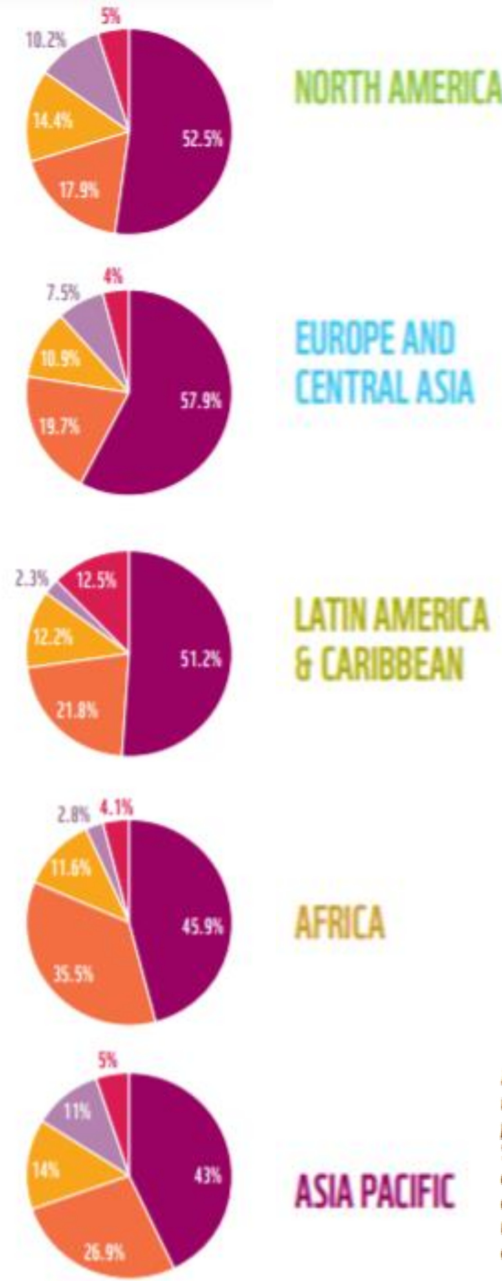


Figure 5: The proportion of threats recorded in each category for populations in each IPBES region The number of populations with threat data available is shown next to the pie chart [107]. The colour of each section refers to the colour for each threat category on the opposite page.*

Living planet report, 2020

Ecosystem Functions

- Regulating Functions
- Production Functions
- Habitat Functions
- Information functions

Regulating Functions

1. Gas regulation
2. Climate regulation
3. Disturbance regulation
4. Water regulation
5. Water supply
6. Soil retention
7. Soil formation
8. Nutrition regulation
9. Waste treatment
10. Pollination
11. Biological control

Grut et al., 2002

Ecosystem Functions

Production Functions

1. Food
2. Raw Materials
3. Genetic Resources
4. Medicinal resources
5. Ornamental

Habitat functions

1. Refugium function
2. Nursery function

Information function

1. Aesthetic information
2. Recreation
3. Cultural and artistic information
4. Spiritual and historic
5. Science and education

Grut et al., 2002

Ecosystem Functions
(Costanza et al., 1997, De Groot, 1992, De Groot et al., 2000.

	Functions	Ecosystem processes and components	Goods and services (examples)
	Regulation Functions	*Maintenance of essential ecological processes and life support systems*	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/O_2 balance, ozone layer, etc.)	1.1 UVb-protection by O_3 (preventing disease). 1.2 Maintenance of (good) air quality. 1.3 Influence on climate (see also function 2.)
2	Climate regulation	Influence of land cover and biol. mediated processes (e.g. DMS-production) on climate	Maintenance of a favorable climate (temp., precipitation, etc) for, for example, human habitation, health, cultivation
3	Disturbance prevention	Influence of ecosystem structure on dampening env. disturbances	3.1 Storm protection (e.g. by coral reefs). 3.2 Flood prevention (e.g. by wetlands and forests)
4	Water regulation	Role of land cover in regulating runoff & river discharge	4.1 Drainage and natural irrigation. 4.2 Medium for transport

Ecosystem Functions
(Costanza et al., 1997, De Groot, 1992, De Groot et al., 2000.

5	Water supply	Filtering, retention and storage of fresh water (e.g. in aquifers)	Provision of water for consumptive use (e.g.drinking, irrigation and industrial use)
6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	6.1 Maintenance of arable land.
			6.2 Prevention of damage from erosion/siltation
7	Soil formation	Weathering of rock, accumulation of organic matter	7.1 Maintenance of productivity on arable land.
			7.2 Maintenance of natural productive soils
8	Nutrient regulation	Role of biota in storage and re-cycling of nutrients (eg. N,P&S)	Maintenance of healthy soils and productive ecosystems
9	Waste treatment	Role of vegetation & biota in removal or breakdown of xenic nutrients and compounds	9.1 Pollution control/detoxification. 9.2 Filtering of dust particles.

Ecosystem Functions
(Costanza et al., 1997, De Groot, 1992, De Groot et al., 2000.

10	Pollination	Role of biota in movement of floral gametes	10.1 Pollination of wild plant species. 10.2 Pollination of crops
11	Biological control	Population control through trophic-dynamic relations	11.1 Control of pests and diseases. 11.2 Reduction of herbivory (crop damage)
	Habitat Functions	*Providing habitat (suitable living space) for wild plant and animal species*	Maintenance of biological & genetic diversity (and thus the basis for most other functions)
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of commercially harvested species
13	Nursery function	Suitable reproduction habitat	13.1 Hunting, gathering of fish, game, fruits, etc. 13.2 Small-scale subsistence farming & aquaculture
	Production Functions	*Provision of natural resources*	
14	Food	Conversion of solar energy into edible plants and animals	14.1 Building & Manufacturing (e.g. lumber, skins). 14.2 Fuel and energy (e.g. fuel wood, organic matter). 14.3 Fodder and fertilizer (e.g. krill, leaves, litter)
15	Raw materials	Conversion of solar energy into biomass for human construction and other uses	15.1 Improve crop resistance to pathogens & pests. 15.2 Other applications (e.g. health care)

Ecosystem Functions
(Costanza et al., 1997, De Groot, 1992, De Groot et al., 2000.

16	Genetic resources	Genetic material and evolution in wild plants and animals	16.1 Drugs and pharmaceuticals. 16.2 Chemical models & tools. 16.3 Test- and essay organisms
17	Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	Resources for fashion, handicraft, jewelry, pets, worship, decoration & souvenirs (e.g. furs, feathers ivory, orchids, butterflies, aquarium fish, shells, etc.)
18	Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	
	Information Functions	*Providing opportunities for cognitive development*	
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing, etc.)

Ecosystem Functions
(Costanza et al., 1997, De Groot, 1992, De Groot et al., 2000.

20	Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21	Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architect., advertising, etc.
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
23	Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

Case study- China- Forest Ecosystem

ELSEVIER

Ecological Economics
Volume 38, Issue 1, July 2001, Pages 141-154

ANALYSIS

Ecosystem functions, services and their values – a case study in Xingshan County of China

Zhongwei Guo [a], Xiangming Xiao [b], Yaling Gan [c], Yuejun Zheng [d]

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Case study- China- Forest Ecosystem

Xingshan County is situated in the west part of Hubei Province, China and covers about 2316 km^2.

The area of forestland reaches 107 000 ha,

accounting for 50.64% of the total land area of the county.

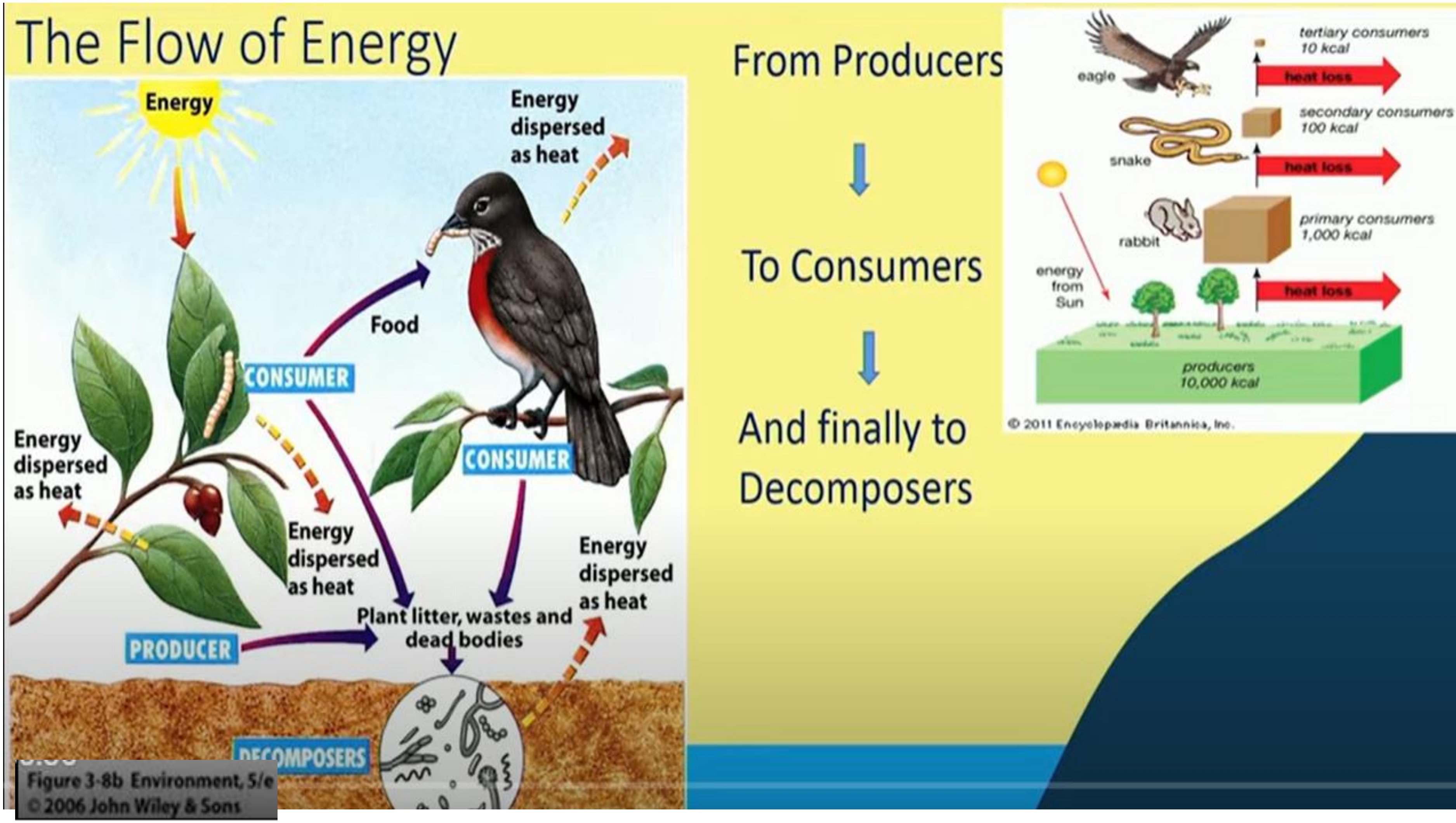
Table 1. Forest ecosystem services assessed in this study

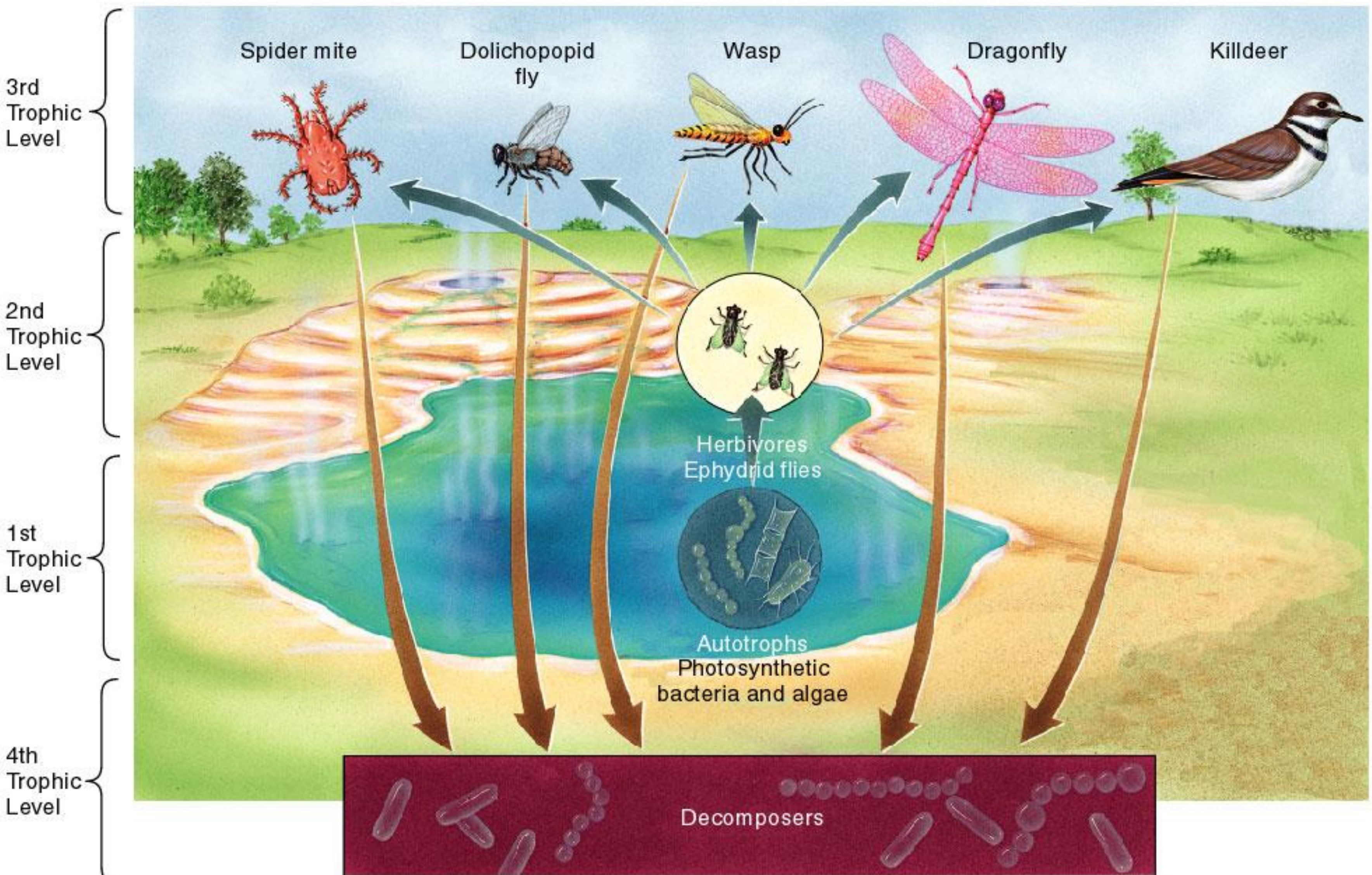
Type	Benefit	Services	Functions
Ecosystem goods	Direct economic value	Timber and other forest products	
		Taking forest tour	
Ecosystem services	Indirect economic value	Water conservation	Hydrological flow regulation
			Water retention and storage
		Soil conservation	Reduction of soil disuse
			Prevention of silt accretion
			Decrease of soil deposit
			Protection of soil fertility
		Gas regulation	Carbon fixation
			Oxygen supply

Case study- China- Forest Ecosystem

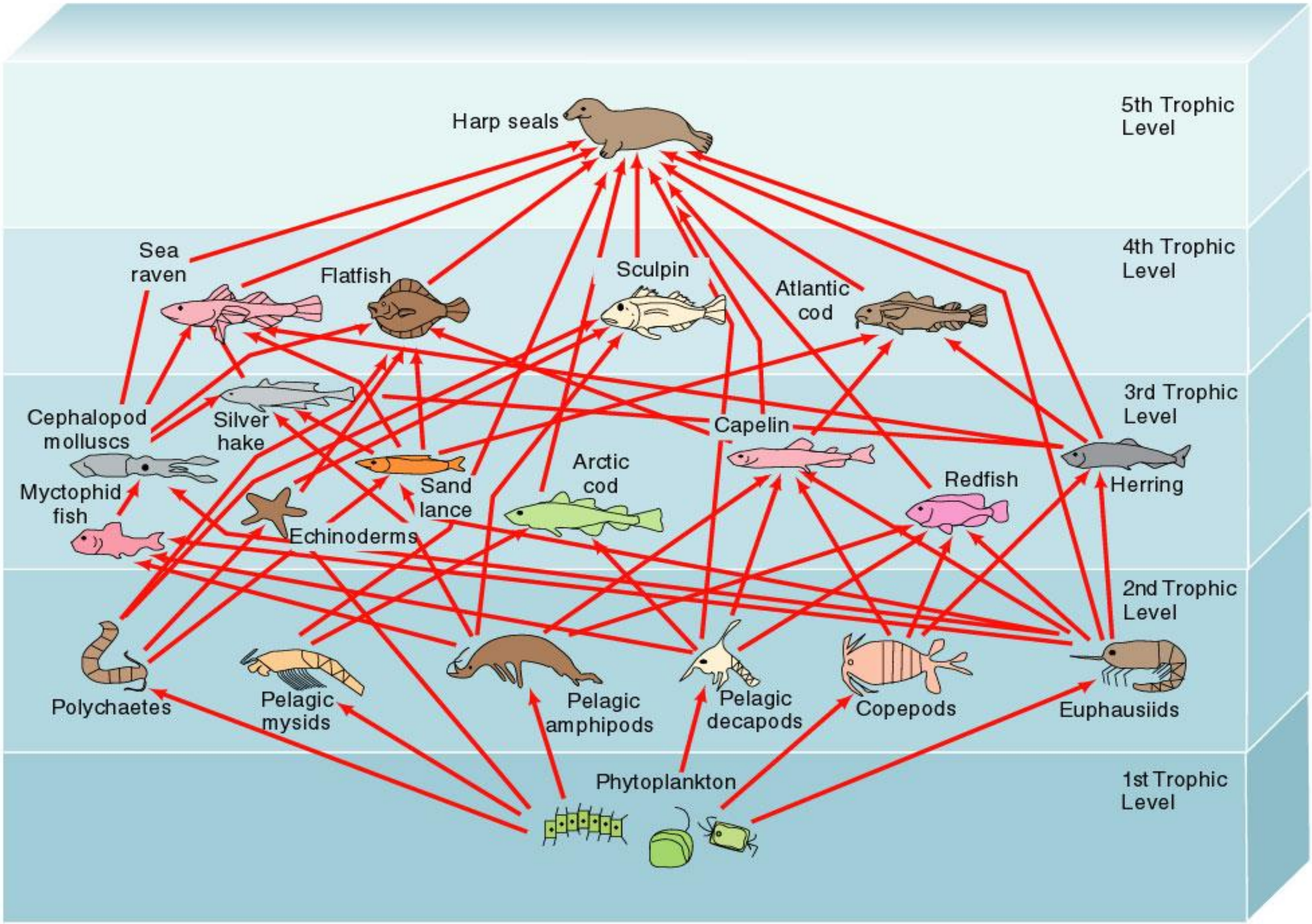
Type	Ecosystem service	Value (million RMB)
Direct value		54.23
	Timber and other forest products	48.43
	Taking forest tour	5.8
Indirect value		528.73
	Water conservation:	
	Hydrological flow regulation	59.78
	Water retention and storage	3.59
	Soil conservation:	
	Reduction of land disuse	2.94
	Prevention of silt accretion	78.02
	Decrease of soil deposit	50.38
	Protection of soil fertility	241.3
	Gas regulation:	
	Carbon fixation	46.45
	Oxygen supply	46.27
Total value		582.96

Energy Flow in Ecosystem



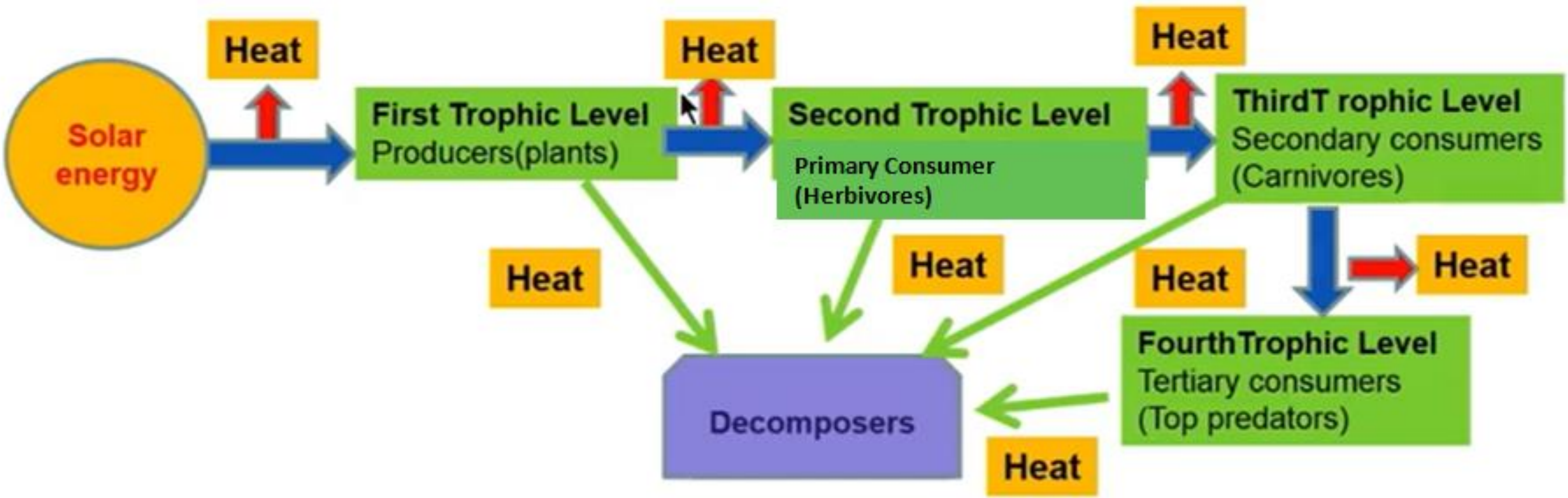


Souce: Google Images



Souce: Google Images

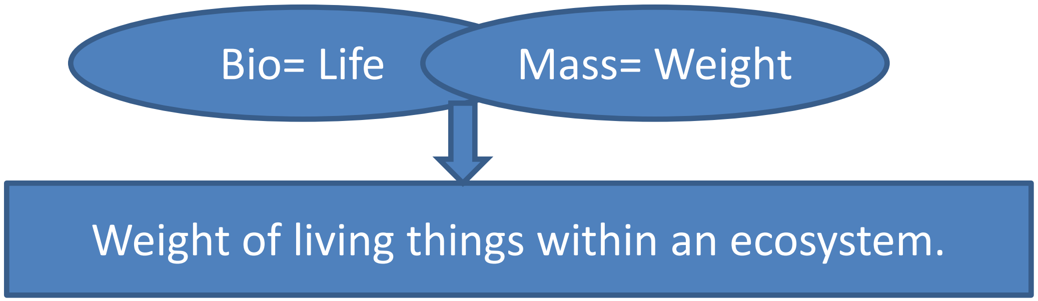
- Energy collected by plants from the Sun flows through ecosystems in food chains and food webs



Source: NPTEL SWAYAM

nptel.ac.in/courses/

- Energy is **sometimes considered in terms of biomass**, the mass of all the organisms and organic material in an area.



Ecological Pyramids

- Pyramid of number--- Mostly Upright
- Pyramid of biomass- In terms of Kg
- Pyramid of Energy

<u>Pyramid of numbers-</u>

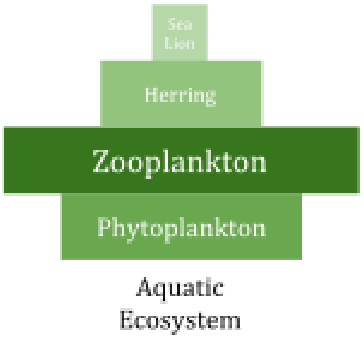
- Eltonian pyramids- Developed by Charles Elton
- Number of individuals per species
- Does not consider individual sizes or biomass.
- Need not be always upright

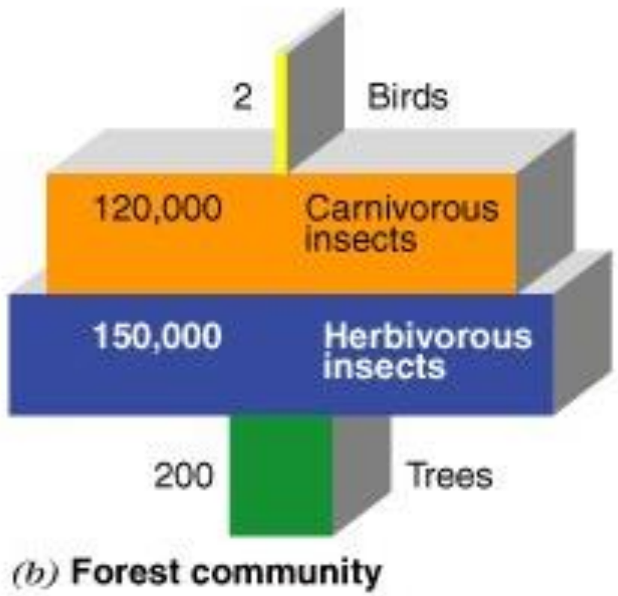
(a) Grassland community

(b) Forest community

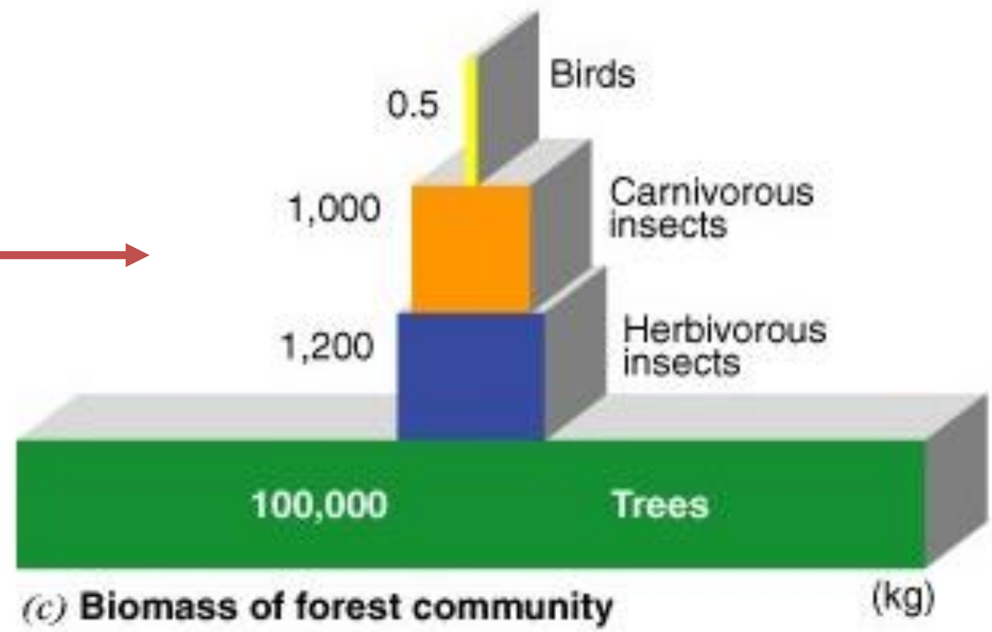
Pyramid of Biomass:

- Each species into biomass instead of absolute numbers
- Can be inverted



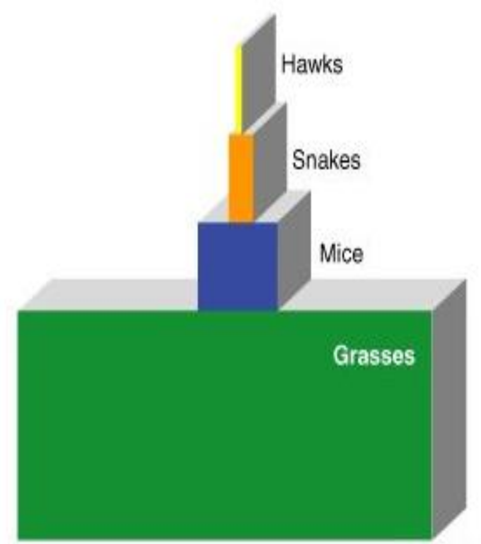


Number



Energy Pyramid

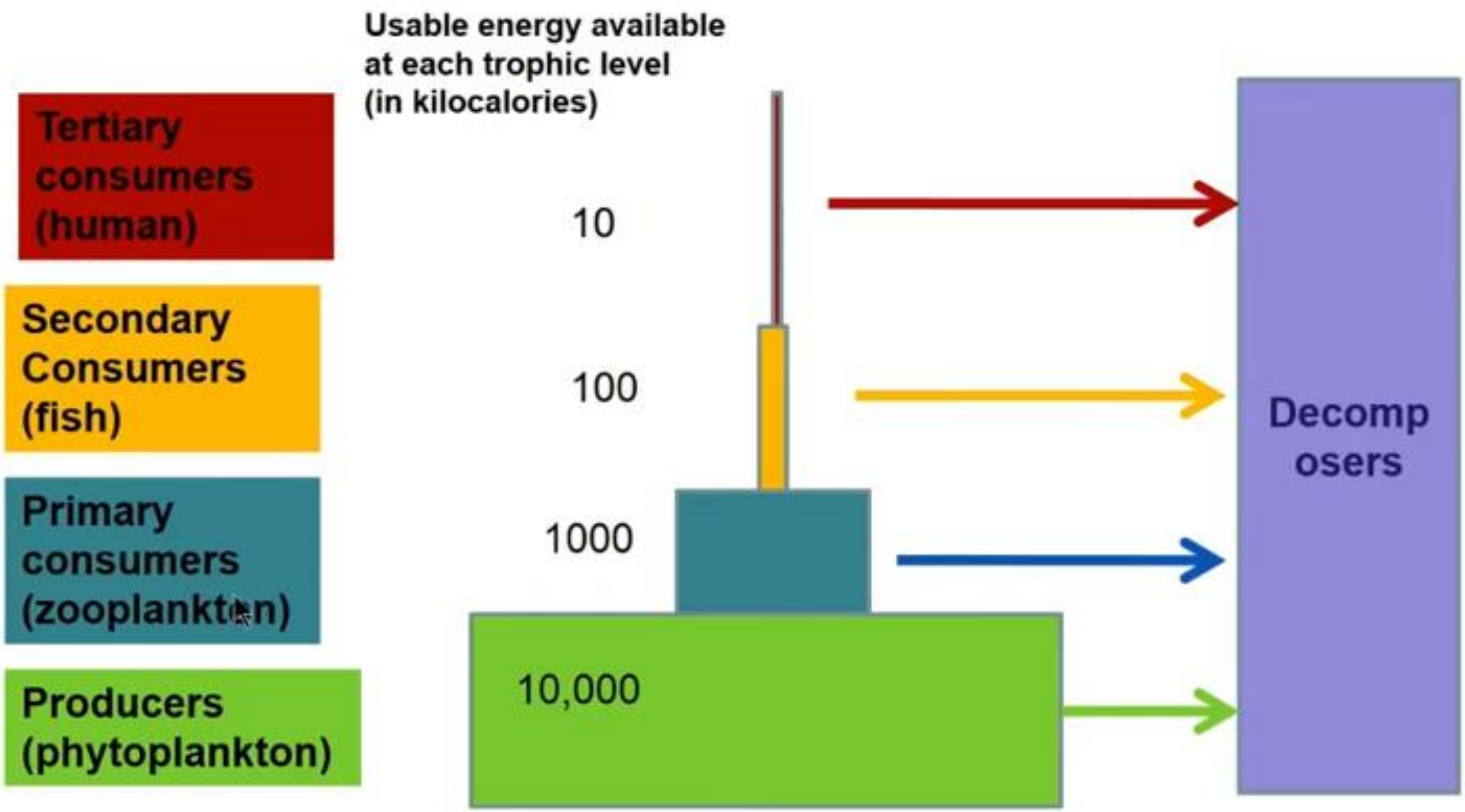
- The greatest amount of energy is found at the base of the pyramid.
- The least amount of energy is found at top of the pyramid.
- **Energy pyramids can never be inverted.**



(e) Energy levels of a stable community

Energy and material flow in the

Generalized *pyramid of energy flow* showing the decrease in usable chemical energy available at each succeeding trophic level in a food chain or web.
Ecological efficiency varies from 2- 40%, with 10% efficiency common.



Source: NPTEL SWAYAM

Ecological efficiency

- Direct energy harvesting- solar energy harvesting agent- plants which are producing it.

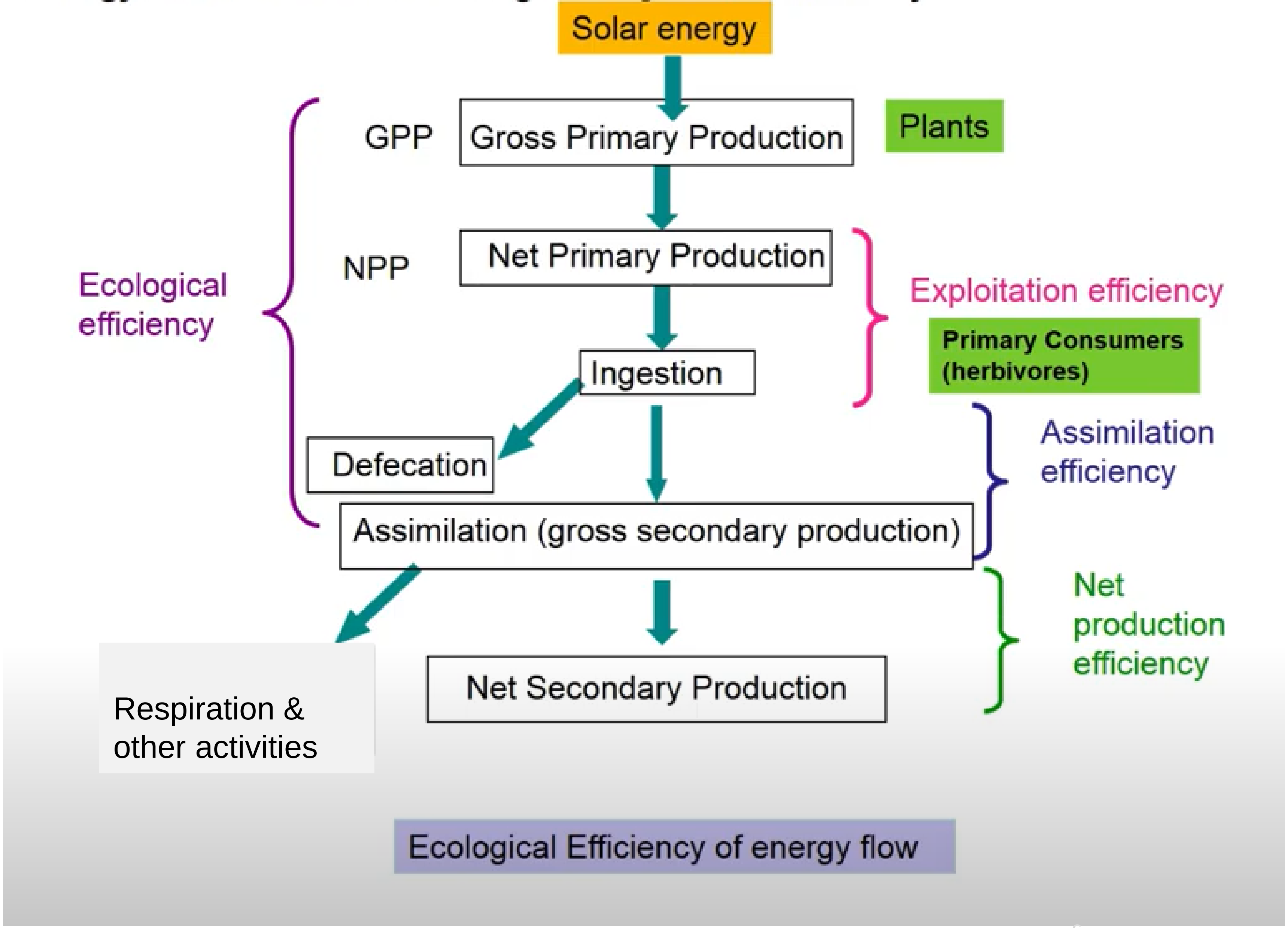
- energy is flowing through the ecosystems in food chains, and webs.

- as energy flows through ecosystems in food chains, and webs, the amount of chemical energy available to organisms at each succeeding tropic level decreases.

Ecological efficiency

- Efficiency with which the energy is flowing at each tropic level.
- So, how does energy and material flow through these ecosystems is an important thing.
- Ecological efficiency can be defined in various way--- such as NPP

Energy and Material Flow through Ecosystems- Efficiency



Source: NPTEL/SWAYAMCOURSE/

Ecological productivity

- Ecological productivity refers to the primary fixation of solar energy by plants and subsequent usage of the energy by herbivores then by carnivores and so on which creates a complex food web
- **Gross primary production** is the first stage which is like taking energy from sun
- Plants convert that energy into useful glucose or matter and that glucose is transferred from the plants. Plants used the energy for respiration etc.
- NPP= GPP- loss due to respiration
- Net primary production that is what is the plant mass that we see growing on earth

Ecological productivity

- Herbivores eat the plants, so that is the next level of energy flow.

- **Exploitation efficiency:** efficiently a herbivore is exploiting the available food sources that is present there.

- Primary consumer--- Ingest the food and some amount will be defecated and **lost from the system** and remaining things will be assimilated part of which will be used for their growth. So, this energy is considered as the **gross secondary production** here.

- **Assimilation** at this stage is the energy remaining as after defecation

- Energy being used for respiration and other activities and remaining amount that is the net secondary production, so basically net secondary productivity

- Ecological efficiencies defined as the sum of this or the processes that goes on from gross primary production till assimilation of the nutrients in a herbivore.

Ecological efficiency of Plants

Plants- Net Primary Productivity (NPP) and Efficiency

- The rate at which plants synthesise glucose from CO_2 and H_2O using photons from solar energy is Net Primary Productivity. Methods of measuring primary production are:
  - Harvest method
  - Oxygen measurement (light and dark bottle method)
  - CO_2 measurement (terrestrial ecosystems)
  - Aerodynamics method (CO_2 flux in a community measured using sensors)
  - pH method
  - Indirect methods such a Leaf Area Index (LAI) using satellite imaging

Source: NPTEL/SWAYAMCOURSE/

Ecological efficiency of Plants

Light & dark bottle method:

- In this method, a sample of water is placed into two bottles
- One bottle is stored in the dark and the other in a lighted area.
- Only respiration can occur in the bottle stored in the dark.
- The decrease in dissolved oxygen (DO) in the dark bottle over time is a measure of the rate of respiration.
- Both photosynthesis and respiration can occur in the bottle exposed to light
- Difference between the amount of oxygen produced through photosynthesis and that consumed through aerobic respiration is the **net productivity.**
- The difference in dissolved oxygen over time between the bottles stored in the light and in the dark is a measure of the total amount of oxygen produced by photosynthesis. The total amount of oxygen produced is called the gross productivity.

Ecological efficiency of plants

Net primary productivity (NPP) is defined as the net flux of carbon from the atmosphere into green plants per unit time. NPP refers to a rate process, i.e., the amount of vegetable matter produced (net primary production) per day, week, or year. NPP is a fundamental ecological variable, not only because it measures the energy input to the biosphere and terrestrial carbon dioxide assimilation, but also because of its significance in indicating the condition of the land surface area and status of a wide range of ecological processes.

Estimating NPP

- There are many ways to estimate terrestrial NPP from field measurements that depend on the type of plants and available measurements.

- The efficiency with which plants of a community harvest energy is the efficiency with which energy is transformed into the 6-carbon sugar, glucose, by photosynthesis on a field scale. The chemistry of photosynthesis is essentially the same in all green plants for >1000 million years.
- Photosynthetic reaction can be summarised as:

$$6\,CO_2 + 12\,H_2O \qquad C_6H_{12}O_6 + 6\,O_2 + 6H_2O$$

Source: NPTEL/SWAYAMCOURSE/

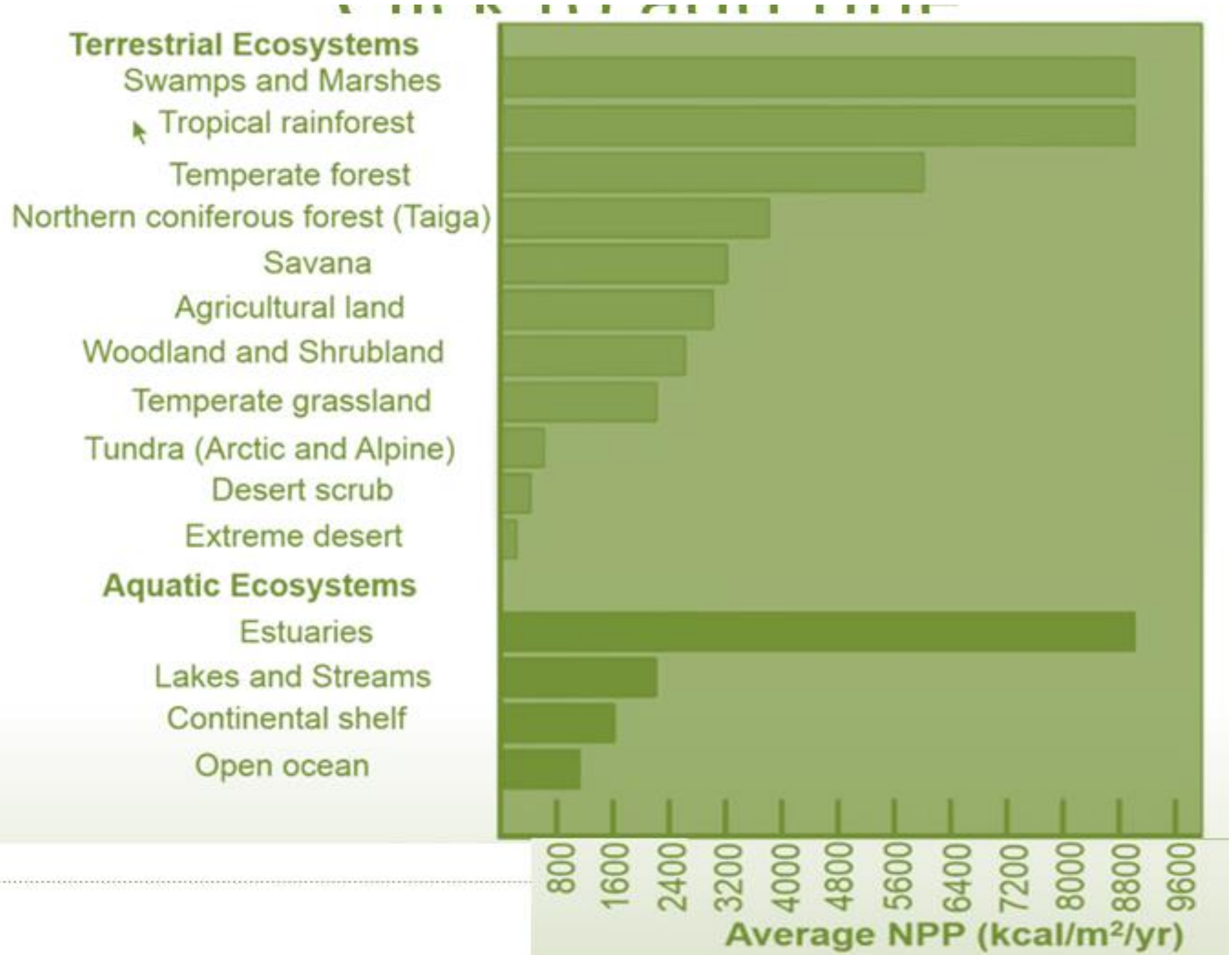
Harvest method based on standing crops (Transeu, 1926)

Example calculation of NPP

- Assume that one acre of good agricultural land supports 10,000 wheat plants at harvest and they take 100 days from sprouting to harvest. Then,
  - **Total dry weight of 10,000 wheat plants (roots, stems, leaves and fruits) = 6000 kg (dry wheat)**
  - **Total ash content of 10,000 wheat plants (minerals from soil left after burning) = 322 kg (ash)**
  - **Total organic content per acre = 6000-322 = 5678 kg (dry carbohydrate)**
  - **Average organic matter contains 44.58% of carbon. Therefore carbon per acre = 5678 x44.58/100= 2531kg (carbon)**
  - **Therefore, glucose content = 2531 x 180/72 = 6328 kg (glucose)**
- 6328 kg represents the standing crop of wheat at harvest described as mass of glucose. But, the standing crop represents only a portion of the glucose that had originally been made (that was left after the plants had used glucose fuel for living and growing for 100 days).
- typical plants of various ages gave him an average figure for respiration of 1 % of the mass of each plant per day.

The rate at which plants synthesise glucose can be arrived by various indirect means:

- Measurements made on typical plants of various ages gave an average figure for respiration of 1 % of the mass of each plant per day.
- Since the crop at the end of the season weighed 6000 kg, the average dry weight for the season = 3000kg (dry wheat, for one season)
- Average respiration was 1% of this, which = 30 kg (dry wheat)
- Therefore total CO_2 released in 100 days = 30 x100 = 3000kg (CO_2)
- Carbon equivalent of 3000kg of CO_2 = 3000 x 12/44 = 818 kg
- Glucose equivalent of 818 kg of carbon = 818 x 180/72 = 2045 kg
- Gross primary production of glucose = NPP+ R
  = 6328 + 2045 = 8373 kg (glucose)
- The energy required to produce 1 kg of glucose = 3760 kcal (from bomb calorimetry)
- Therefore, total energy consumed in photosynthesis of 1 acre of wheat in100 days
  = 8373 x 3760 = 31482480 kcal
- Energy received by 1 acre of farm (in specific location) in 100 days = 2,043 x 10^6 kcal (solar energy received on earth's surface can vary from place to place)
- **Therefore efficiency of photosynthesis = 31.5 x 10^6/2043 x 10^6 x100 = 1. 54%**



Terrestrial Ecosystems
Swamps and Marshes
Tropical rainforest
Temperate forest
Northern coniferous forest (Taiga)
Savana
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
1600
2400
3200
4000
4800
5600
6400
7200
8000
8800
9600
Average NPP (kcal/m²/yr)

Ecological efficiency of animal

An individual may be thought of as a device programmed by a base-pair sequence of DNA to collect reduced carbon fuel and process as much possible of this fuel as possible into offspring.

$$E_h = \frac{\lambda_n(herbivores)}{\lambda_{n-1}(plants)} \times 100$$

E_h – ecological efficiency of herbivores
λ_n – energy flowing into a trophic level in unit time
λ_{n-1} – energy flowing into the next lower trophic level

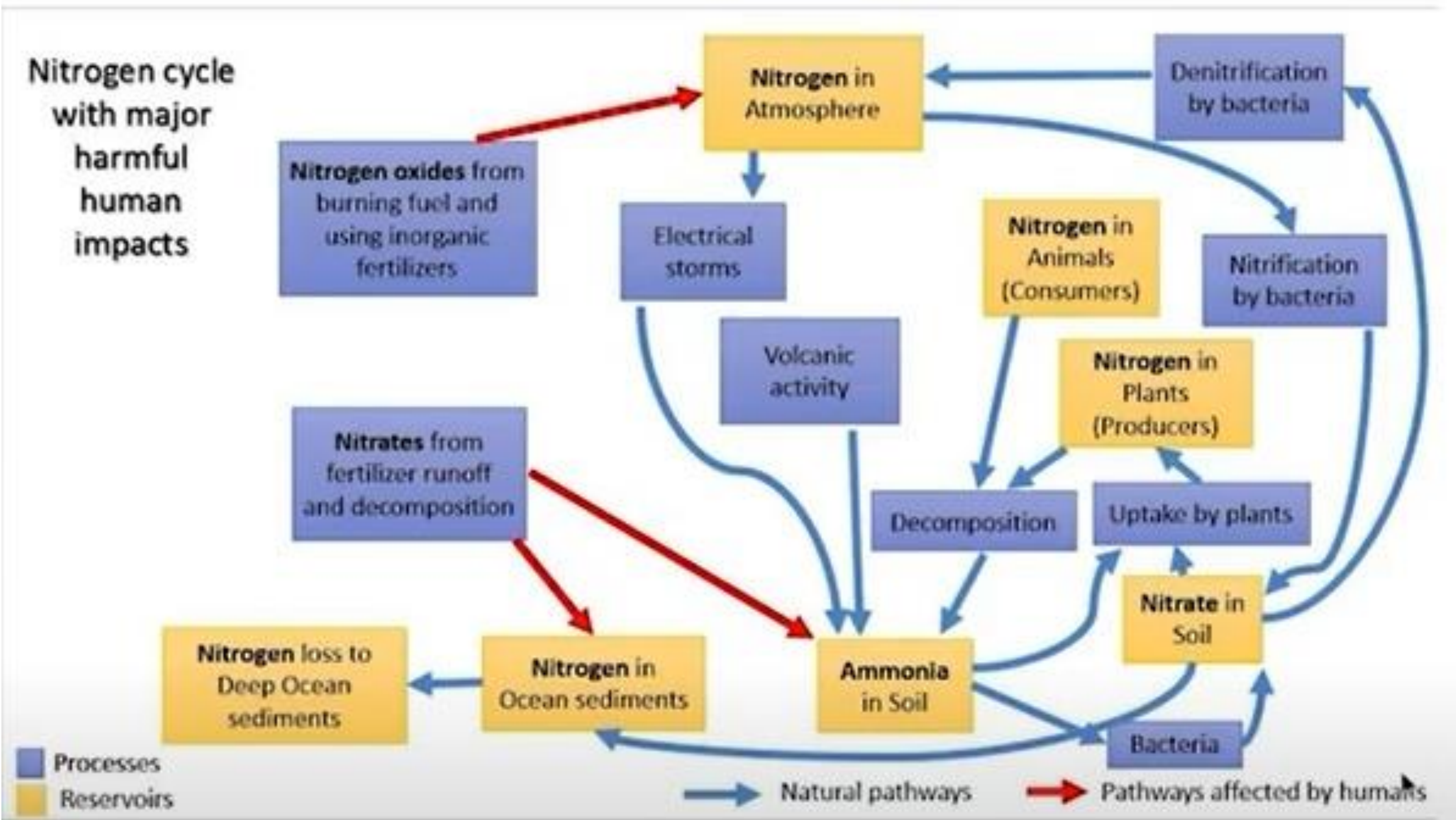
$$E_{c^1} = \frac{\lambda_{n+1}(primarycarnivore)}{\lambda_n(herbivores)} \times 100$$

Transfer of matter in ecosystem

<u>What happens to matter in ecosystems</u>

- Matter in the form of nutrient cycles (**biogeochemical cycles**) within and among ecosystems and the biosphere
- Human activities are altering the chemical cycles
- Water or hydrologic cycle
- Carbon cycle
- Nitrogen cycle
- Phosphorous cycle
- Sulphur cycle

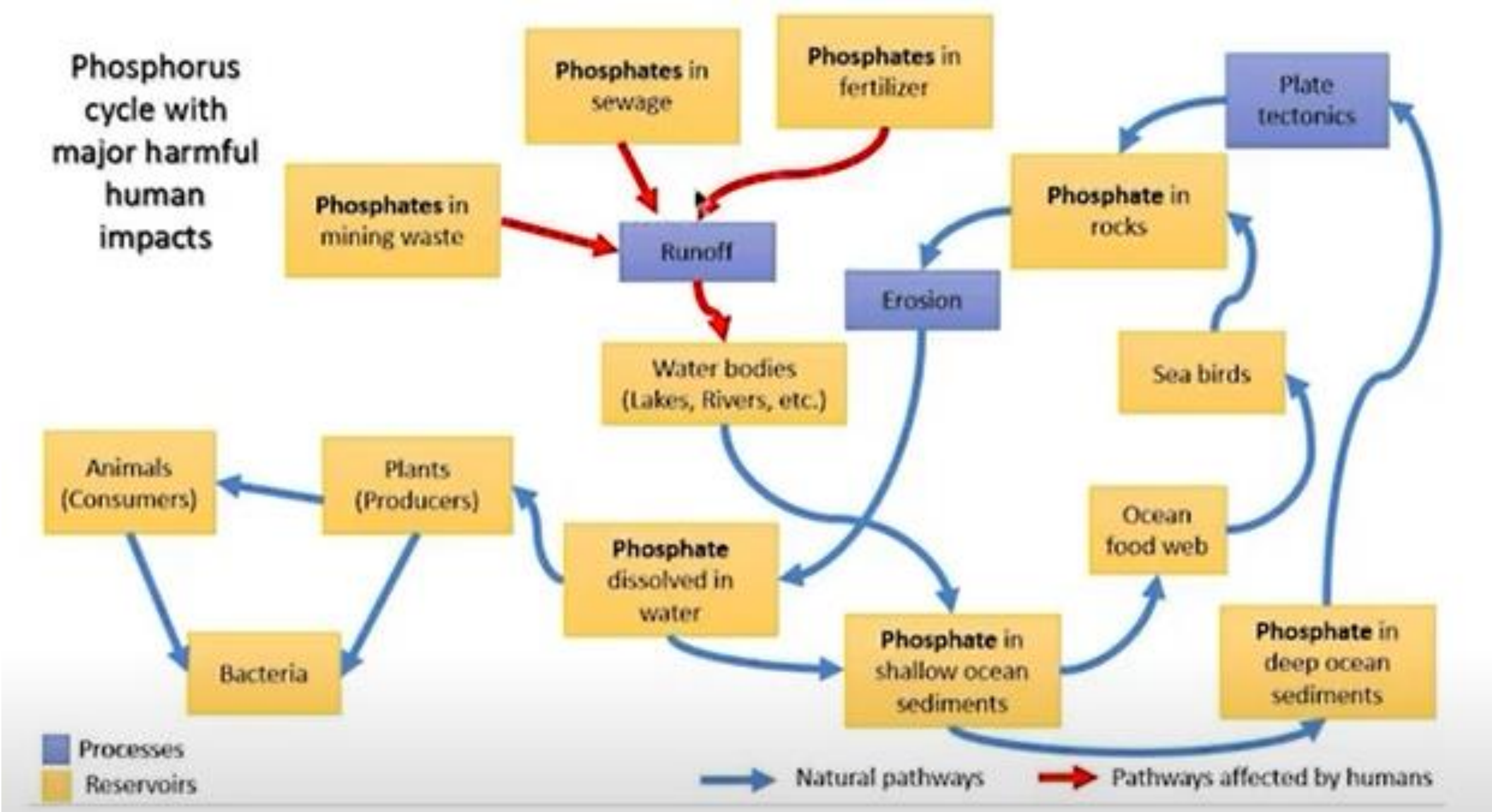
Nitrogen Cycle and Human Impact

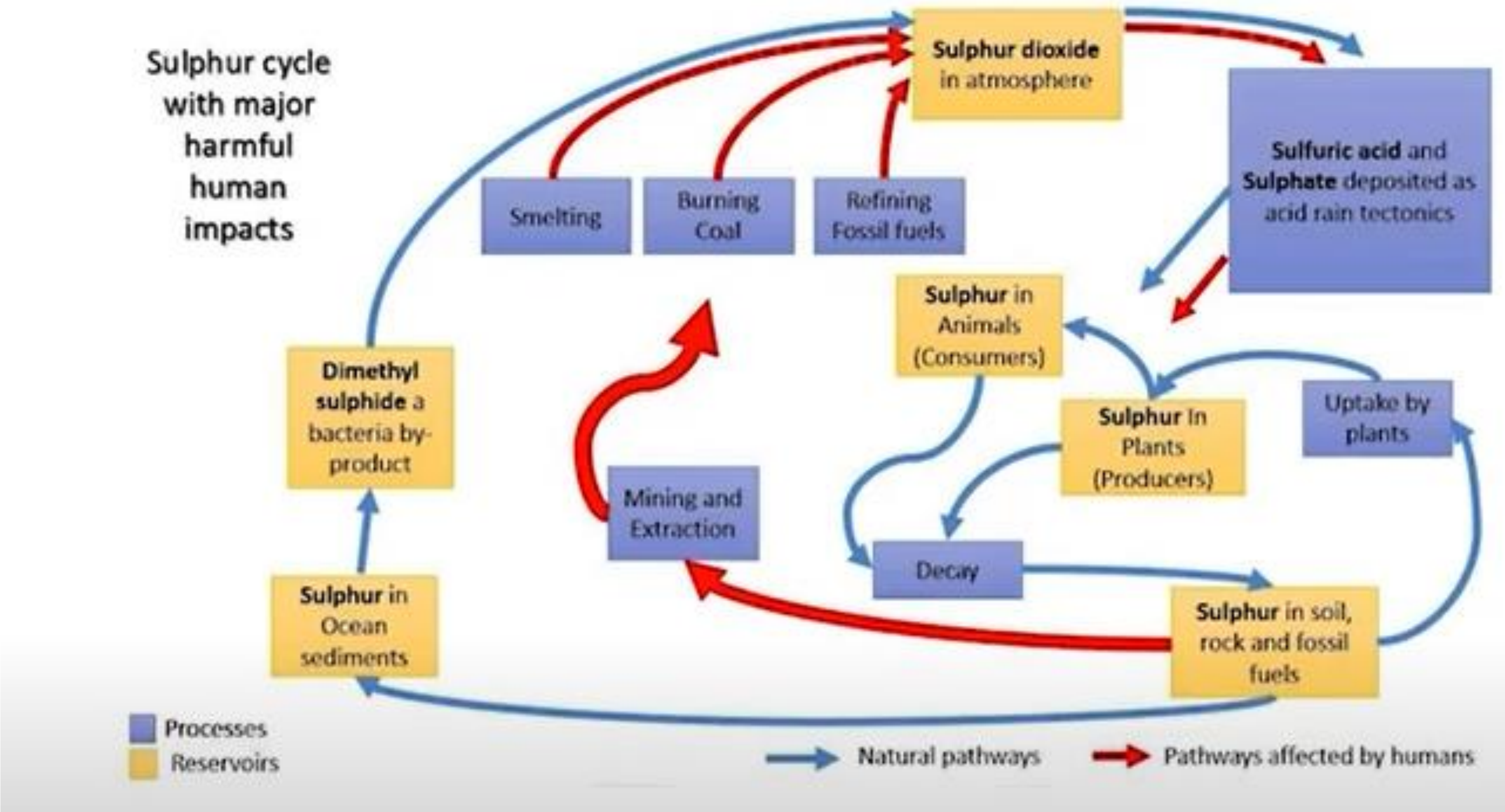


Nitrogen Cycle and Human Impact

- Red arrows indicate in the previous fig are the pathways which are affected by human activities.
- Blue boxes- Nitrogen processes, eg: lightening, volucanic eruption, bacteria
- Yellow boxes- Reservoir or storage of N_2
- E.g: nitrogen oxides which are from burning fuel and using inorganic fertilizers are released into the atmosphere, and that affects again the other natural flow of nitrogen into the environment.

Phosphorous Cycle and Human Impact




Sulphur cycle with major harmful human impacts
Sulphur dioxide in atmosphere
Sulfuric acid and Sulphate deposited as acid rain tectonics
Smelting
Burning Coal
Refining Fossil fuels
Sulphur in Animals (Consumers)
Uptake by plants
Sulphur In Plants (Producers)
Dimethyl sulphide a bacteria by-product
Mining and Extraction
Decay
Sulphur in Ocean sediments
Sulphur in soil, rock and fossil fuels
Processes
Reservoirs
Natural pathways
Pathways affected by humans

Ecological Niche

- Species have particular or common trait that's known as niche
- Certain skills and adaptation
- Traits are inherited through genes
- Every species has its niche or a unique position in a food web or ecosystem, unique function in life or a unique set of resources or factors needed for survival (e.g Sunbird- a particular kind of flower, insects in grass field visit different types if grass)
- In a particular ecosystem or area is more than one species with same resource requirement are available – there is a chance one will over run other based on resource availability

Ecological Niche

Definitions for niche

- Elton in 1927, defined niche as "the animals place in the biotic environment, it is relation to food and enemies"
  - a frog will be taking food from its surroundings it may be capturing some of the insects around, but at the same time a frog is also food to snake.
- Grinnel, 1904, niche has a property of an individual species population, so which means a specific set of capabilities for **extracting resources for surviving hazard** and for competing coupled with a corresponding set of needs.

e.g. Myna (bird) plays a role in the community as a worm puller and food for Eagles (class I)

Myna pulls worms and avoids eagles as part of a programme working to thrust more robins into the next generation. (class II)

Ecological Niche

Definitions for niche

- A niche is that set of ecological conditions under which a species can exploit a source of energy effectively enough to be able to reproduce and colonize further (class III).

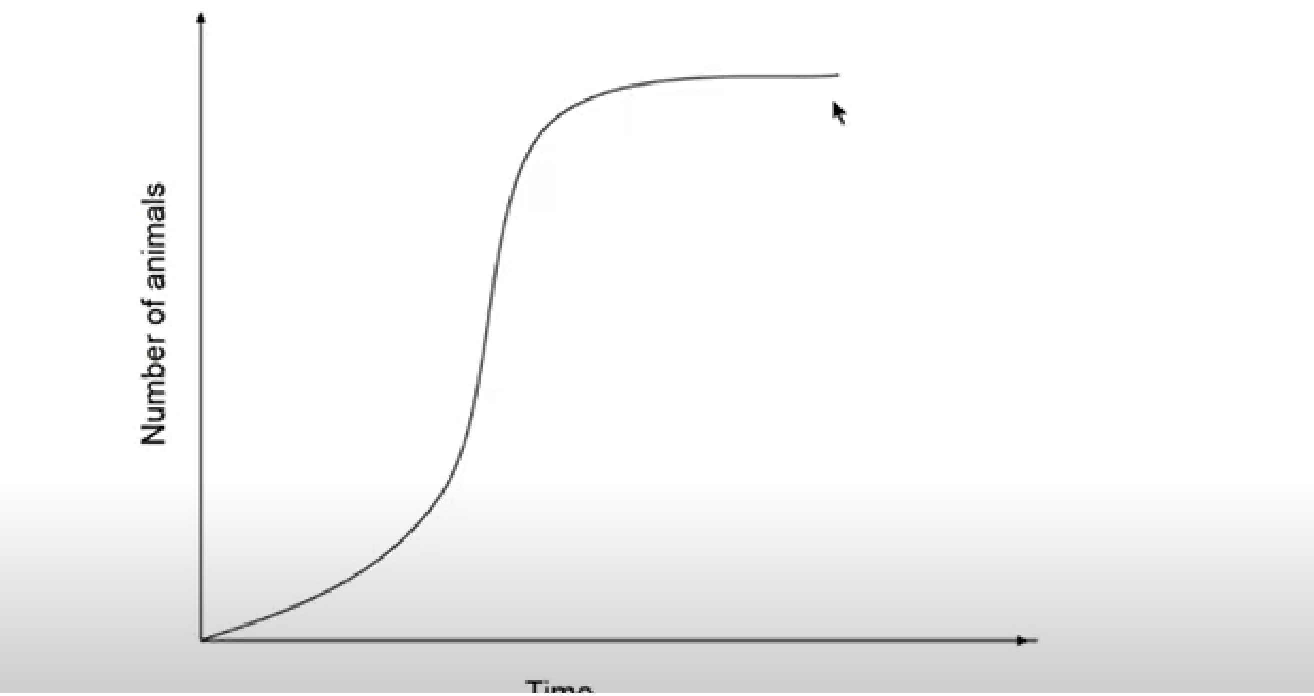
Think !!!!!!

- if a species population lives without competitors or other organisms that would interfere with it……………………….

- Then the size of the niche should be set by physical needs and food alone (which is also known as a fundamental niche of the species)

- **How the population number of in individual species will be, how they are controlled?**

Logistic Model of population growth



- This hypothesis of a population regulated by crowding to an equilibrium number can be modeled as:

$$R = rN\left(1 - \frac{N}{K}\right)$$

Logistic equation

or

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

Where, R is the population growth rate dN/dt
r is the intrinsic rate of increase
N is the number of animals present at time t
K is the number of animals able to live in the container at population equilibrium

- Logistic equation can be applied where the population growth is continuous
- Crucial to the logistic statement is the concept of carrying capacity (K)
- K is a property of the container and is expressed as a number
- The logistics hypothesis states that as the population number N approaches the saturation number K, then rN becomes zero and the population growth ceases.

- Sigmoid growth histories reflect changing intensities of competition
- Fecundity or the rate at which individuals produce offspring should be high when there is plenty of food supply (high intrinsic rate of increase)
- Fecundity, survival or both should drop when there is crowding
- Population growth would slow until it ceased altogether

Types of Species

Based on species roles, they are classified into:

- Native species
- Non-native species
- Indicator species (fish, frog, birds, bees etc)
- Keystone species
- Foundation species

Determine the structure and function of
Their ecosystem

Human Impact on Environment

Source: The Hindu

Human Impact on Environment

Source: the Hindu

Human Impact on Environment

Source: The Hindu

Human Impact on Environment

Source: The Hindu

Human Impact on environment

- Buildings in the US consume more than 30% of their total energy and 60% of electricity annually (oil and coal based)
- Average US citizen uses 1,86,000 calories of energy per day (basic need 2,200-3000 cals)
- They consume **18×10^9 litres** of potable water per day to flush toilets.
- For every **100 g** of product, we create **3,200 g** of waste
- On average food travels about **2000 km** from where it is grown/produced to where it is eaten

- The level of environmental destruction rises with the volume of stuff consumed and with the distance it travelled

- "**Ecological footprint**" of an average North American is about 5 hectares of arable land/person/year

- But the world has only 1.2 hectares of usable land per person!

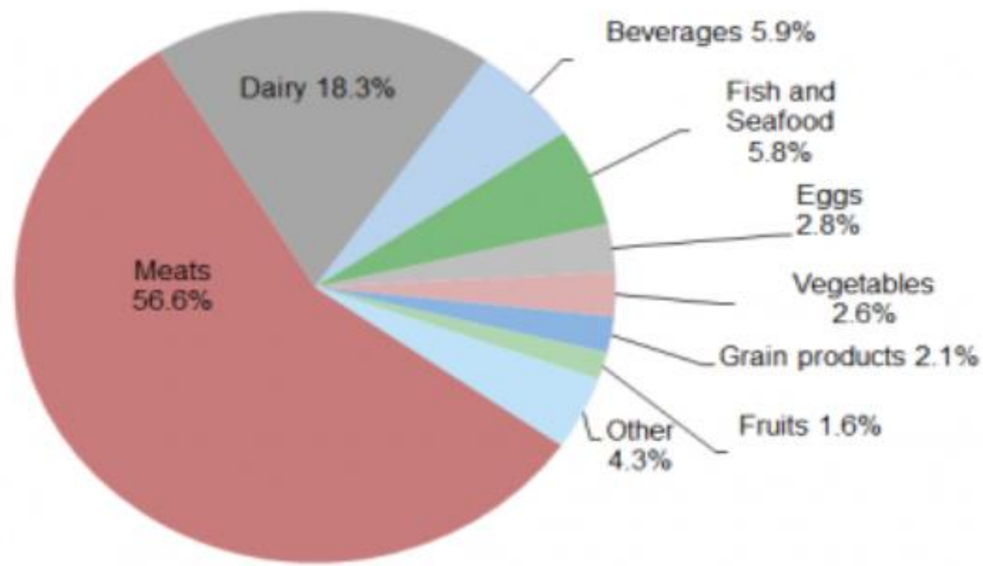
Ecological Footprint

Is the measure of the land required to grow our food, process our organic wastes, sequester our CO_2 and provide our material needs

Carbon foot print

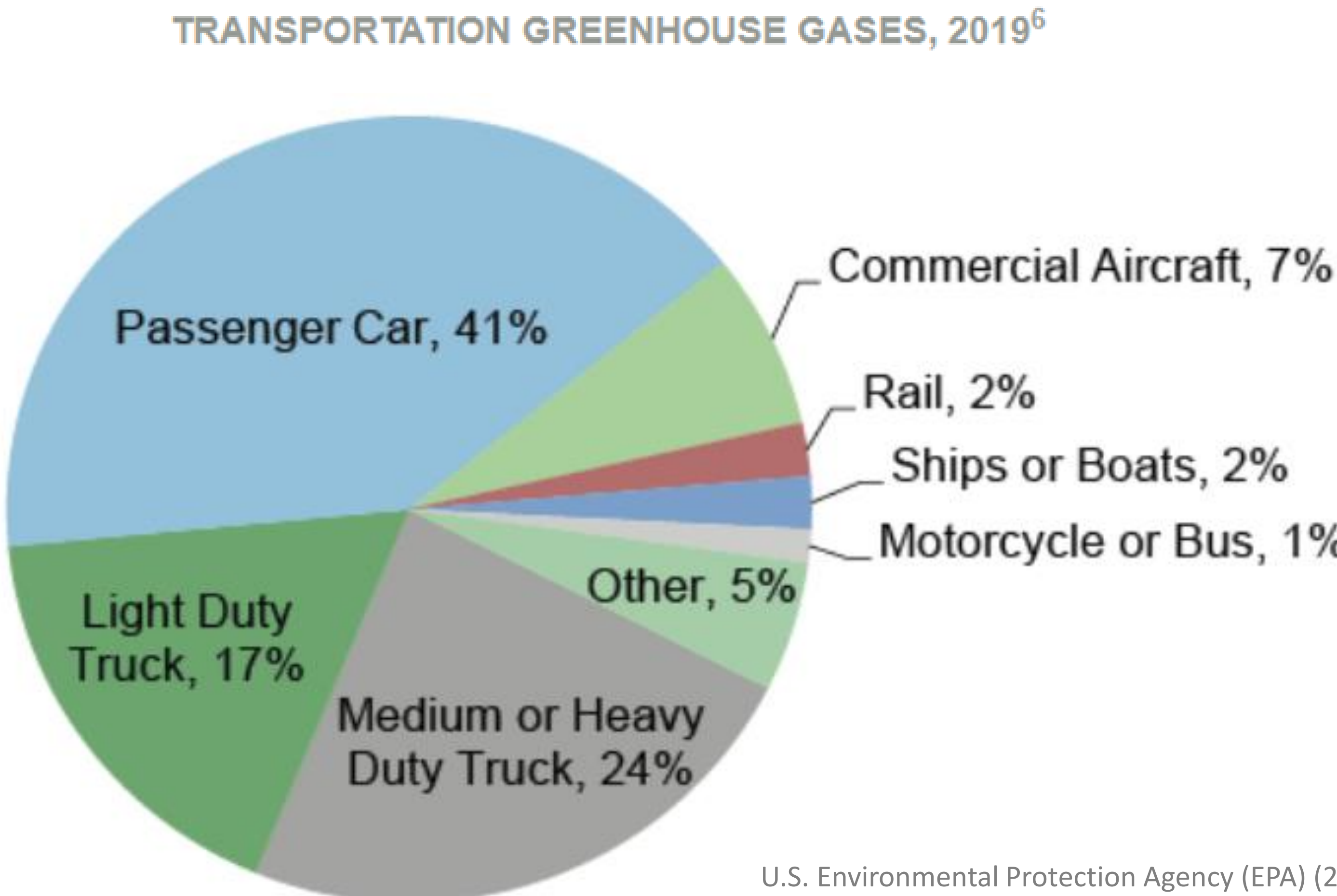
- A carbon footprint is the total greenhouse gas (GHG) emissions caused directly and indirectly by an individual, organization, event or product.
- Emissions resulting from every stage of a product or service's lifetime (material production, manufacturing, use, and end-of-life).
- Throughout a product's lifetime, or lifecycle, different GHGs may be emitted, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)
- greater or lesser ability to trap heat in the atmosphere. These differences are accounted for by the global warming potential (GWP) of each gas, resulting in a carbon footprint in units of mass of carbon dioxide equivalents (CO_2e)
- A typical U.S. household has a carbon footprint of 48 metric tons CO_2e/yr.

GREENHOUSE GASES CONTRIBUTION BY FOOD TYPE IN AVERAGE DIET



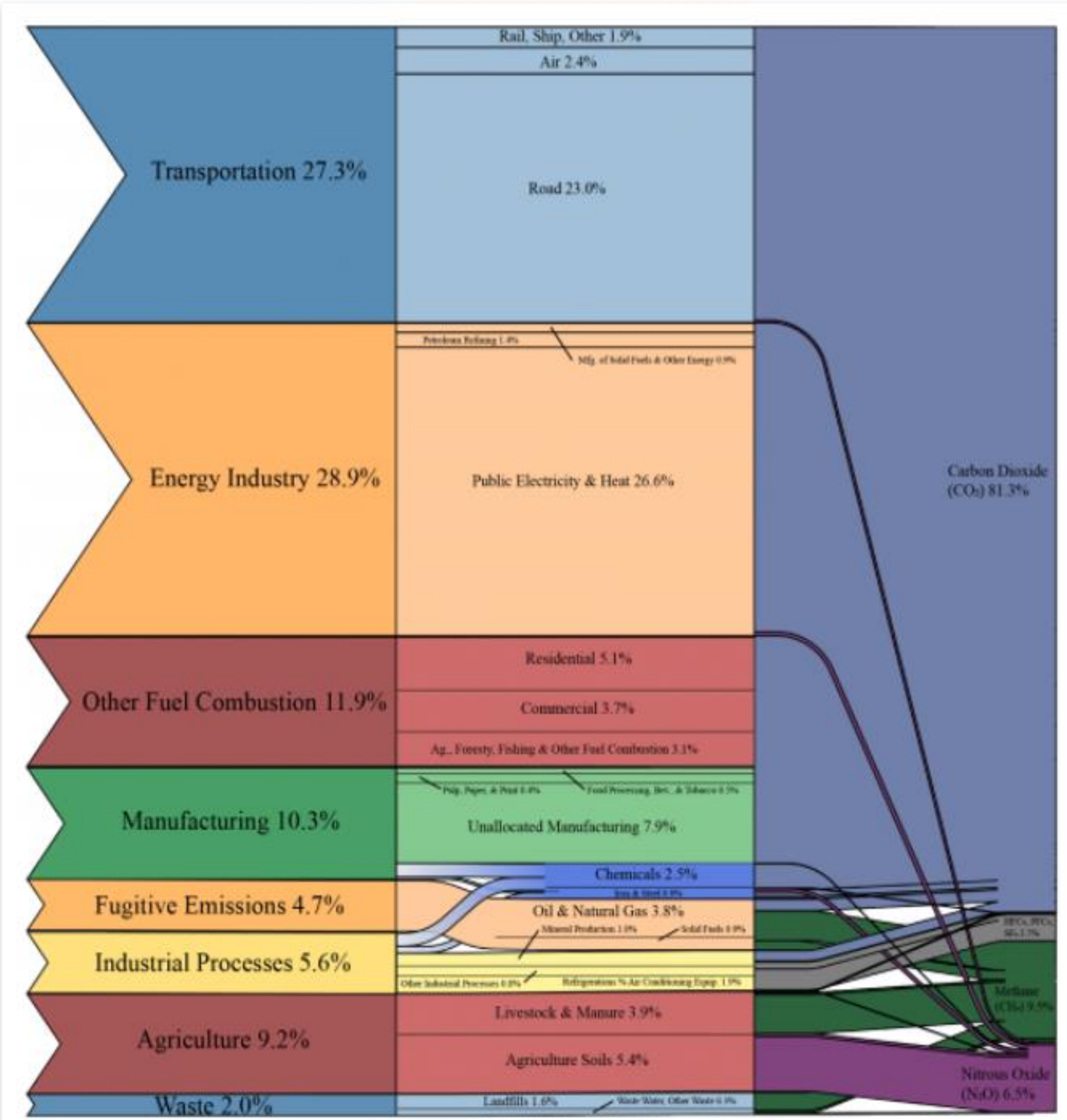
POUNDS OF CO_2E PER SERVING[13]

Heller, M.C., et al. (2018). Greenhouse gas emissions and energy use associated with production of individual self-selected US diets. Environmental Research Letters, 13(4), 044004



U.S. Environmental Protection Agency (EPA) (2021) Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2019

U.S. GREENHOUSE GAS EMISSIONS, 2018[28]



U.S. EPA (2020) 2020 Common Reporting Format (CRF) Table.

Carbon and Ecological Footprint Calculators

- U.S. Environmental Protection Agency:

www.epa.gov/carbon-footprint-calculator/

- The Nature Conservancy:

www.nature.org/greenliving/carboncalculator/

- Global Footprint Network:

https://www.footprintcalculator.org/