Environmental Biology

(22ZOOC24)

Characteristics of Population and Biosphere

Population

- A population is a group of individuals of the same species that inhabit a given area.
- Population has two important features.
- First, individuals of the same species, has the potential for interbreeding among members of the population.
- Second, the population is a spatial concept, requiring a defined spatial boundary of given area. The study of the group characteristics of a population, their changes over time and prediction of future changes is known as **demography.**

Organisms - Unitary or Modular ?

- Unitary- The zygote, formed through sexual reproduction, grows into a genetically unique organism.
- Modular organisms- the zygote develops into a unit of construction (a module) that then produces further, similar modules.
- Most plants are modular.

Population density

- The size of the population is represented by its fundamental property called **density.**
- It is generally expressed as the number of individuals or the population biomass per unit area or volume.
- Two types of densities are described – **crude density** and **specific** (or ecological) density.

- **Crude density** is the density per unit of total space.
- Generally, populations do not occupy all the space as whole because all area may not be habitable.
- **Specific density** density per unit of habitable space.
- It includes only that portion of total space that can actually be colonized by the population.

Population size

- Population size is a function of population density and the area that is occupied (geographic distribution).
- population size is estimated by counting all the individuals from a smaller sample area, then extrapolated over a larger area.
- **mark-recapture method:** individuals are very mobile and frequently move from one area to another.
- **Lincoln-Peterson index to population size.**
- We can use a simple formula for estimating total population size (N):

$$N = \frac{\text{Total individuals marked in first sample} \times \text{Size of second sample}}{\text{Number of marked individuals recaptured in second sample}}$$

Natality

- **Natality refers to the birth of individuals in a population.**
- The natality rate (or birth rate) is expressed as the number of individuals produced per female per unit time.
- Natality may be maximum natality or ecological natality.

Species Distribution

- Individuals within a population distributed as **random, clumped,** and **uniform distribution patterns.**

Figure 2. Species may have a random, clumped, or uniform distribution. Plants such as (a) dandelions with wind-dispersed seeds tend to be randomly distributed. Animals such as (b) elephants that travel in groups exhibit a clumped distribution. Territorial birds such as (c) penguins tend to have a uniform distribution. (credit a: modification of work by Rosendahl; credit b: modification of work by Rebecca Wood; credit c: modification of work by Ben Tubby)

- **Survivorship curve**
  - A graph of the number of individuals surviving at each age interval versus time.
  - These curves allow to compare the life histories of different populations.
  - Three types of survivorship curves. **Type I, Type II** and **Type III**

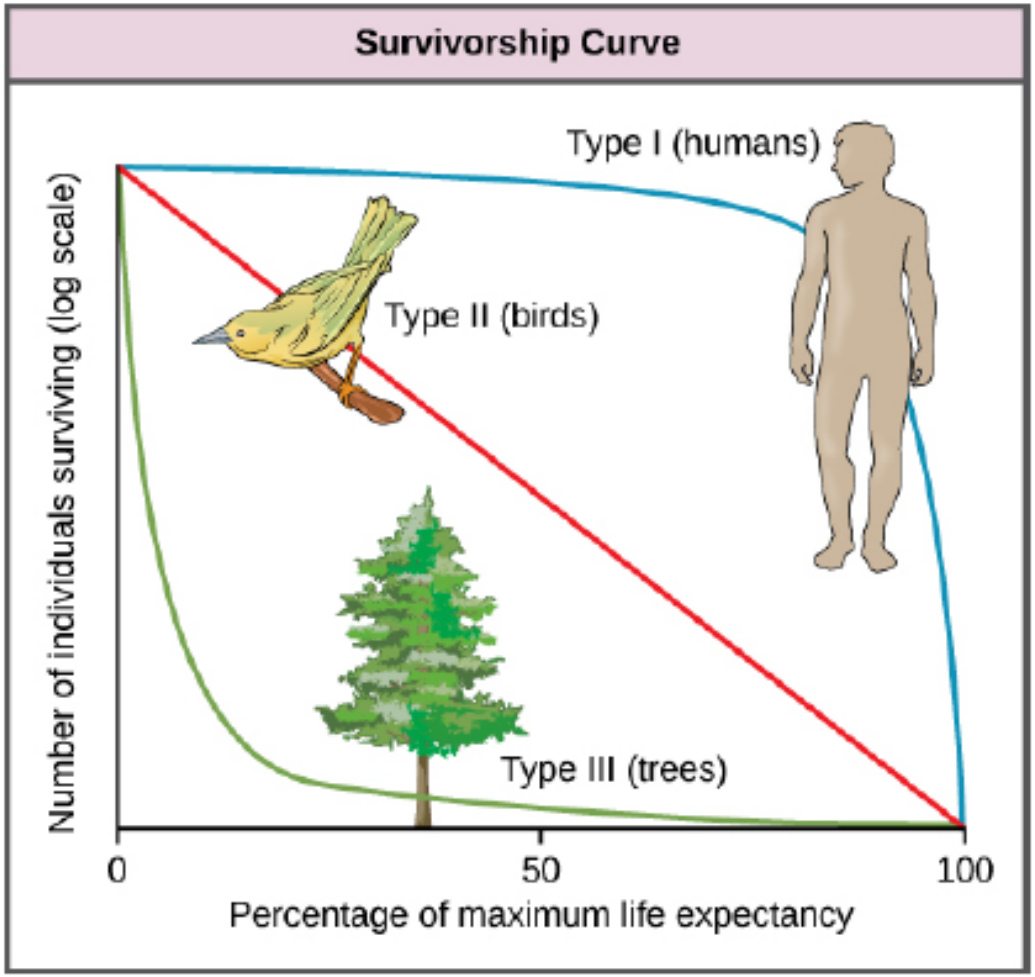


Figure 3. Survivorship curves show the distribution of individuals in a population according to age. Humans and most mammals have a Type I survivorship curve, because death primarily occurs in the older years. Birds have a Type II survivorship curve, as death at any age is equally probable. Trees have a Type III survivorship curve because very few survive the younger years, but after a certain age, individuals are much more likely to survive.

Population Growth and Regulation

- The two simplest models of population growth
- To describe the rate of change in the size of a population over time.
- The first models, **exponential growth:**
- describes populations that increase in numbers without any limits to their growth.
- The second model, **logistic growth:**
- limits the reproductive growth that as the population size increases.
- Neither model adequately describes natural populations, but they provide points of comparison**.**

Carrying Capacity and the Logistic Model

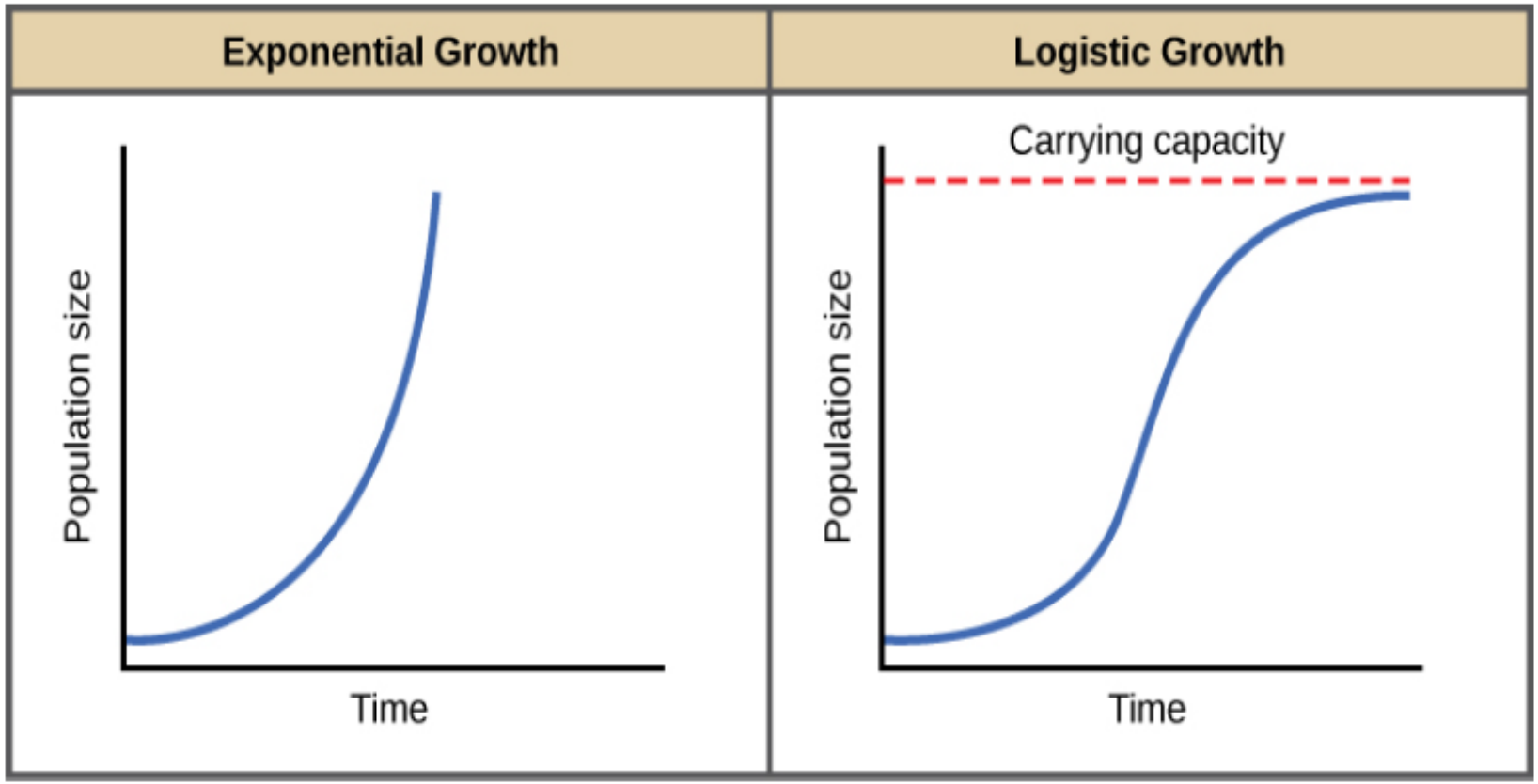
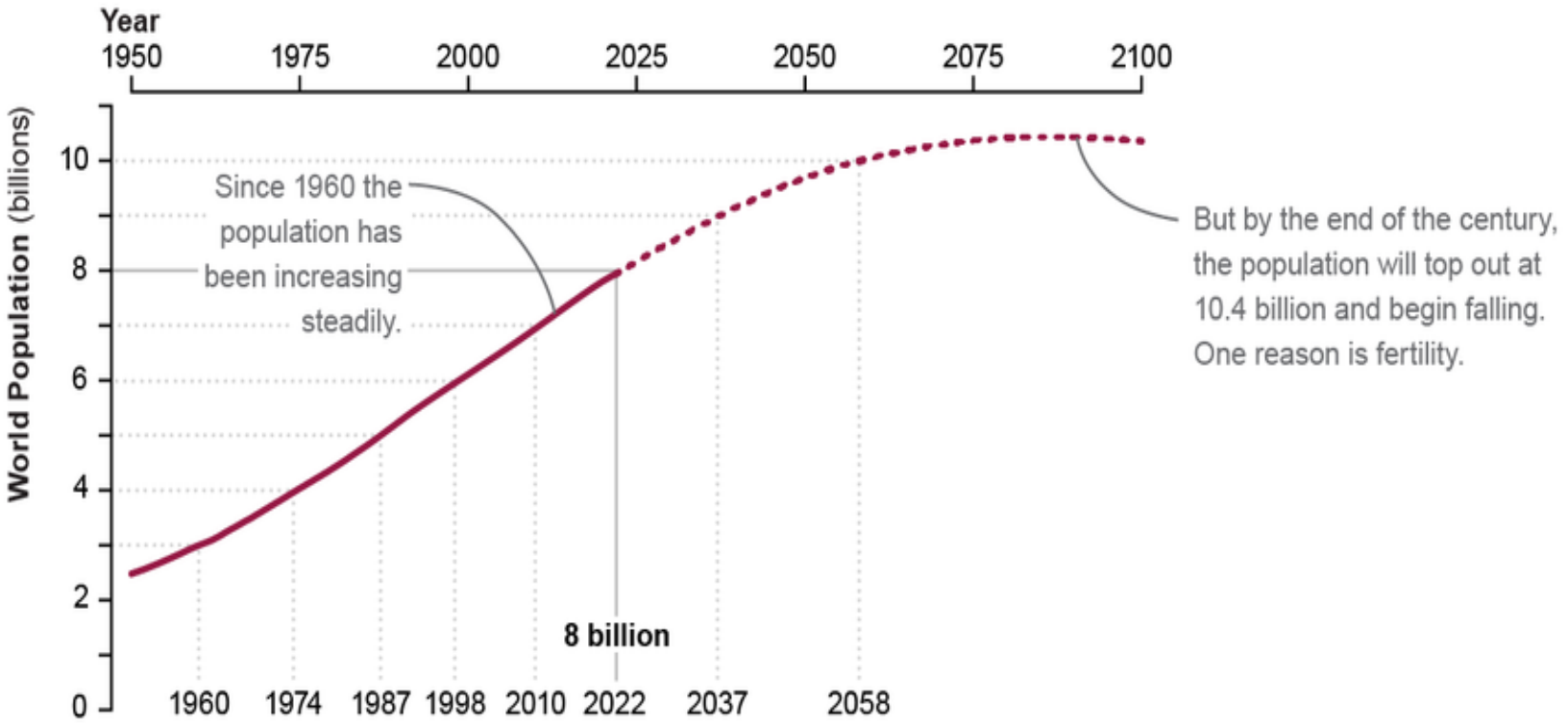


Figure 1. When resources are unlimited, populations exhibit (a) exponential growth, shown in a J-shaped curve. When resources are limited, populations exhibit (b) logistic growth. In logistic growth, population expansion decreases as resources become scarce, and it levels off when the carrying capacity of the environment is reached. The logistic growth curve is S-shaped.

Population Dynamics and Regulation

- The carrying capacity varies annually.
- The carrying capacity during the winter is much lower than it is during the summer.
- Natural events such as earthquakes, volcanoes, and fires can alter an environment and hence its carrying capacity.
- Populations do not usually exist in isolation.
- They share the environment with other species, competing with them for the same resources (interspecific competition).
- These factors are also important to understanding how a specific population will grow.

Global Population Growth



Age Structure, Population Growth, and Economic Development

- Age structure is the proportion of a population in different age classes.
- Models that incorporate age structure allow better prediction of population growth,
- Ability to associate this growth with the level of economic development in a region.
- Countries with rapid growth have a pyramidal shape in their age structure
- Mostly of younger individuals of reproductive age.
- This pattern is most often observed in underdeveloped countries where individuals do not live to old age because of less-than-optimal living conditions, and there is a high birth rate.

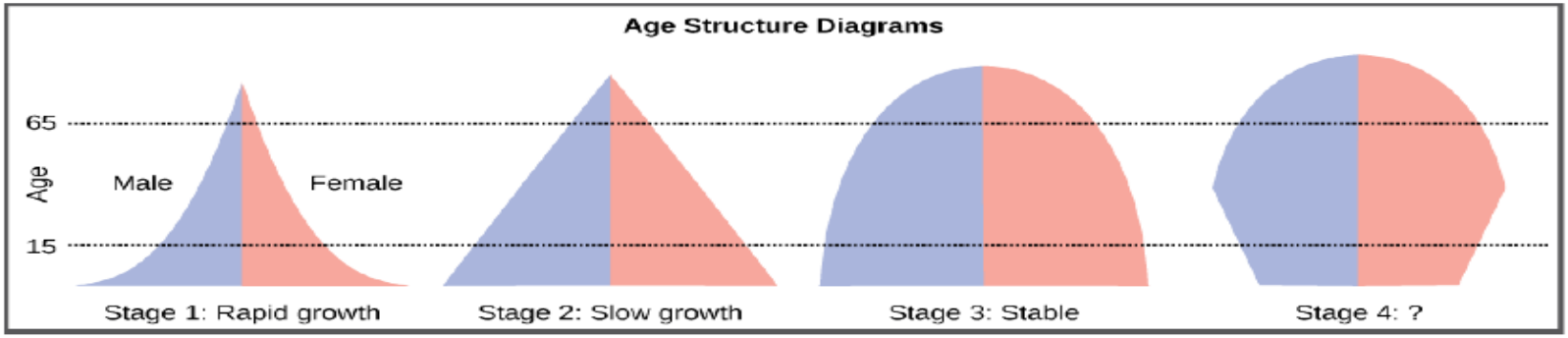


Figure 3. Typical age structure diagrams are shown. The rapid growth diagram narrows to a point, indicating that the number of individuals decreases rapidly with age. In the slow growth model, the number of individuals decreases steadily with age. Stable population diagrams are rounded on the top, showing that the number of individuals per age group decreases gradually, and then increases for the older part of the population.

Biosphere

Ecosystem

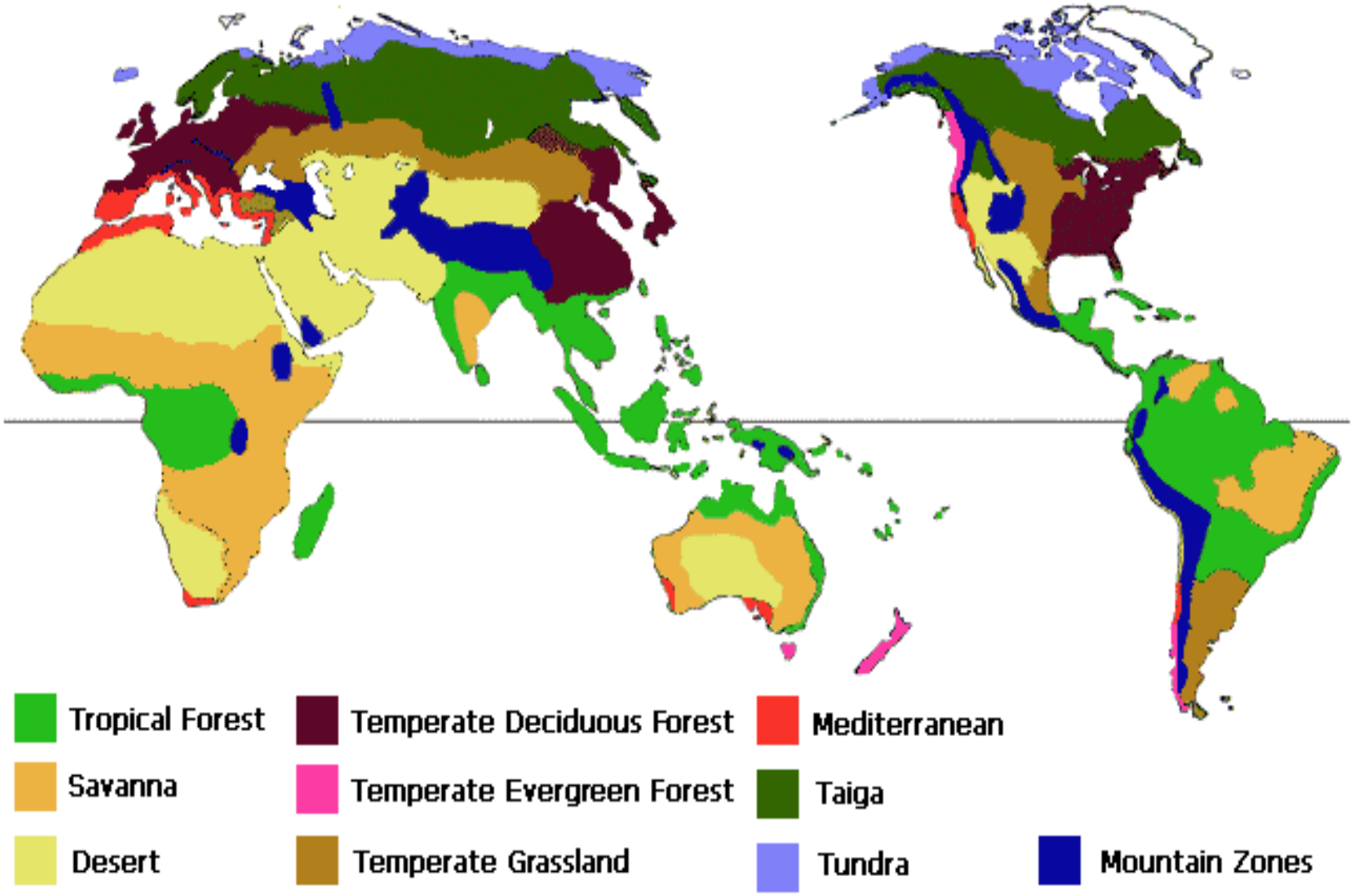
- An **ecosystem** is a community of organisms and their abiotic (non-living) environment.
- There are three broad categories of ecosystems based on their general environment:
  - Freshwater.
  - Marine
  - Terrestrial.

Terrestrial Biomes

- There are eight major terrestrial biomes:
  - Tropical rainforests.
  - Savannas.
  - Subtropical deserts.
  - Chaparral.
  - Temperate grasslands.
  - Temperate forests.
  - Boreal forests.
  - Arctic tundra.

- Biomes are large-scale environments.
- Each biome is defined by climate
- Characteristic of biomes- temperature ranges and amounts of precipitation.
- Two variables affect the types of vegetation and animal life that exist in those areas.
- The same biome can occur in geographically distinct areas with similar climates.

Terrestrial Biomes of the World



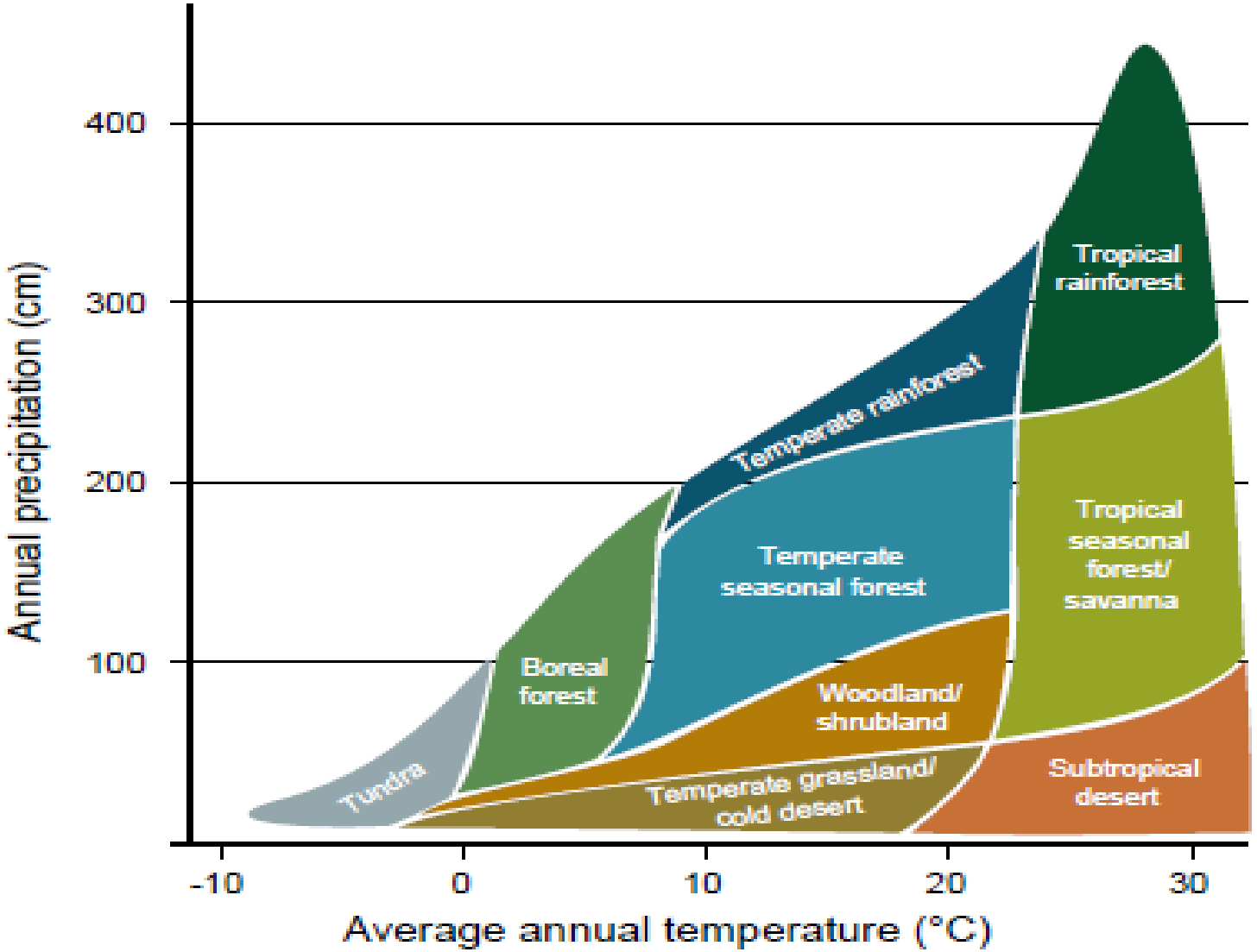


Figure 2. Precipitation and temperature are the two most important climatic variables that determine the type of biome in a particular location. Credit: "Climate influence on terrestrial biome" by Navarras is in the Public Domain, CC0

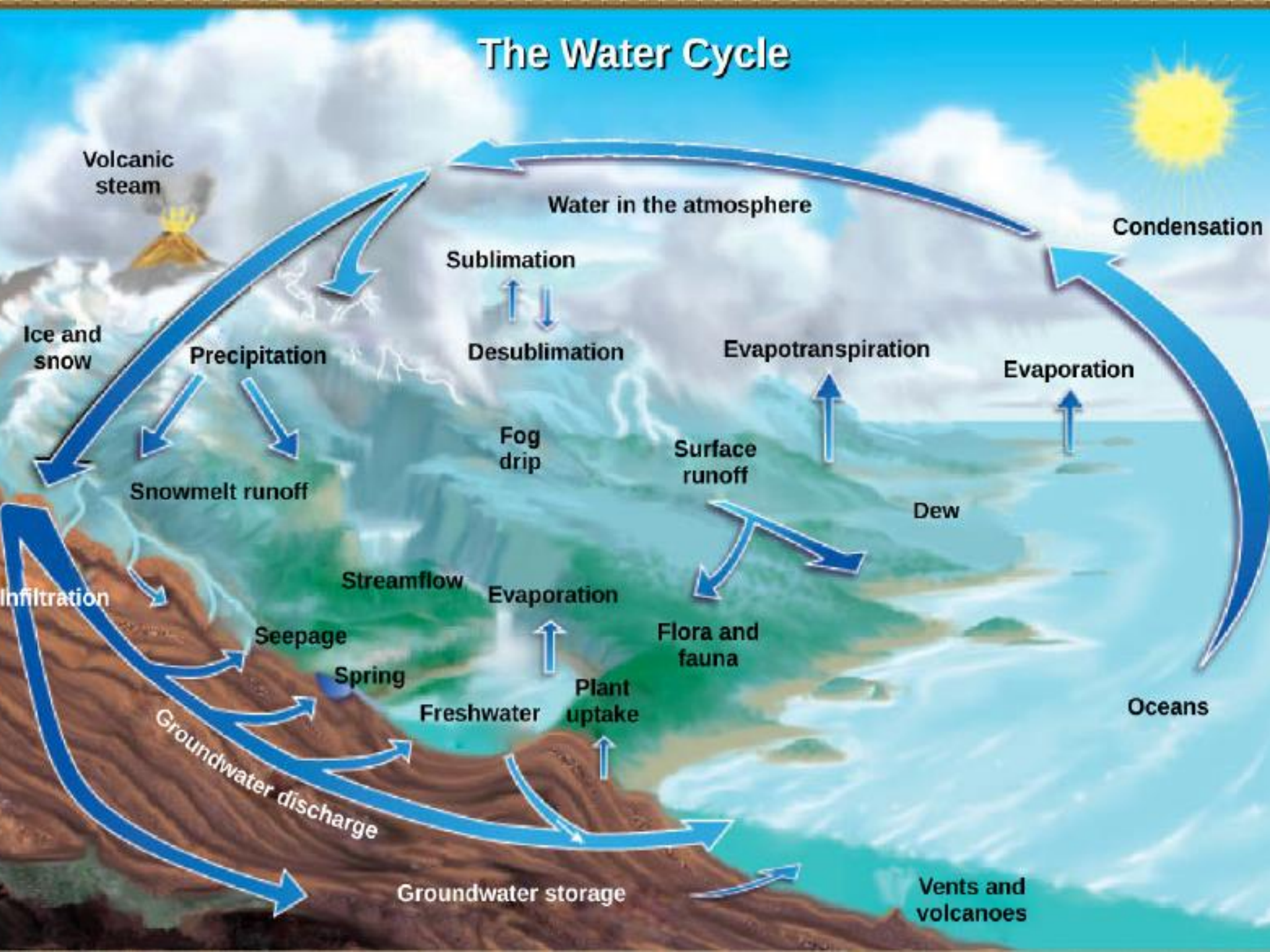
Biogeochemical cycle
And
Global Climatic Changes

Biogeochemical cycle

- The recycling of inorganic matter between living organisms and nonliving environment are called **biogeochemical cycles.**
- The matters of organisms is conserved and recycled.
- The six most common elements of organic molecules— **carbon, nitrogen, hydrogen, oxygen, phosphorus, and sulfur**
- Exist in the atmosphere, on land, in water, or beneath Earth's surface.
- **Geologic processes-** weathering, erosion, water drainage, and the subduction of the continental plates, all play a role in the cycling of elements on Earth.

The water cycle

- The **hydrosphere -** Earth water movement and storage occurs:
  - Liquid water on the surface (rivers, lakes, oceans) and
  - Beneath the surface (groundwater)
  - Ice (polar ice caps and glaciers)
  - Water vapor in the atmosphere.
- The various processes that occur during the cycling of water are
  - evaporation and sublimation
  - condensation and precipitation
  - subsurface water flow
  - surface runoff and snowmelt
  - streamflow
  - groundwater reservoirs, or **aquifers**


The Water Cycle
Volcanic steam
Water in the atmosphere
Condensation
Sublimation
Desublimation
Ice and snow
Precipitation
Evapotranspiration
Evaporation
Fog drip
Surface runoff
Snowmelt runoff
Dew
Infiltration
Streamflow
Evaporation
Seepage
Flora and fauna
Spring
Plant uptake
Freshwater
Oceans
Groundwater discharge
Groundwater storage
Vents and volcanoes

The carbon cycle

- Second most abundant element in organisms, by mass.
- Increase in carbon dioxide -climate change and major environmental concern worldwide.
- Carbon compounds contain energy.
- Carbons from dead plants and algae have fossilized over millions of years -**fossil fuels.**
- Atmospheric carbon dioxide-exchange of carbon between heterotrophs and autotrophs
- **Carbon sourse:**
  - Terrestrial autotrophs - carbon dioxide directly from the atmosphere.
  - Marine autotrophs -dissolved form bicarbonate, HCO3–.
- A **non-renewable resource is either regenerated very slowly or not at all.**
- **Subduction:** the movement of one tectonic plate beneath another.
- Carbon is released as carbon dioxide when a volcano erupts or from volcanic hydrothermal vents

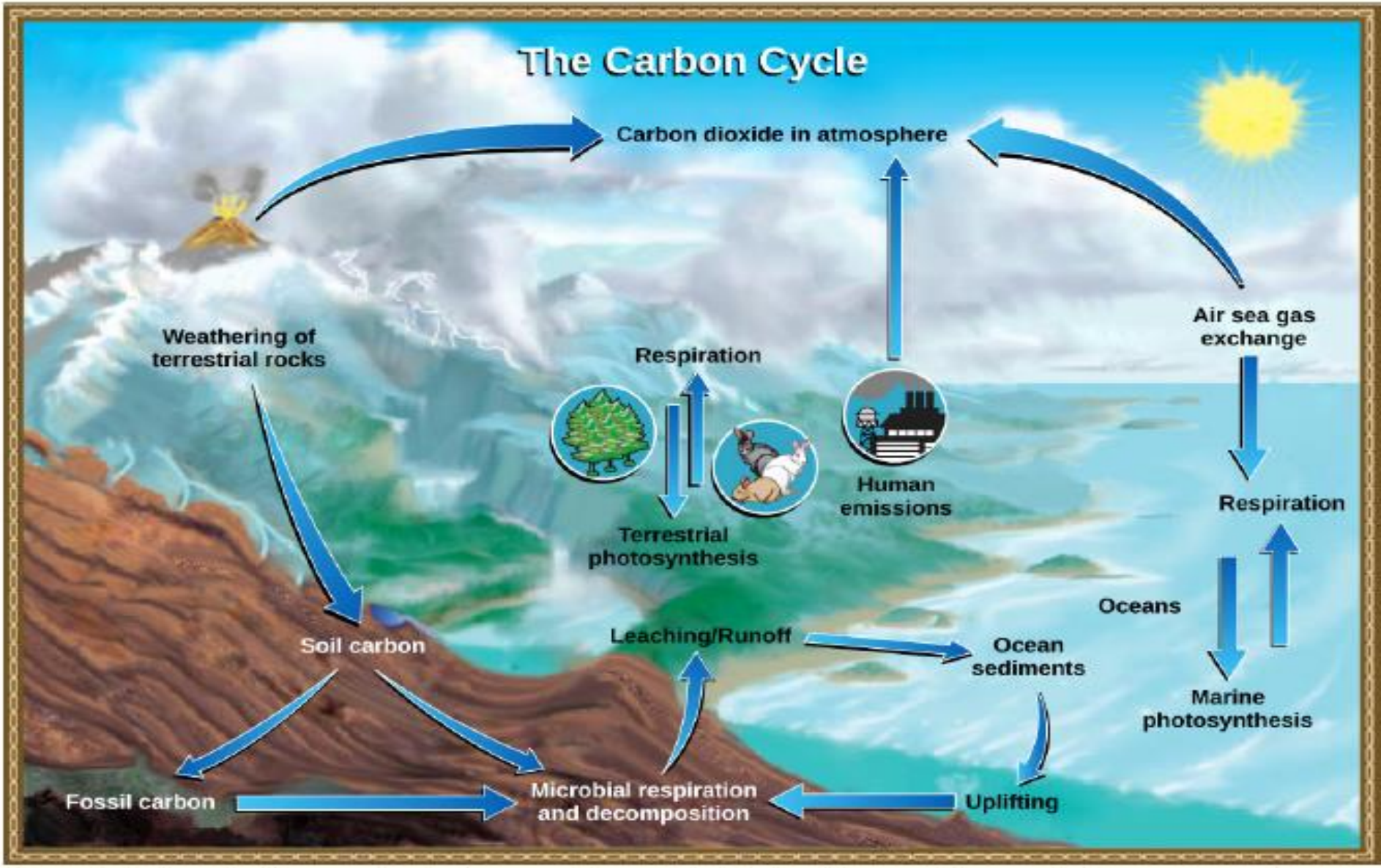


Figure 3. Carbon dioxide gas exists in the atmosphere and is dissolved in water. Photosynthesis converts carbon dioxide gas to organic carbon, and respiration cycles the organic carbon back into carbon dioxide gas. Long-term storage of organic carbon occurs when matter from living organisms is buried deep underground and becomes fossilized. Volcanic activity and, more recently, human emissions bring this stored carbon back into the carbon cycle. (credit: modification of work by John M. Evans and Howard Perlman, USGS)

The Nitrogen Cycle

- Human activity can alter the nitrogen cycle by two primary means:
  - the combustion of fossil fuels,
  - use of artificial fertilizers (which contain nitrogen and phosphorus compounds) in agriculture.
- They washed into lakes, streams, and rivers by surface runoff.
- Atmospheric nitrogen is associated with the production of acid rain (as nitric acid, HNO3) and greenhouse gas effects (as nitrous oxide, N2O).
- **Eutrophication (overgrowth of algae, the depletion of oxygen, and death of aquatic fauna.).**
- Marine ecosystems, nitrogen compounds collected in ocean floor sediments.
- Incorporated into terrestrial rock.

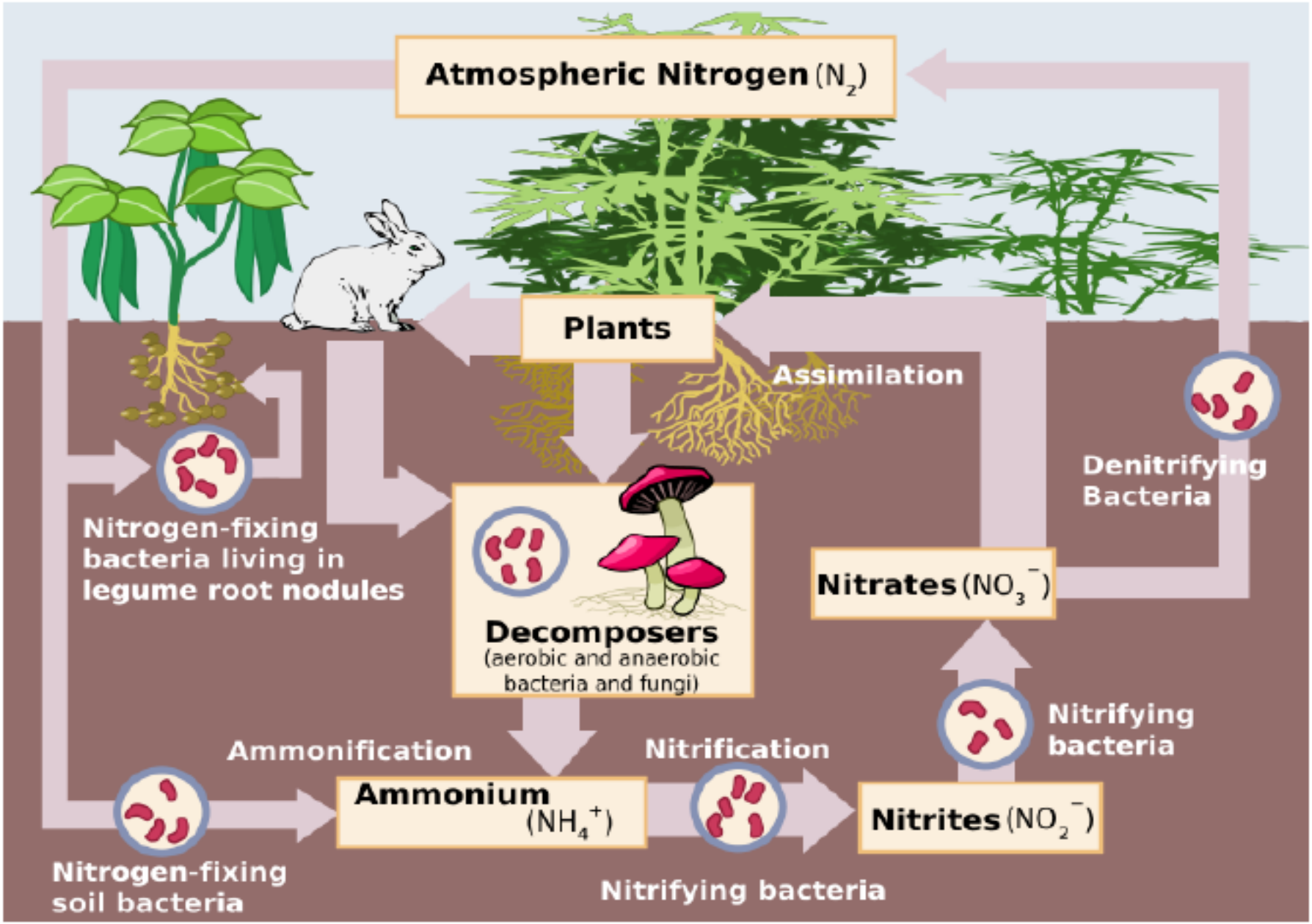
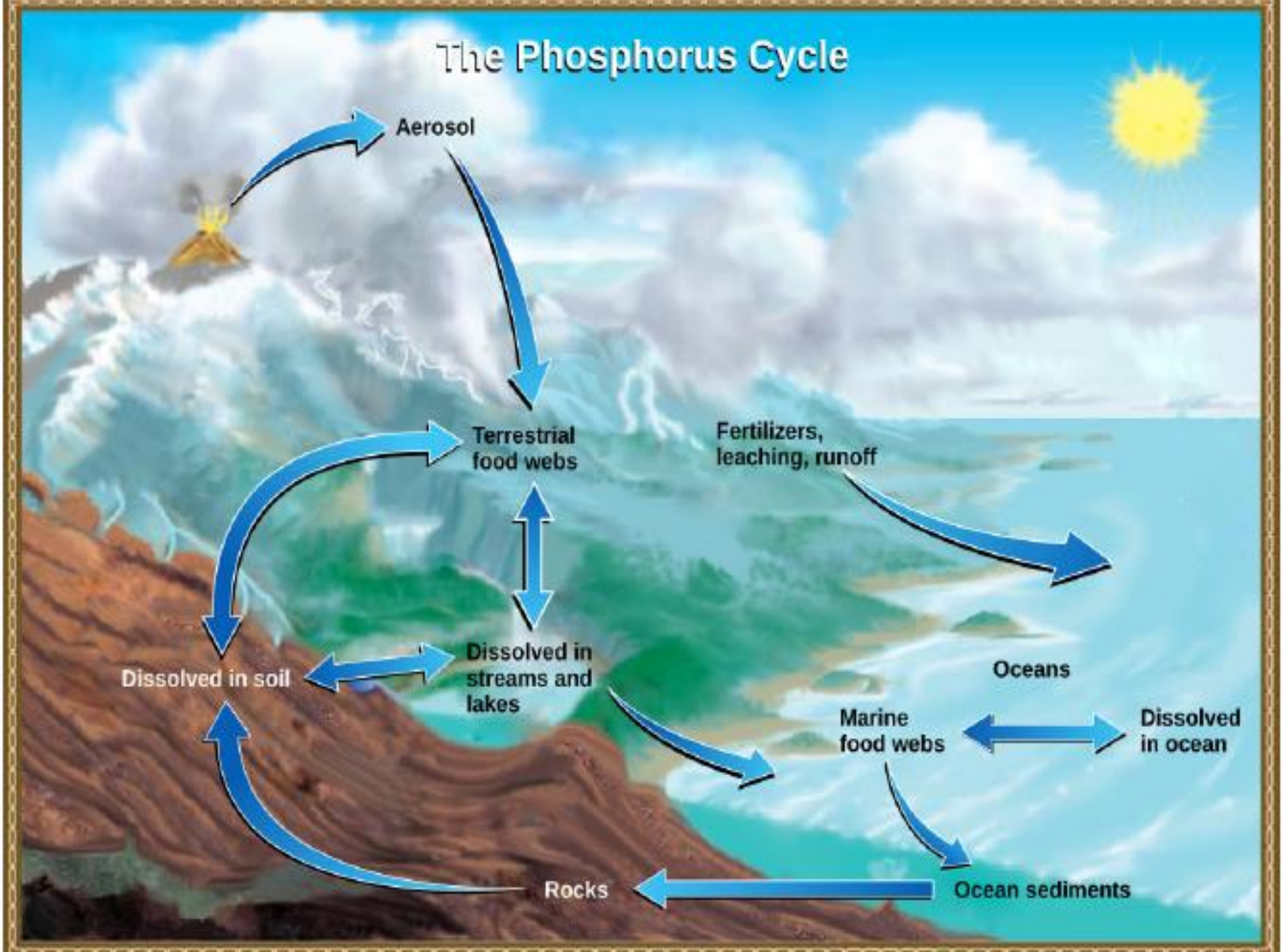


Figure 4. Nitrogen enters the living world from the atmosphere via nitrogen-fixing bacteria. This nitrogen and nitrogenous waste from animals is then processed back into gaseous nitrogen by soil bacteria, which also supply terrestrial food webs with the organic nitrogen they need. (credit: "Nitrogen cycle" by Johann Dréo & Raeky is licensed under CC BY-SA 3.0)

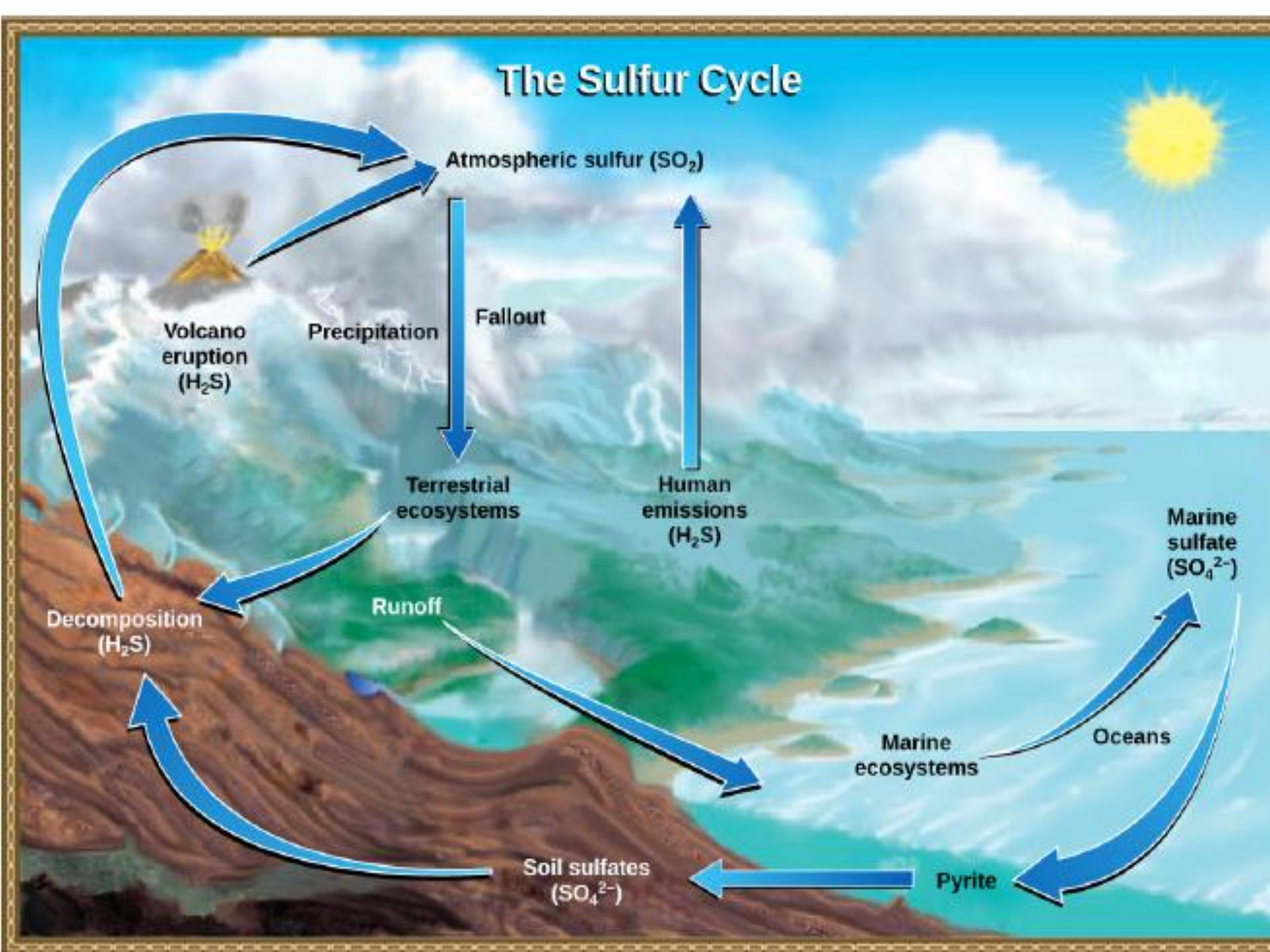
Phosphorus cycle

- Phosphorus is an essential nutrient for living processes.
- Major component of nucleic acids and phospholipids, and, as calcium phosphate.
- Phosphorus occurs in nature as the phosphate ion (PO43-).
- Excess phosphorus and nitrogen that enter these ecosystems from fertilizer runoff and from sewage cause excessive growth of algae.
- A **dead zone** is an area in lakes and oceans near the mouths of rivers where large areas are periodically depleted of their normal flora and faun


The Phosphorus Cycle
Aerosol
Terrestrial food webs
Fertilizers, leaching, runoff
Dissolved in soil
Dissolved in streams and lakes
Oceans
Marine food webs
Dissolved in ocean
Rocks
Ocean sediments

The Sulfur Cycle

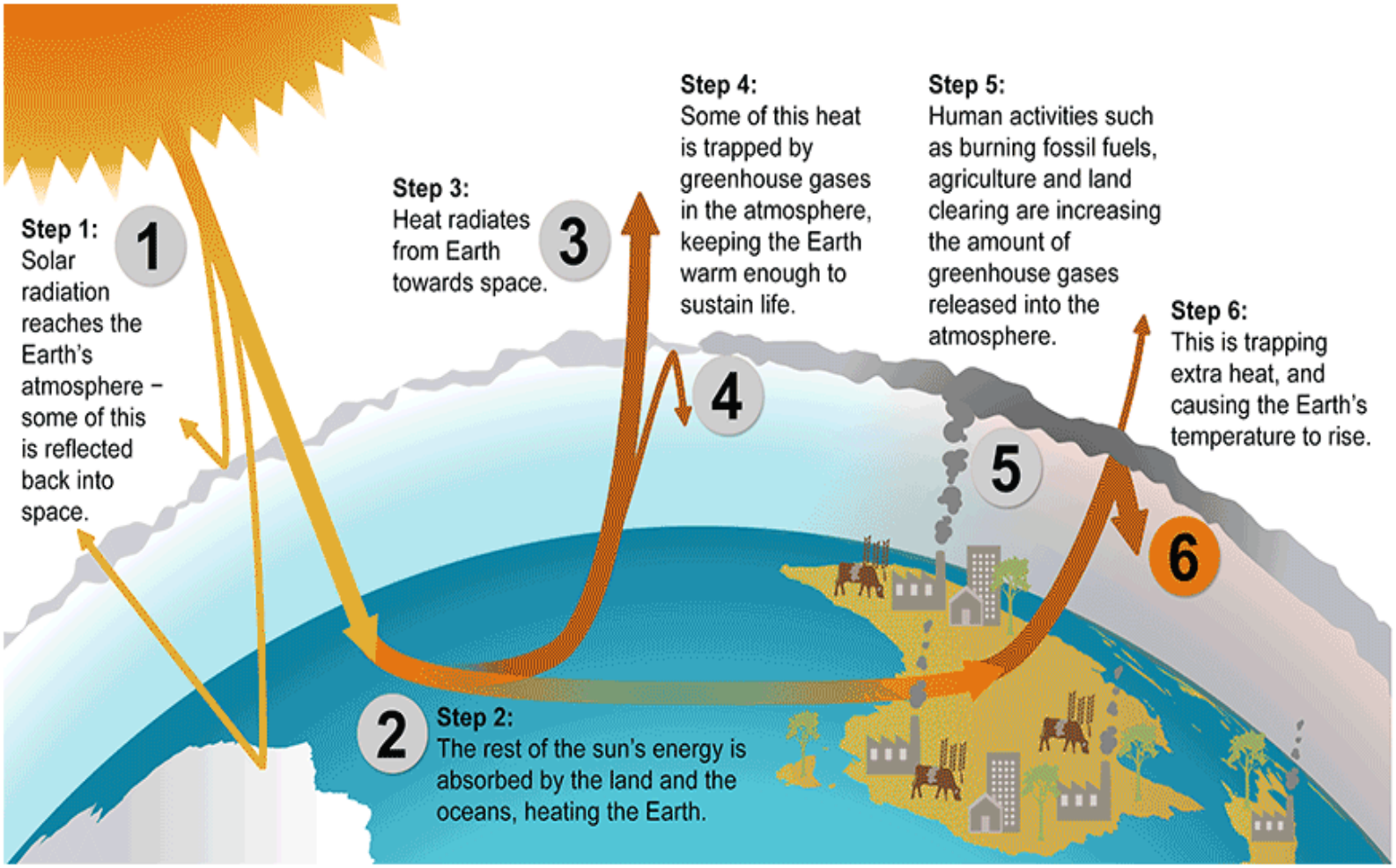
- Atmospheric sulfur is found in the form of sulfur dioxide (SO2).
- rain falls leads to sulfur dissolved in the form of weak sulfuric acid (H2SO4).
- Source- the decomposition of organic molecules; volcanic activity and geothermal vents; and the burning of fossil fuels by humans.
- The burning of large quantities of fossil fuels (coal) releases larger amounts of hydrogen sulfide gas into the atmosphere.
- **Acid rain,** damages the natural environment by lowering the pH of lakes, thus killing many of the resident plants and animals.


The Sulfur Cycle
Atmospheric sulfur (SO_2)
Volcano eruption (H_2S)
Precipitation
Fallout
Terrestrial ecosystems
Human emissions (H_2S)
Marine sulfate (SO_4^{2-})
Decomposition (H_2S)
Runoff
Marine ecosystems
Oceans
Soil sulfates (SO_4^{2-})
Pyrite

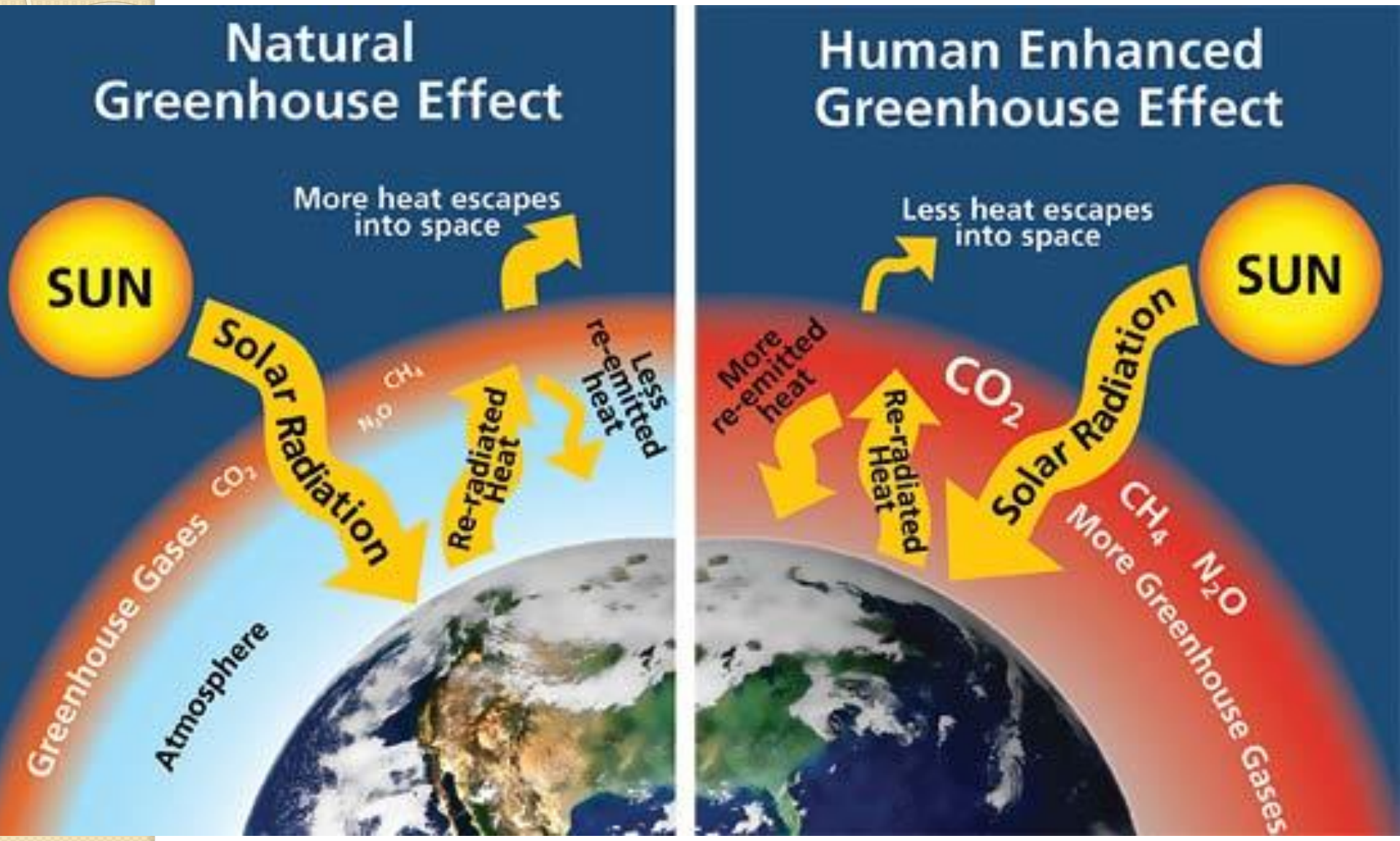
Factors contributing to Climatic change

- Temperature
- Green house effect
  - Carbondioxide, methane, Nitrous oxide (N2O), Water Vapour Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF6) and Nitrogen trifluoride (NF3)
- Global warming
- Ozone layer depletion
- Rise in sea level
- Acid rain
- Nitrogen deposition

Green house effect



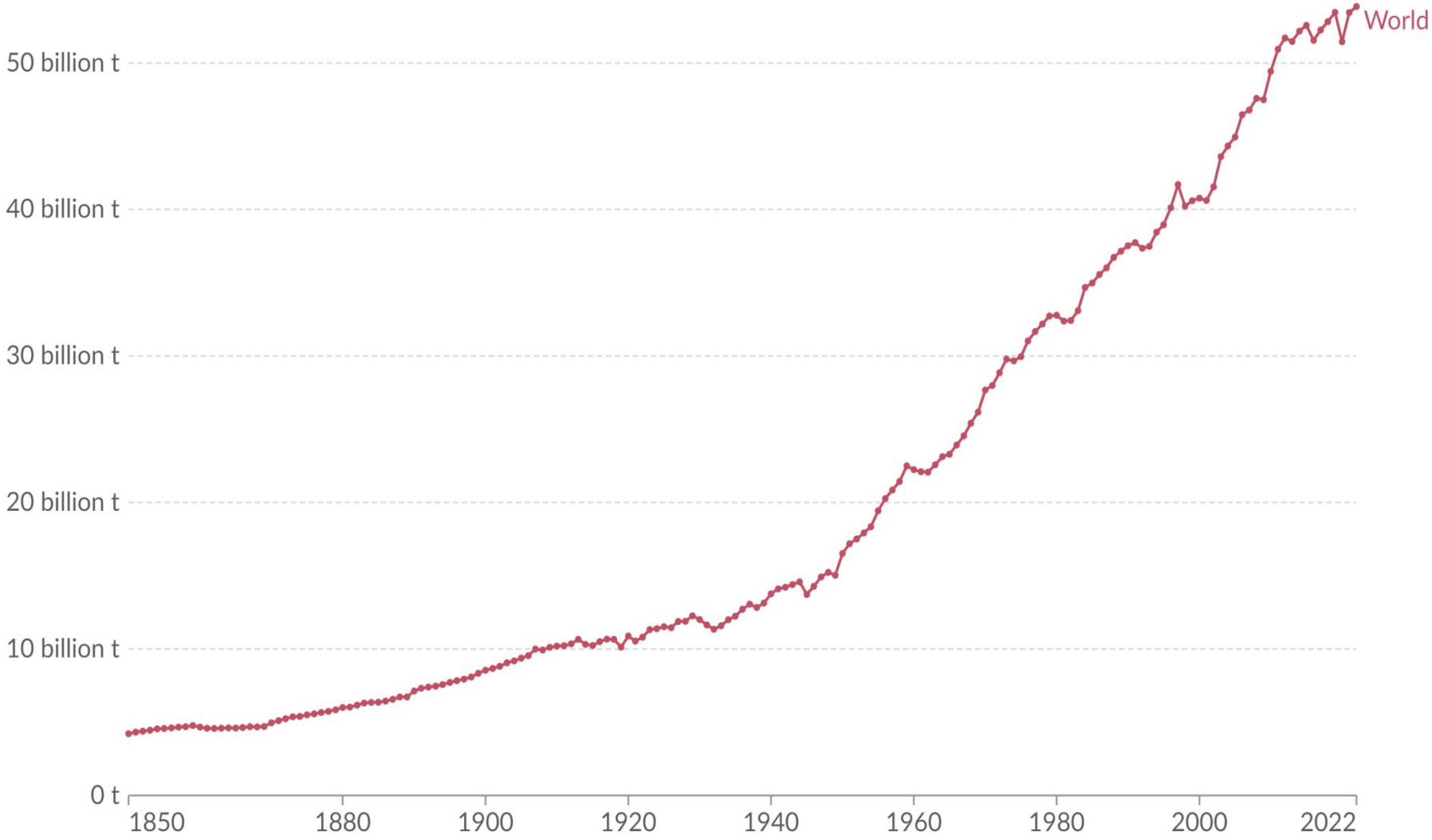
Green house effect



Greenhouse gas emissions

Our World in Data

Greenhouse gas emissions[1] include carbon dioxide, methane and nitrous oxide from all sources, including land-use change. They are measured in tonnes of carbon dioxide-equivalents[2] over a 100-year timescale.



Data source: Jones et al. (2024)

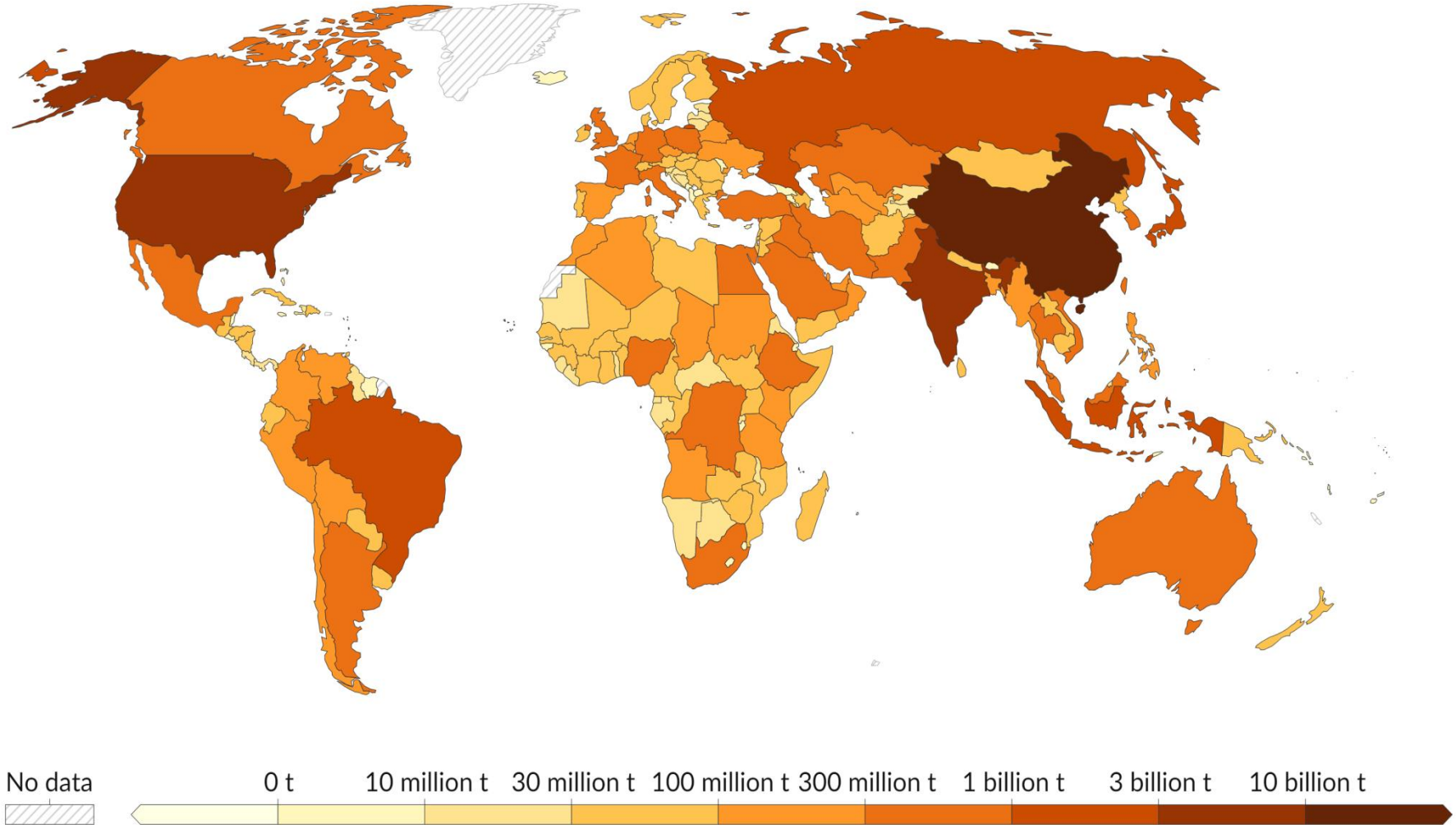
OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

Note: Land-use change emissions can be negative.

Greenhouse gas emissions, 2022

Our World in Data

Greenhouse gas emissions[1] include carbon dioxide, methane and nitrous oxide from all sources, including land-use change. They are measured in tonnes of carbon dioxide-equivalents[2] over a 100-year timescale.

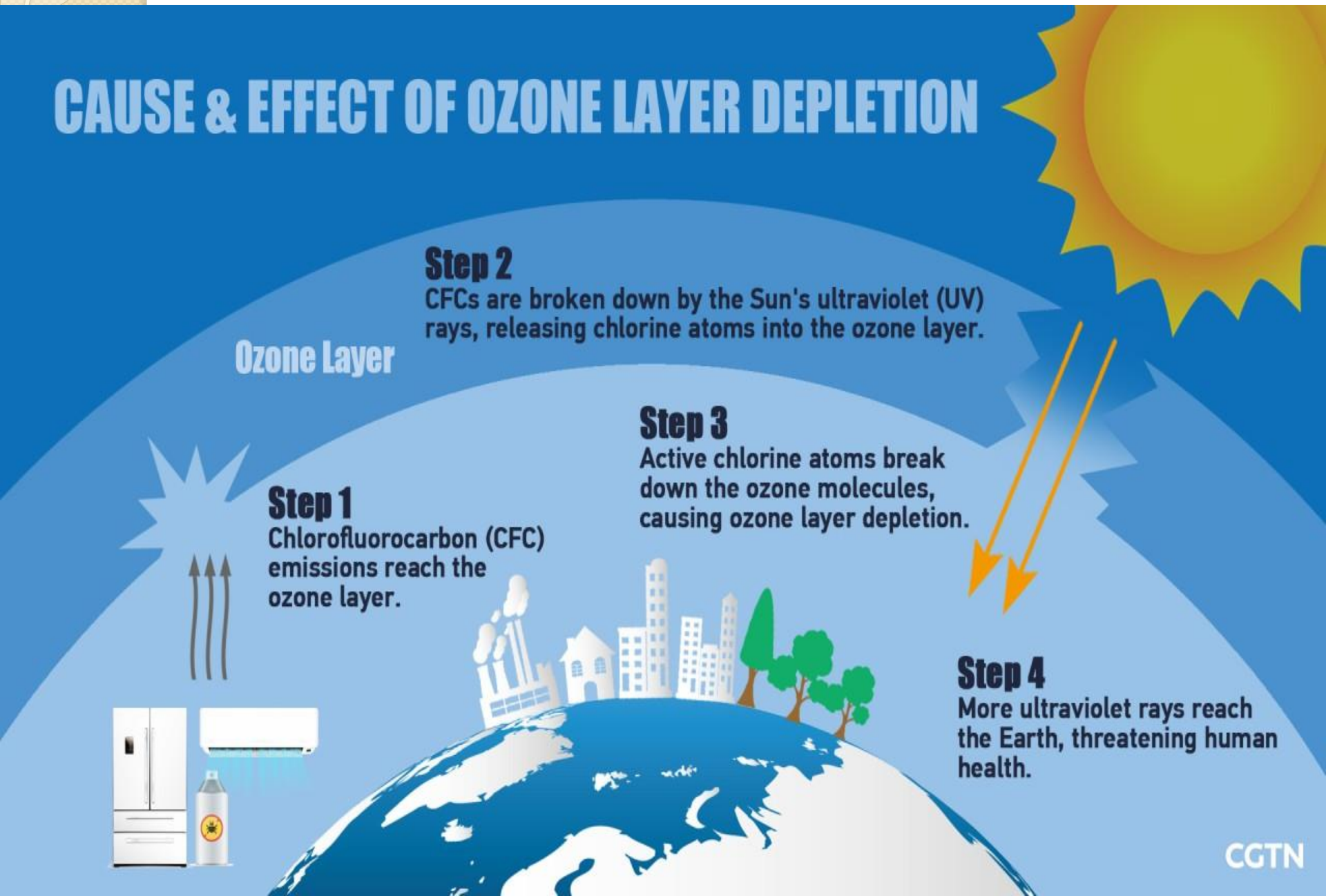


Data source: Jones et al. (2024)

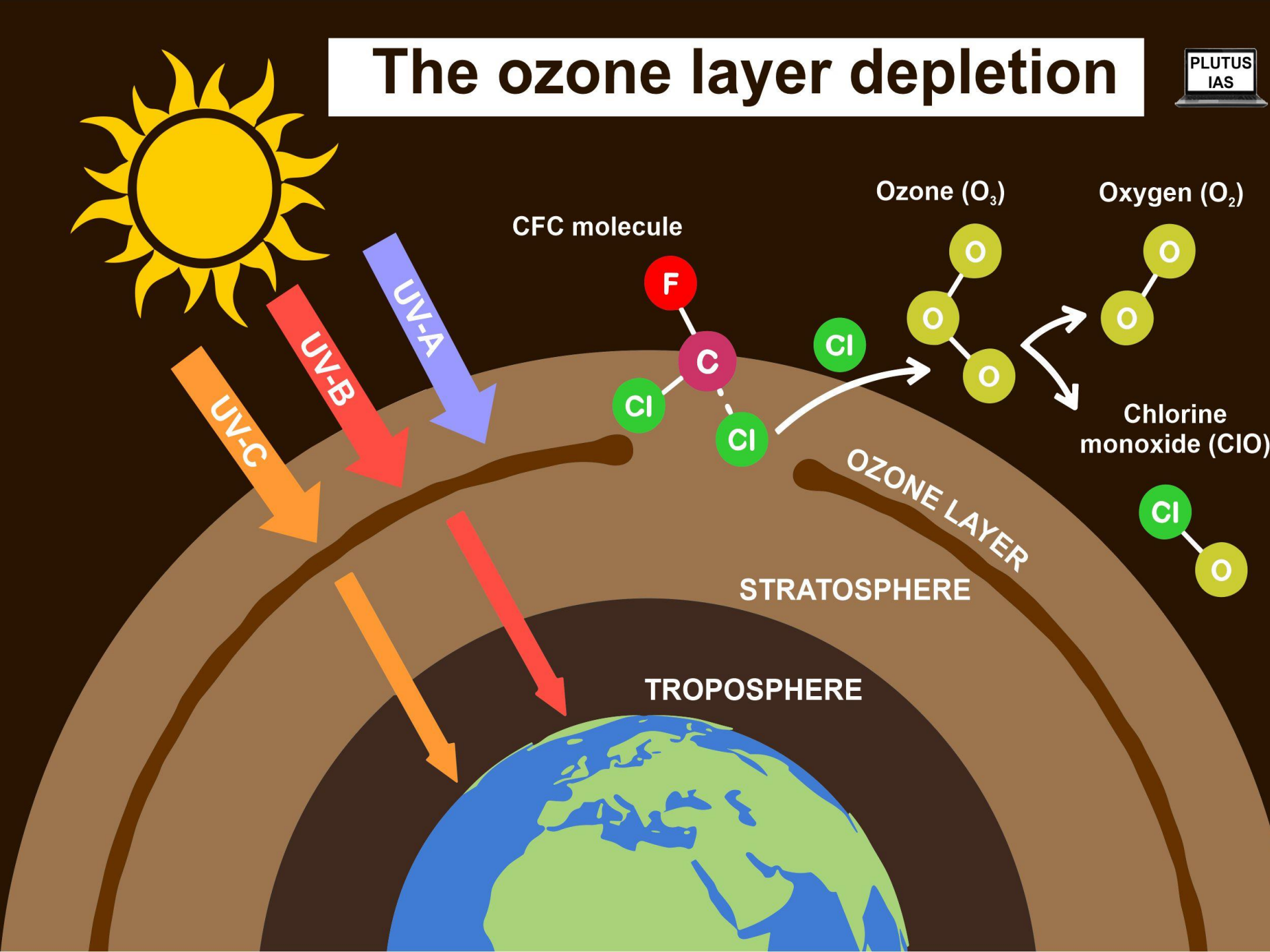
OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

Note: Land-use change emissions can be negative.

Ozone layer depletion



The ozone layer depletion



Biotic and Abiotic Components and Community Ecology

Ecosystem

- An ecosystem is a complex and dynamic system where living organisms interact with each other and their physical environment.
- The structure and function of an ecosystem are closely intertwined, and they contribute to the overall health and sustainability of the system.

Structure of Ecosystem:

Abiotic Components:

- These are the non-living, physical components of the ecosystem.
- Includes soil, water, air, sunlight, and climate.
- These factors shapes and influences the distribution and behaviour of living organisms in the ecosystem.

Biotic factors

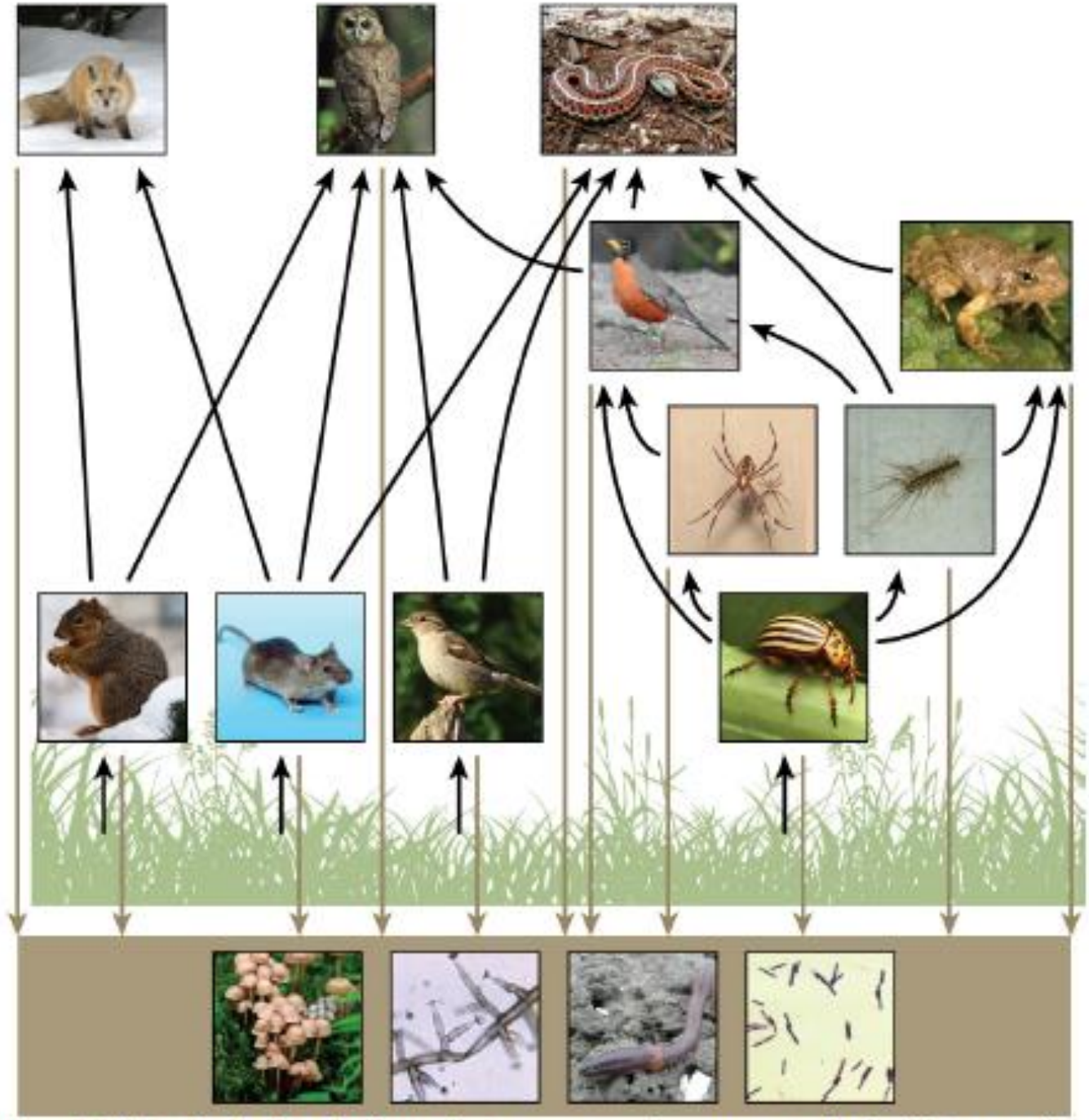
- Living organisms that shape their environment and are part of an ecosystem.
- Biotic factors include plants, animals, and microorganisms

- A food chain is a linear sequence of organisms.
- Nutrients and energy pass as one organism eats another.
- The levels in the food chain are producers, primary consumers, higher-level consumers, and finally decomposers.
- Each organism in a food chain occupies a specific trophic level (energy level), its position in the food chain or food web.

- Photosynthetic organisms (plants or phytoplankton), are called **producers.**
- The organisms that consume the producers are herbivores called **primary consumers**.
- **Secondary consumers** are carnivores that eat the primary consumers.
- **Tertiary consumers** are carnivores that eat other carnivores.
- Higher-level consumers feed on the next lower trophic levels, up to the organisms at the top of the food chain.

- Energy is lost at each trophic level and between trophic levels as heat and in the transfer to decomposers.
- Some organisms can feed at more than one trophic level.
- A **food web** is a concept that accounts for the multiple trophic (feeding) interactions between each species

- Two general types of food webs interacting within a single ecosystem.
- A **grazing food web** has plants or other photosynthetic organisms at its base, followed by herbivores and various carnivores.
- A **detrital food web** consists of a base of organisms that feed on decaying organic matter (dead organisms), including **decomposers.**
- These organisms are usually bacteria, fungi, and invertebrate animals that recycle organic material back into the biotic part of the ecosystem as they themselves are consumed by other organisms.



- Populations interact within a habitat -a **community.**
- The number of species occupying the same habitat and their relative abundance is known as the **diversity** of the community.
- Ecology at the community level
  - species interact with each other and compete for the same resources.

Competitive Exclusion Principle

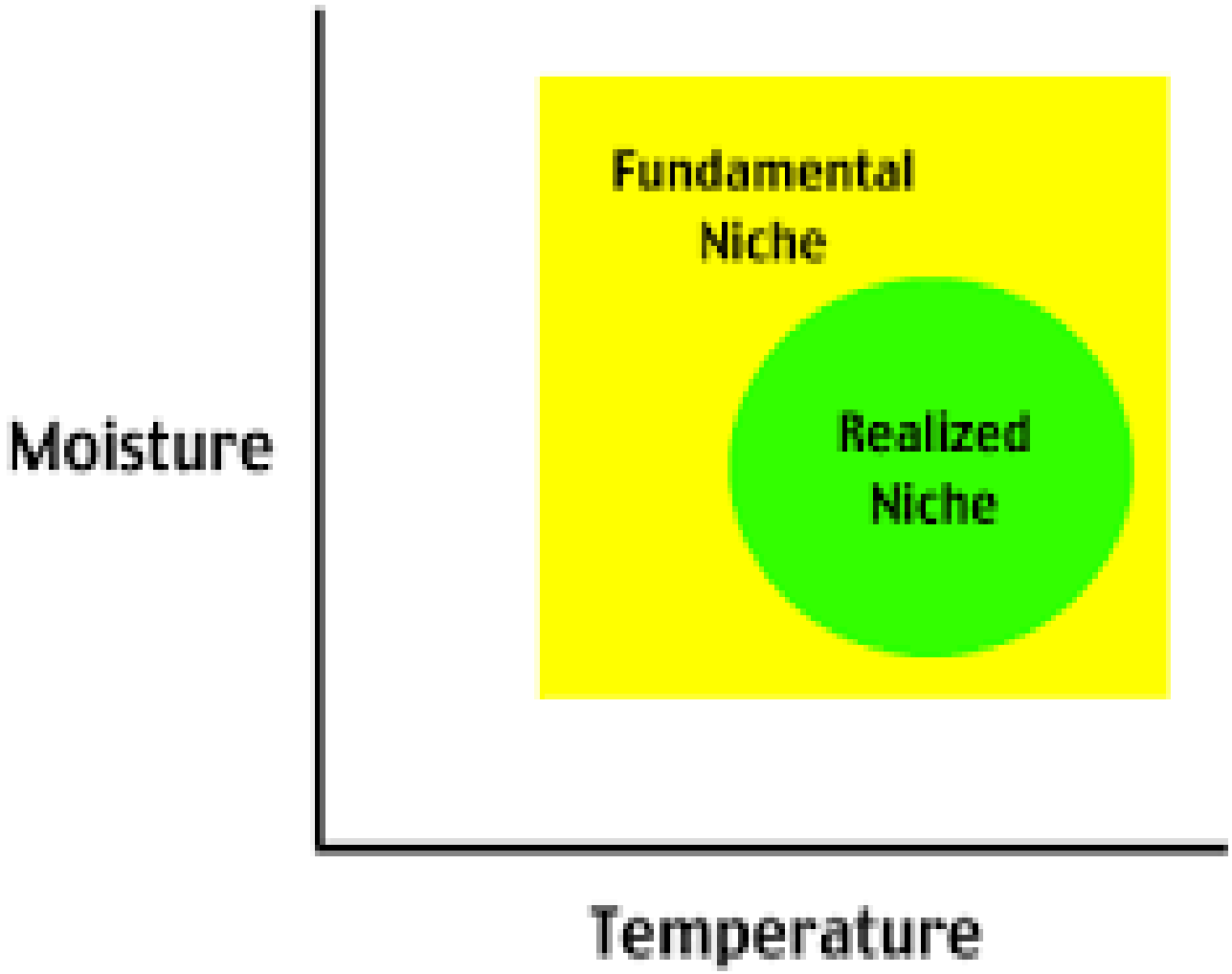
- Within a habitat multiple species compete to obtain the resources that are limited.
- **Ecological niche:** the unique set of resources used by a species, and its interactions with other members of its community
- **The competitive exclusion principle:** two species cannot occupy the exact same niche in a habitat.

Fundamental Niche:

- The fundamental niche refers to the **entire range of environmental conditions and resources that a species is capable of using** and the roles it can perform in the absence of any limiting factors or competitors.

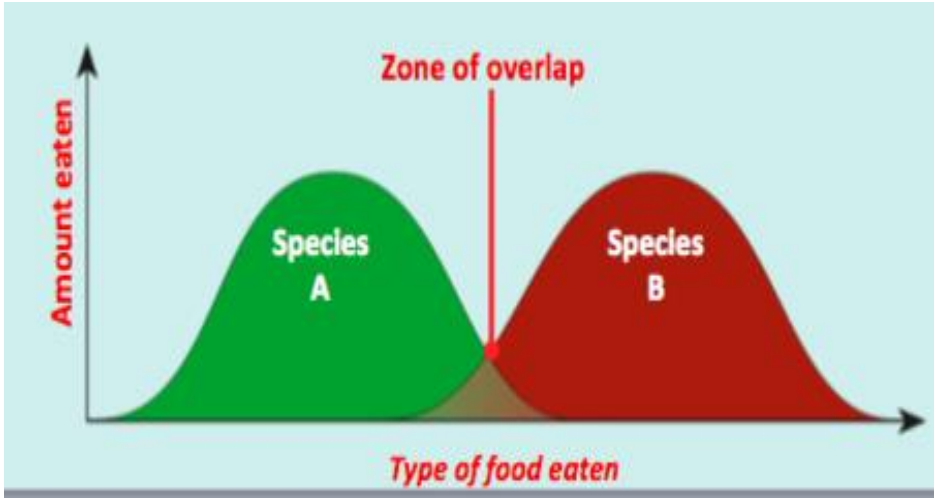
Realized Niche:

- The realized niche, is the resources a species uses under the constraints imposed by biotic interactions and other limiting factors.
- It represents the portion of the fundamental niche that a species effectively occupies in a particular ecosystem.

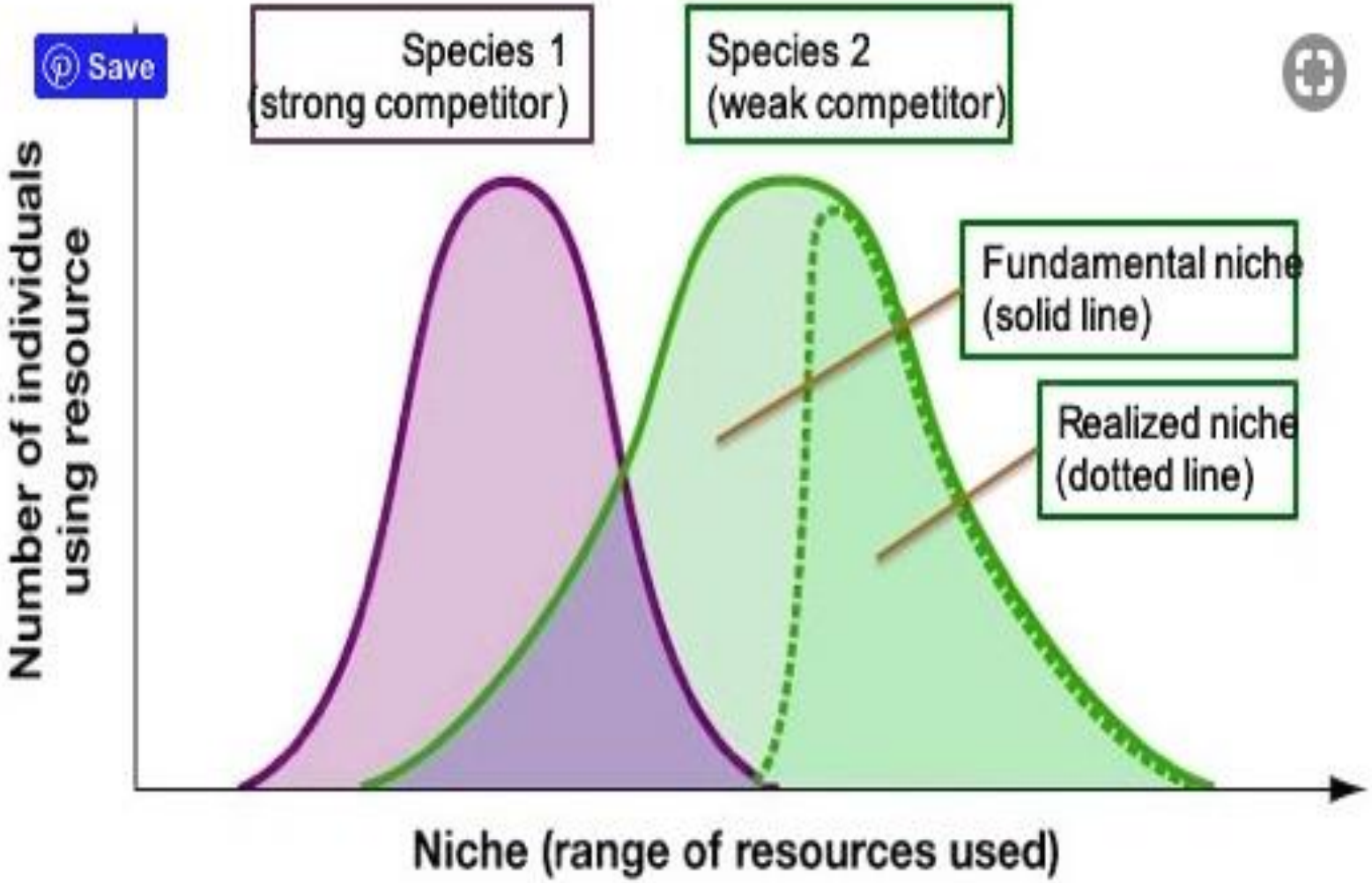

Fundamental
Niche
Realized
Niche
Moisture
Temperature

Niche overlap

- Two or more species in a community share similarities or occupy similar ecological roles.
- Niche overlap can occur in various aspects including resource utilization, habitat preferences, and other ecological requirements.



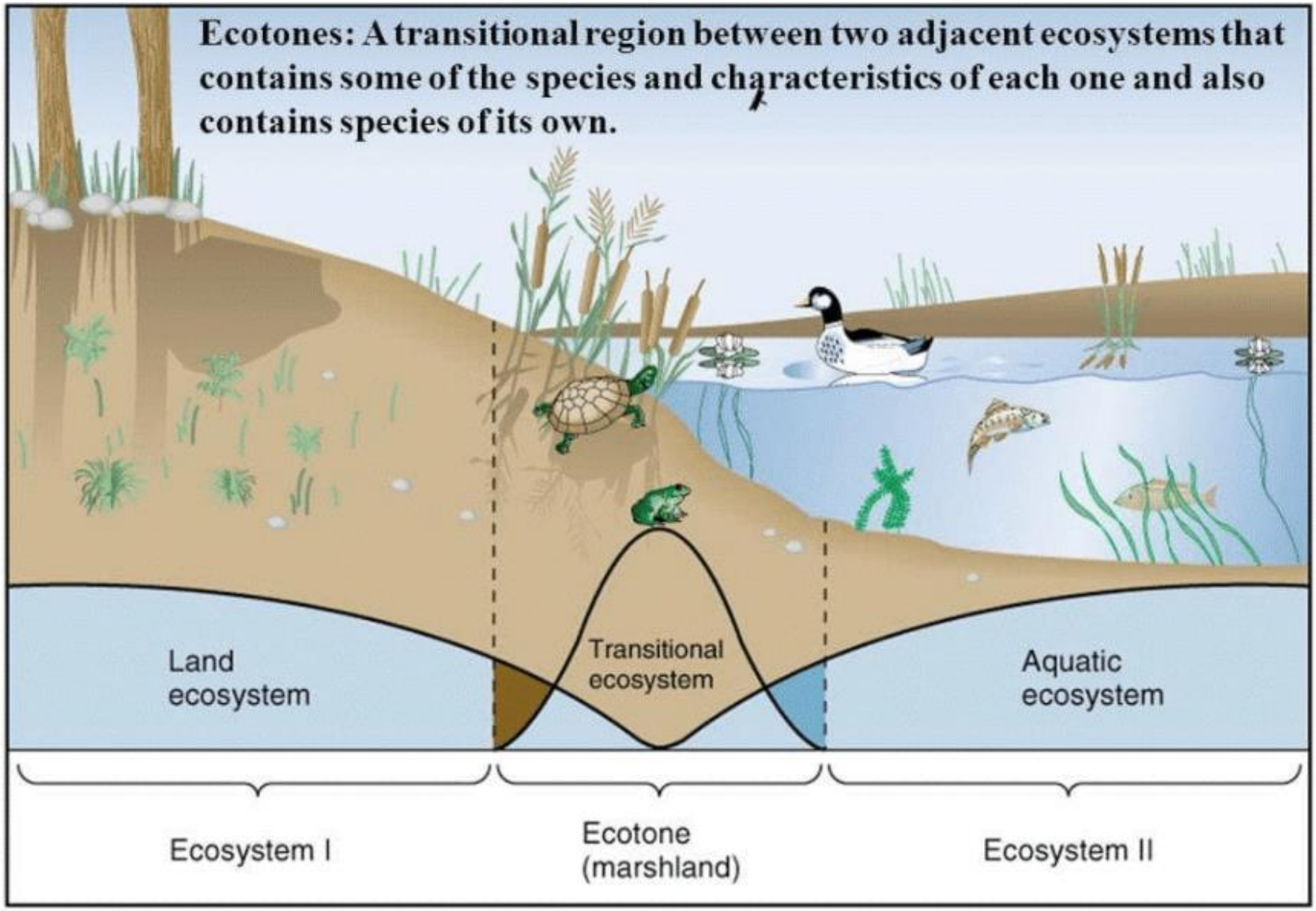
Resourse partitioning



Ecological compression

- **Niche compression**: ecological niches of different species become more similar due to environmental changes or competition.
- This can lead to an overlap in resource use and increased competition, potentially affecting the abundance and distribution of species within a community.

Community gradient and boundary



Edge effect

- **Edge effect (Odum 1958)** - changes in population or community structures occur at the boundary of two habitats (ecotone).
- Species richness and increased species diversity.
- The number of species and the population density of some of the species in the ecotone is much greater than either community.
- Species that occurs at edge for reproduction and survival is called **edge species.**

Keystone species (Robert Paine, 1966)

- Have a large impact on their ecosystem despite their low abundance or biomass.
- Vital for maintaining the balance of the ecosystem by limiting the abundance of other species.
- Their removal can lead to significant changes in the ecosystem, often causing a decline in biodiversity.
- **Example:** in a marine ecosystem, sea otters are control the population of sea urchins, which, could overgraze kelp beds and disrupt the entire ecosystem.

- Pisaster (statfish) a keystone species feed on intertidal organims.

Reference

- Environmental Biology by Matthew R. Fisher