AP ENVIRONMENTAL SCIENCE

UNIT 1

The Living World: Ecosystems

TOPIC 1.1

Introduction to Ecosystems

Required Course Content

ENDURING UNDERSTANDING

ERT-1

Ecosystems are the result of biotic and abiotic interactions.

LEARNING OBJECTIVE

ERT-1.A

Explain how the availability of resources influences species interactions.

ESSENTIAL KNOWLEDGE

ERT-1.A.1

In a predator-prey relationship, the predator is an organism that eats another organism (the prey).

ERT-1.A.2

Symbiosis is a close and long-term interaction between two species in an ecosystem. Types of symbiosis include mutualism, commensalism, and parasitism.

ERT-1.A.3

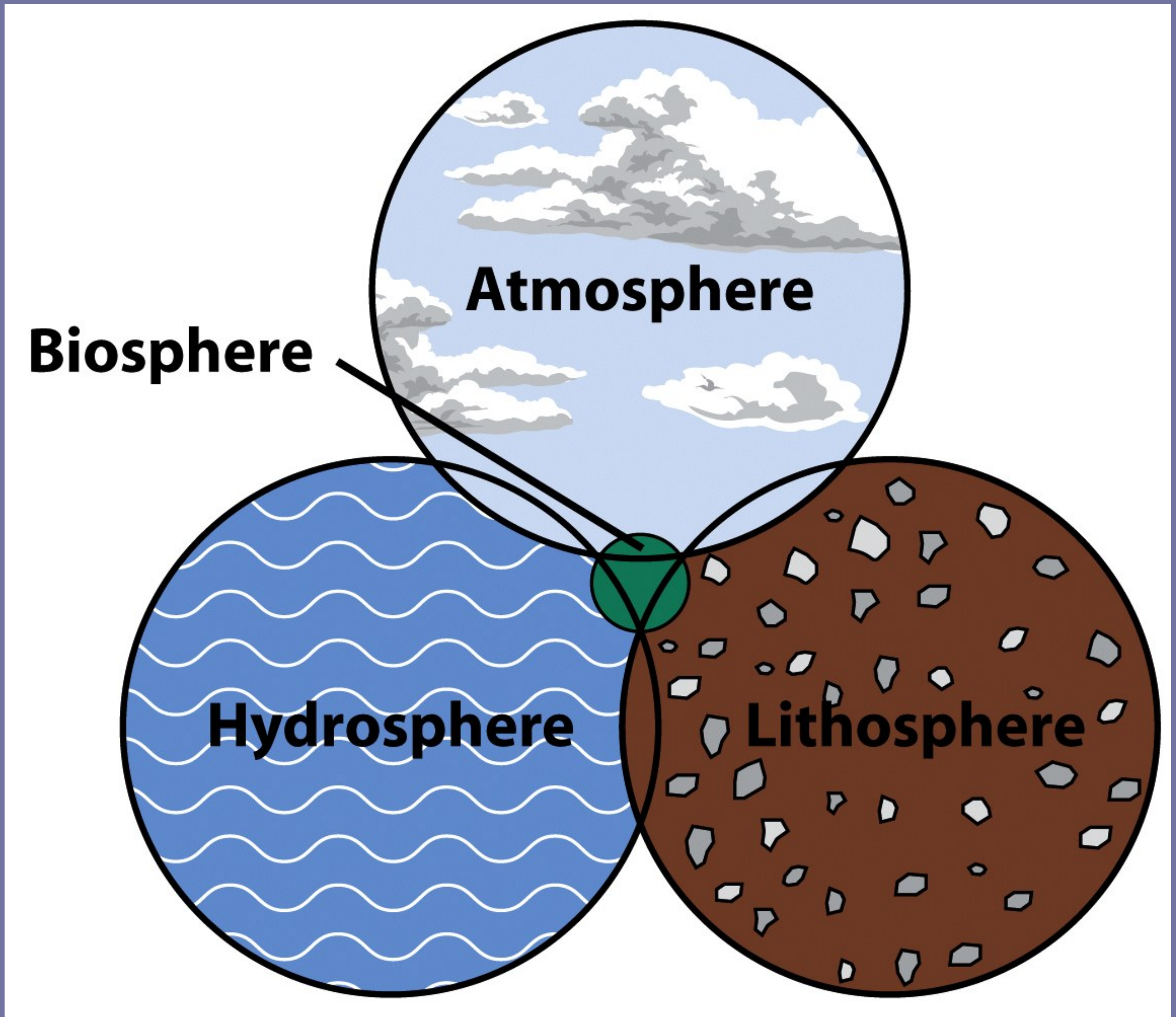
Competition can occur within or between species in an ecosystem where there are limited resources. Resource partitioning—using the resources in different ways, places, or at different times—can reduce the negative impact of competition on survival.

Ecology

- **Ecology**
  - **"eco" house & "logy" study of**
  - The study of interactions among and between organisms in their abiotic environment
- **Biotic** - living environment
  - Includes all organisms
- **Abiotic** - non living or physical environment
  - Includes living space, sunlight, soil, precipitation, etc.

Ecology

- Biosphere includes:
  - Atmosphere - gaseous envelope surrounding earth
  - Hydrosphere - earth's supply of water
  - Lithosphere - soil and rock of the earth's crust



Basic Characteristics of Ecosystems

- Ecosystems have several fundamental characteristics

- **1.Structure**
  - Made up of two major parts; ***living*** (ecological community)and ***non living*** (physical chemical enviro)

Basic Characteristics of Ecosystems

- **2. Processes**
  - ***Cycling of chemical elements*** and ***Flow of energy***

Basic Characteristics of Ecosystems

- **3. Change**
  - Undergo development through ***Succession***

Basic Characteristics of Ecosystems

- **4. Services**
  - Ecosystem services are things that our biosphere provides, ex. Provides oxygen, cleans air

Table 4.1 Ecosystem Services

Ecosystem	*Services Provided by Ecosystem*
Forests	Purify air and water; produce and maintain soil; absorb carbon dioxide (carbon storage); provide wildlife habitat; provide humans with wood and recreation
Freshwater systems (rivers and streams, lakes, and groundwater)	Moderate water flow and mitigate floods; dilute and remove pollutants; provide wildlife habitat; provide humans with drinking and irrigation water, food, transportation corridors, electricity, and recreation
Grasslands	Purify air and water; produce and maintain soil; absorb carbon dioxide (carbon storage); provide wildlife habitat; provide humans with livestock and recreation
Coasts	Provide a buffer against storms; dilute and remove pollutants; provide wildlife habitat, including food and shelter for young marine species; provide humans with food, harbors, transportation routes, and recreation
Sustainable agricultural ecosystems*	Produce and maintain soil; absorb carbon dioxide (carbon storage); provide wildlife habitat for birds, insect pollinators, and soil organisms; provide humans with food and fiber crops

*Sustainable agricultural ecosystems are human-made and therefore inherently different from other ecosystems. Sustainable agriculture is discussed in Chapter 19.
(Adapted from *Climate Change Impacts in the United States*)

1.1

Introduction to Ecosystems

What is an ecosystem?

- An ecosystem is a community of **living organisms** in conjunction with the **non-living components** of their environment, **interacting as a system**.
- “Ecosystems are the result of BIOTIC and ABIOTIC interactions” (ERT-1)

Q: *Based on the definition above, which of the following might be considered an ecosystem interaction? Why?*

Leopard seals hunting penguins on an ice floe

The amount of sunlight available to producers on a savanna

Precipitation in a temperate forest

Bats, salamanders and spiders in a cave

1.1

Biotic and Abiotic Components of Ecosystems

- *Living* (biotic) things, such as…
  - -Producers (plants, photosynthetic algae, phytoplankton, etc.)
  - -Herbivores
  - -Carnivores
  - -Omnivores
  - -Detritivores
  - -Soil

- *Non-living* (abiotic) factors, such as…
  - -Sunlight
  - -Temperature
  - -Precipitation
  - -Moisture/water
  - -pH
  - -Soil

Why is soil in both the biotic AND abiotic lists?

Community Ecology

Main Idea: Species living in close proximity will inevitably interact with each

Main Idea: These interactions can be positive, negative or have little to no effect.

COMMUNITY INTERACTIONS

- A ***community*** is a group of species living close together and interacting
- Some of these interactions affect the survival and reproduction of the two species interacting

Symbiosis

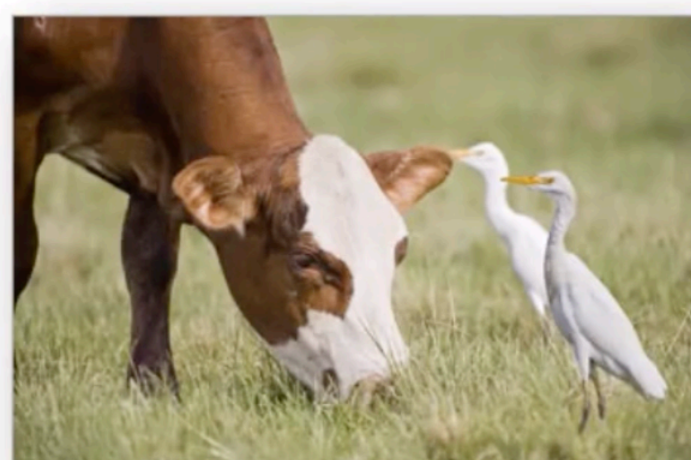
Note: Some define symbiosis narrowly as mutualism however the authors of your text use a broader definition to include *all* direct interactions between species

1.1

Symbiosis

What is symbiosis?

- A close, long-term interaction between two species in an ecosystem.
- From the Greek "sym-" meaning **together**, and "bio-" meaning **living**; so, symbiosis is **"living together"**
- Ecosystems are the result of BIOTIC and ABIOTIC interactions (ERT-1)



1.1

The Big Picture

- Interactions in ecosystems can include…
  - -Predator-prey relationships
  - -Symbiotic interactions, such as
    - Mutualism
    - Commensalism
    - Parasitism
  - -Competition
    - Between different species
    - Within a single species

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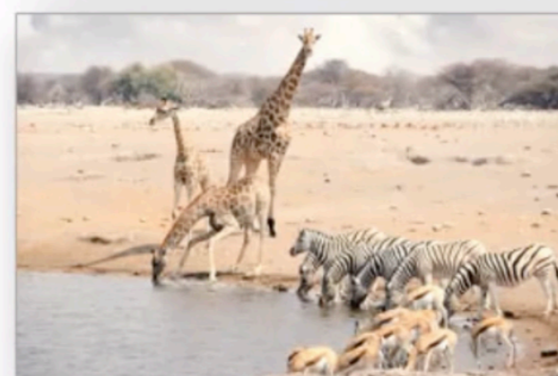

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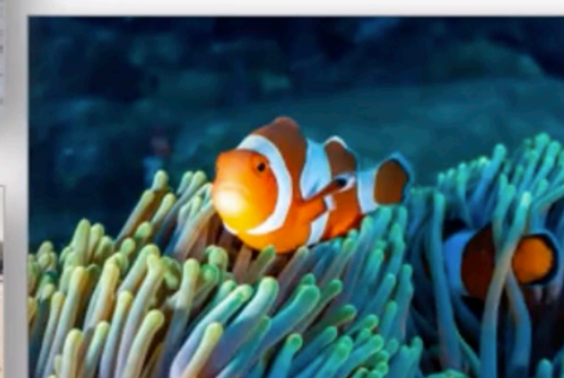

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- As we consider each of these interactions, try to identify the biotic and/or abiotic resources in each, and *explain how the availability of resources influences the interaction* (that's the Learning Objective!)

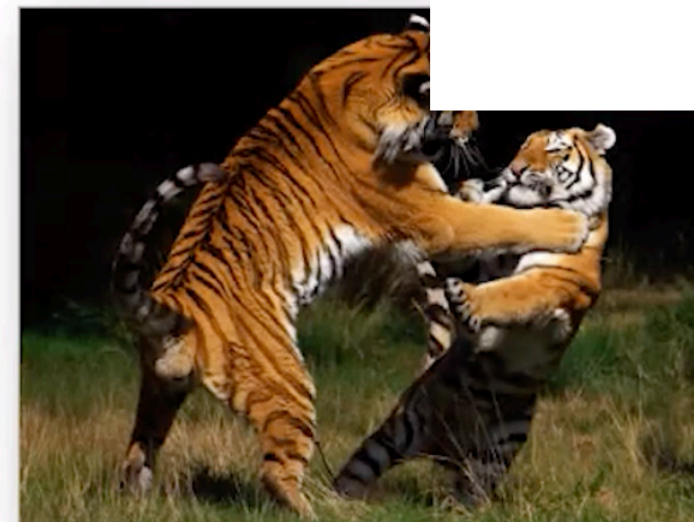
1.1

The Big Picture

- Competitive interactions include…

  -Competition for limiting resources between DIFFERENT species
    - Resources may be biotic or abiotic
    - Results in resource partitioning

  -Competition for limiting resources between members of the SAME species
    - Again, resources may biotic or abiotic
    - Results in increased overall species fitness



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COMMUNITY INTERACTIONS

Competition (-/-)

- Limited resources cause species to compete for them and this lowers the fitness of both species

Competitive Exclusion

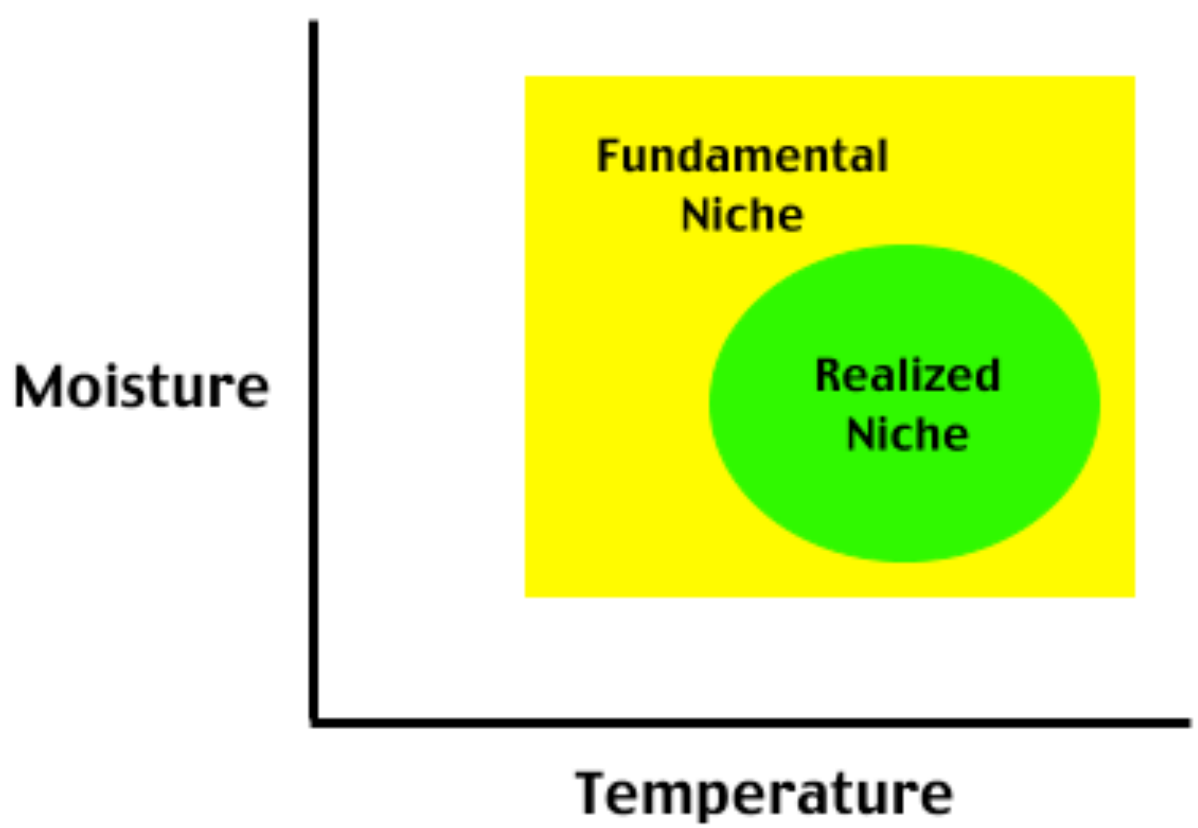
- In 1934, Russian Ecologist G.F. Gause concluded that two competing species could not coexist permanently in the same place
- One species will inevitably have a slight reproductive advantage and eventually eliminate the inferior competitor...***competitive exclusion principle***

Ecological Niches

- Sum use a species resources both abiotic and biotic in their environment…***niche (the role an organism plays)***
- *Competitive exclusion principle* rephrased...no two species can occupy the same niche

Ecological Niches

- Since the two species can not occupy same niche one will use slightly different resources their by differentiating or partitioning the niche
- This resource partitioning allows two species to live in very similar niches



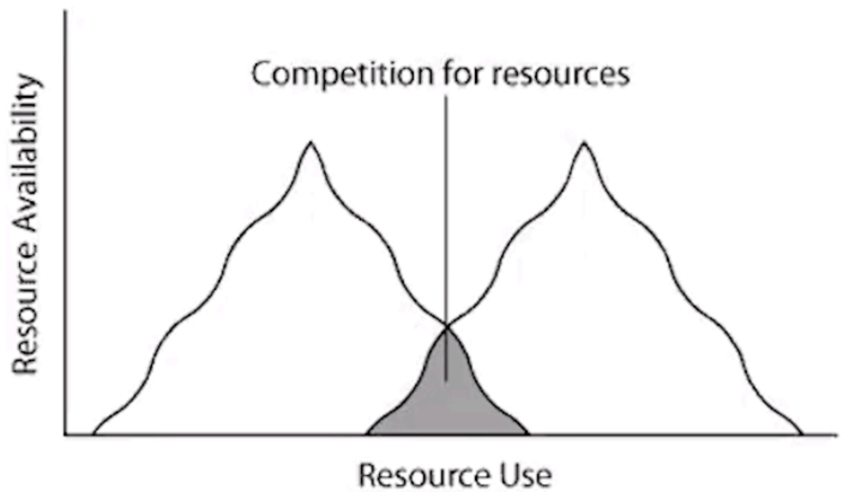
Resource Partitioning

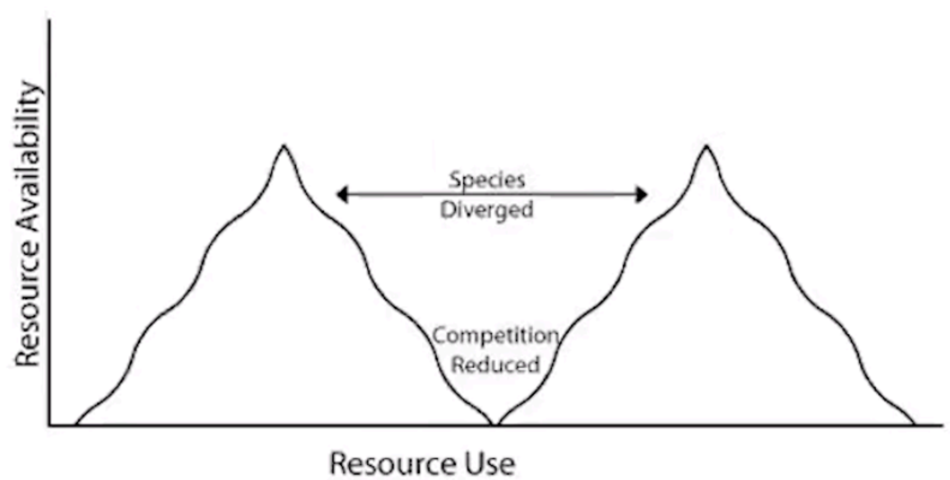
Note: species can partition their niches by space seen here or by time...think diurnal vs nocturnal

1.1

Resource Partitioning

Warbler species use different parts of their preferred habitat to avoid competition





When species compete over a limiting resource, they will eventually limit their use of that resource to avoid competition

1.1

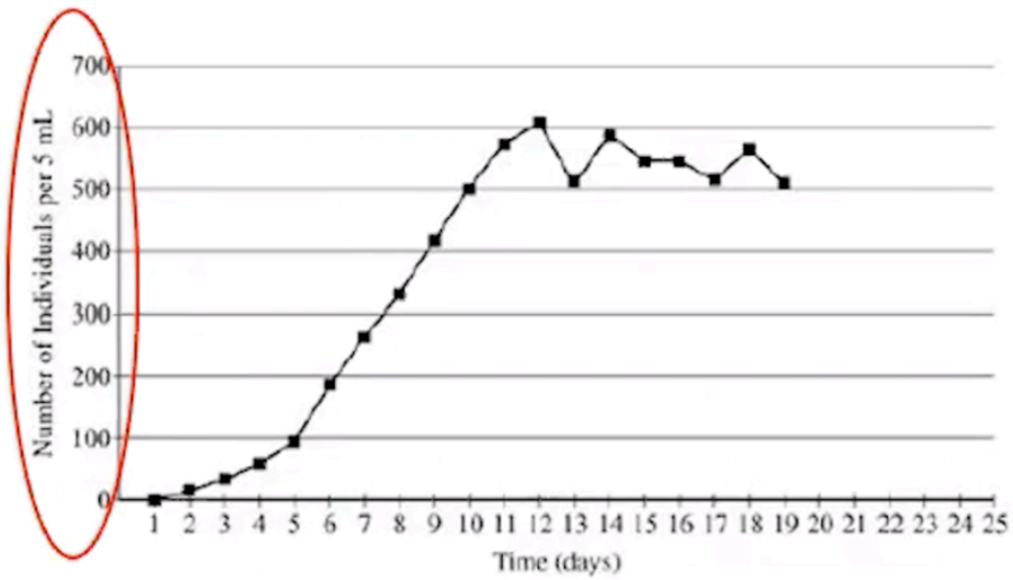


Figure 1. Population of *P. aurelia* cultured alone

P. *aurelia* alone

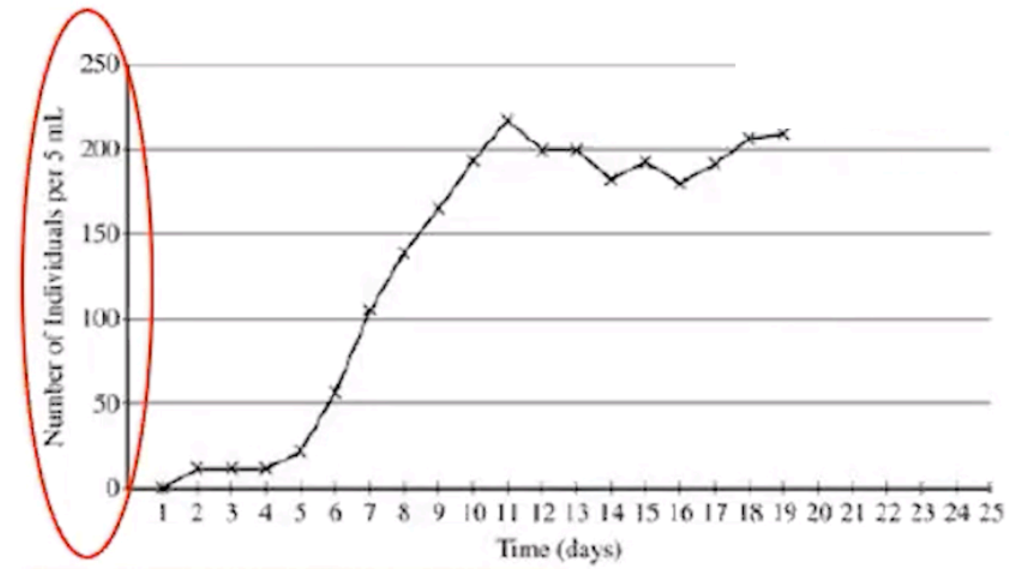
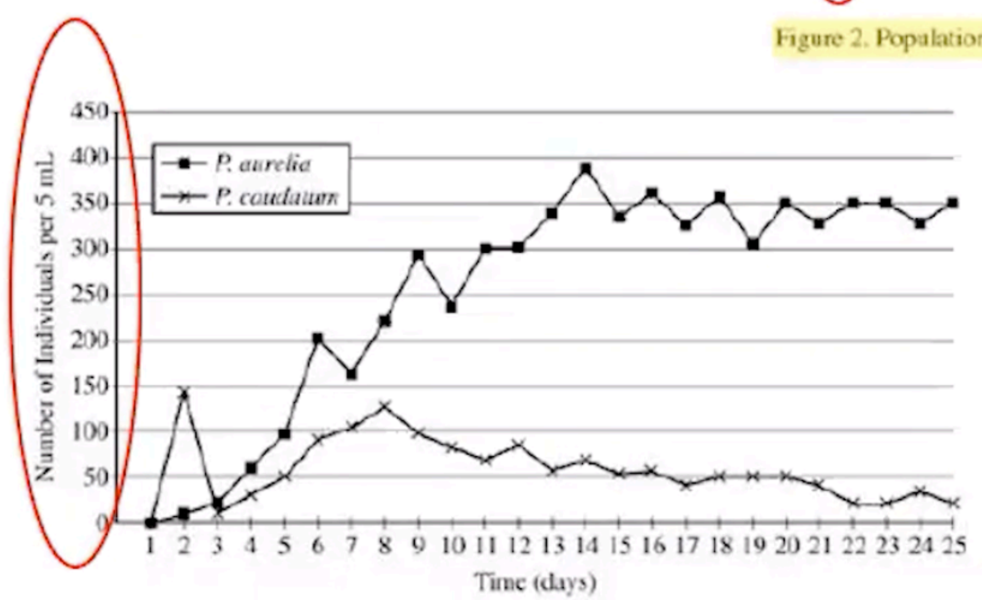


Figure 2. Population of *P. caudatum* cultured alone

P. *caudatum* alone



Predation (+/-)

- Natural selection has fine tuned both predator and prey with remarkable adaptations.
  - **Predators**:
    - acute senses, speed, agility, claws, teeth, fangs, stingers and venoms
  - **Prey**:
    - behavioral defenses; hiding, fleeing, forming herds or schools, alarm calls
    - morphological & physiological defenses; camouflage (cryptic coloration), warning colors (aposematic colorations), spines, poisons, toxins, chemicals, mimicry

Can you think of an example of each?

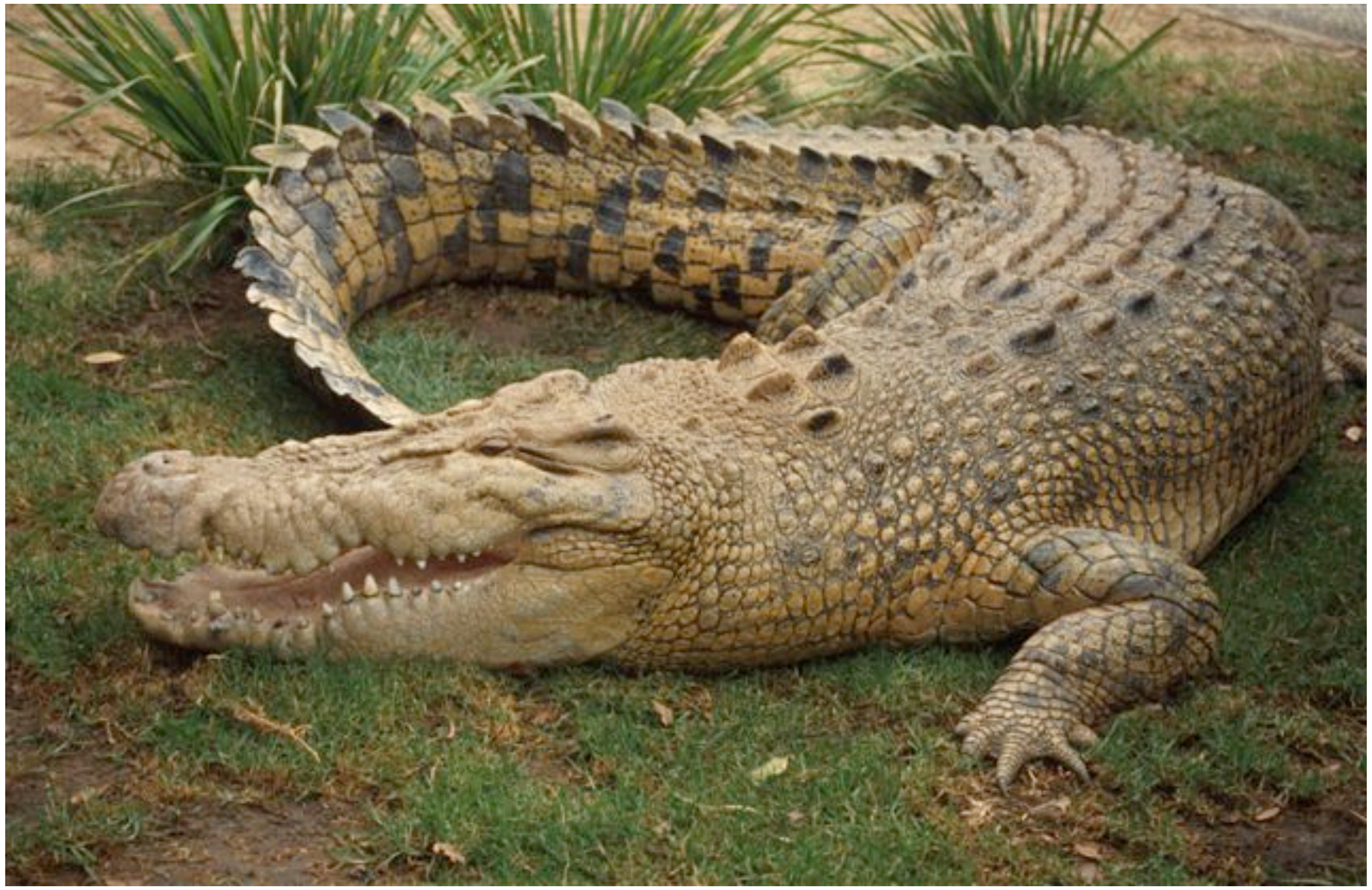
Smell

Hearing

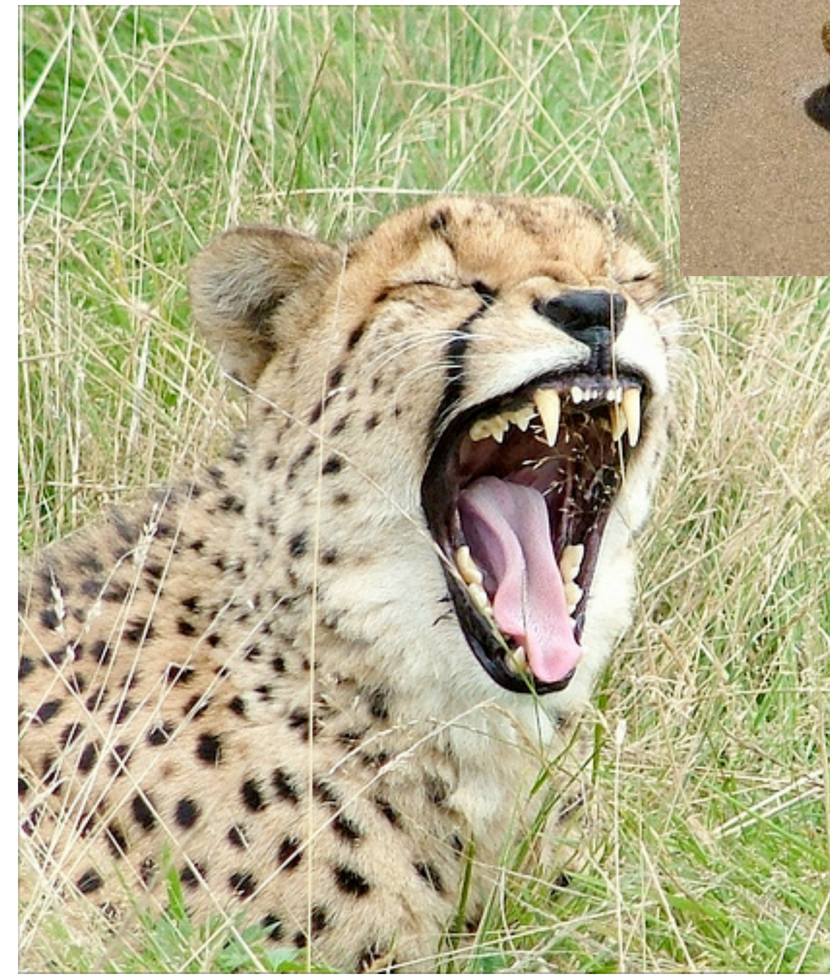
Vision

Taste

Touch

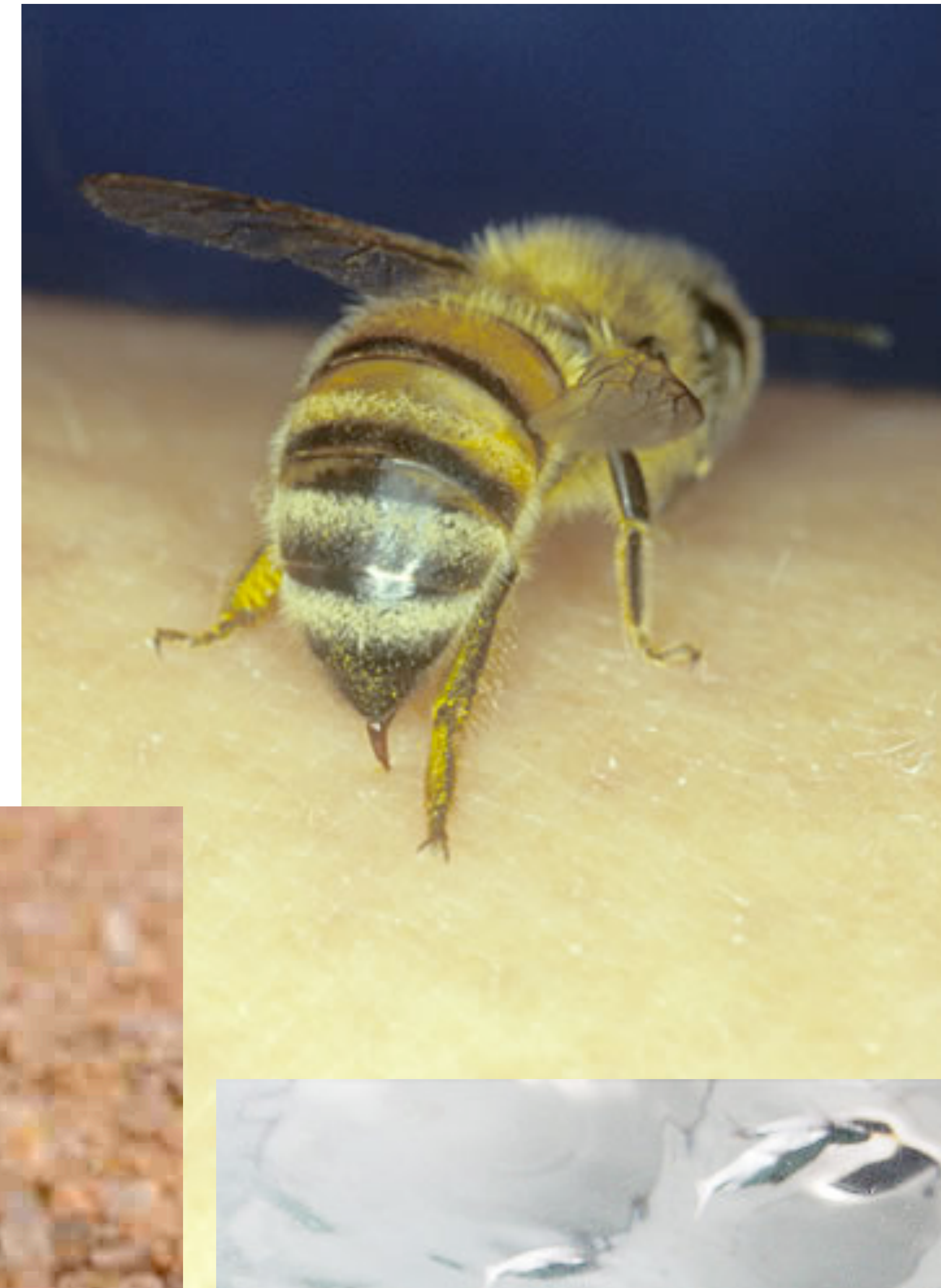


Claws, Teeth & Fangs

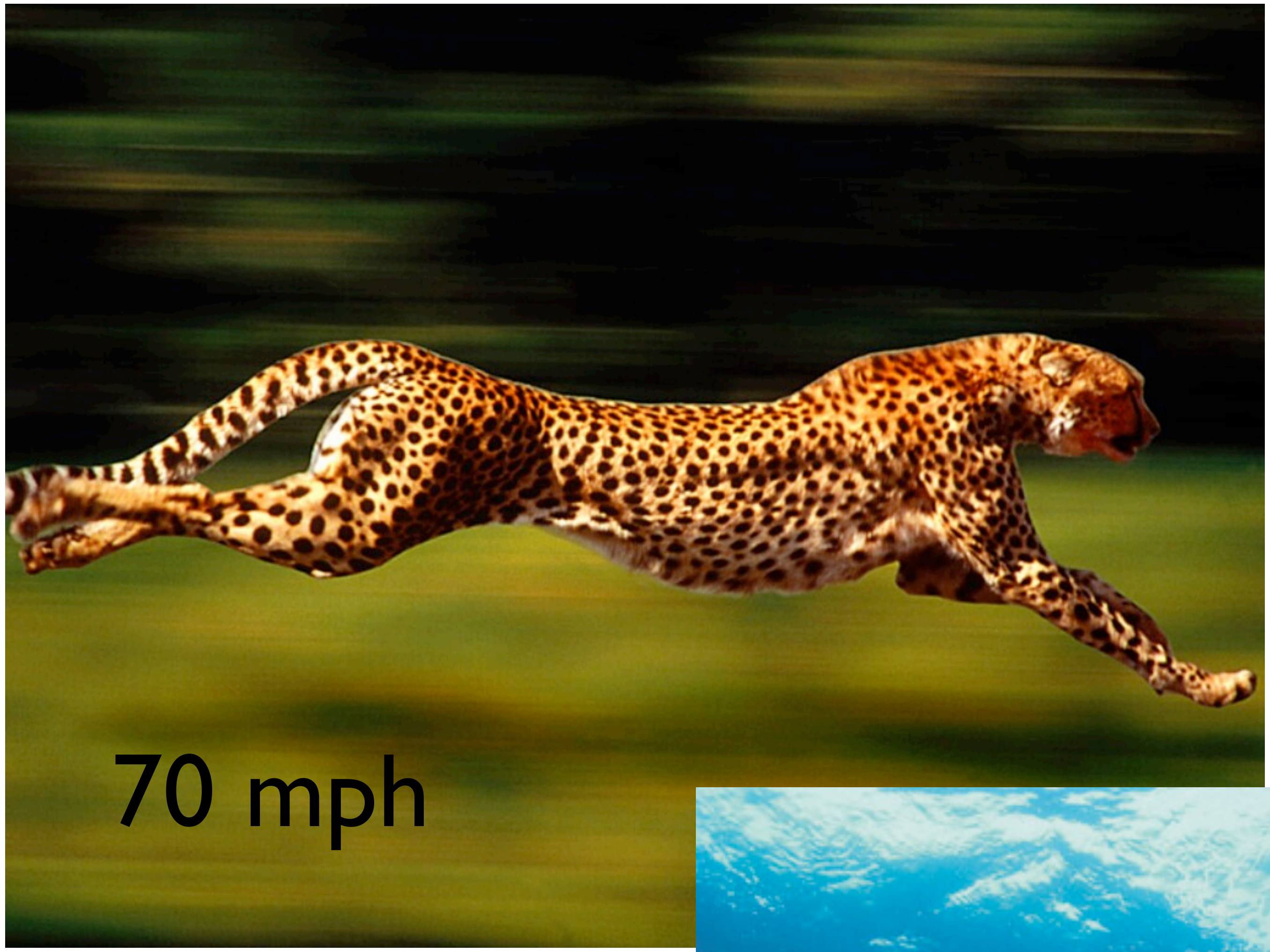



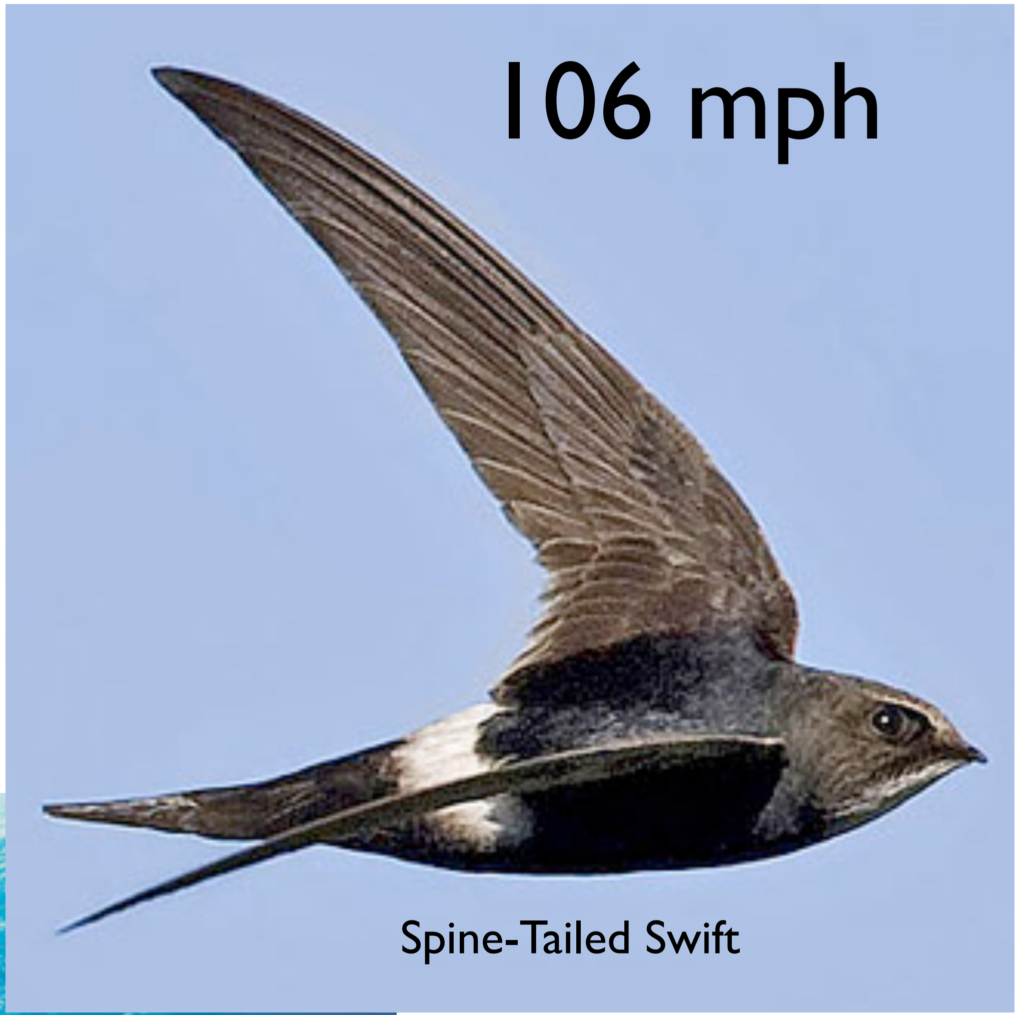


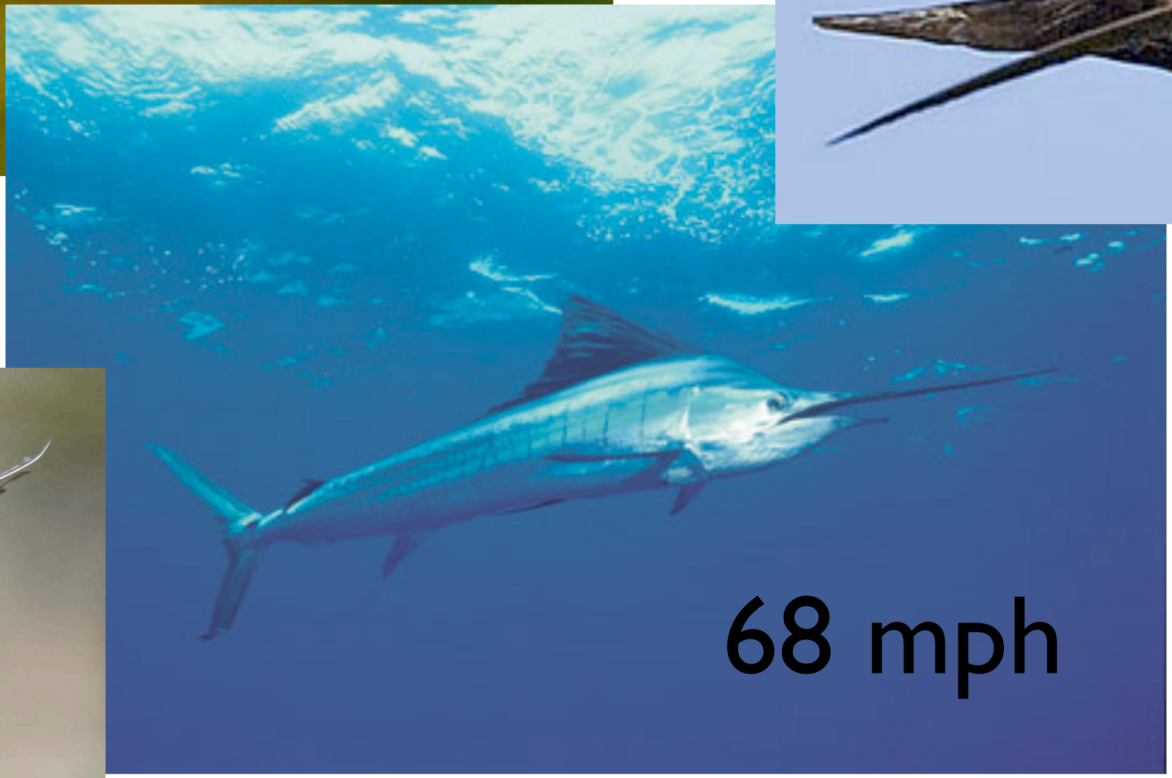
Stingers

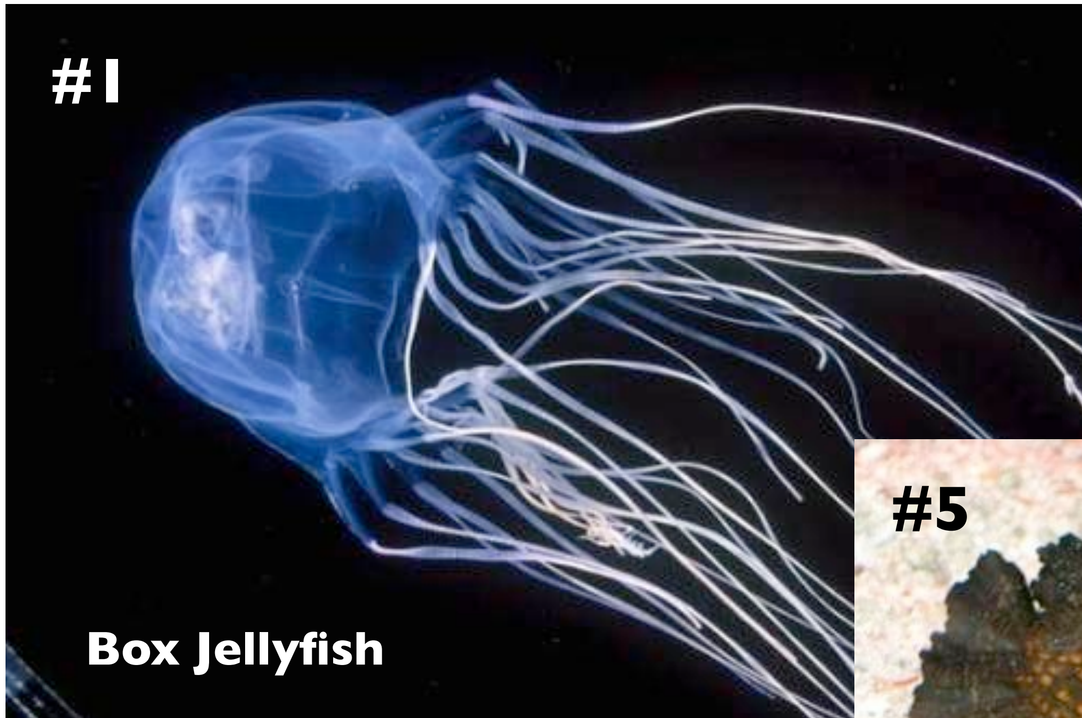
Speed & Agility







Venoms (Top 5?)


#1
Box Jellyfish

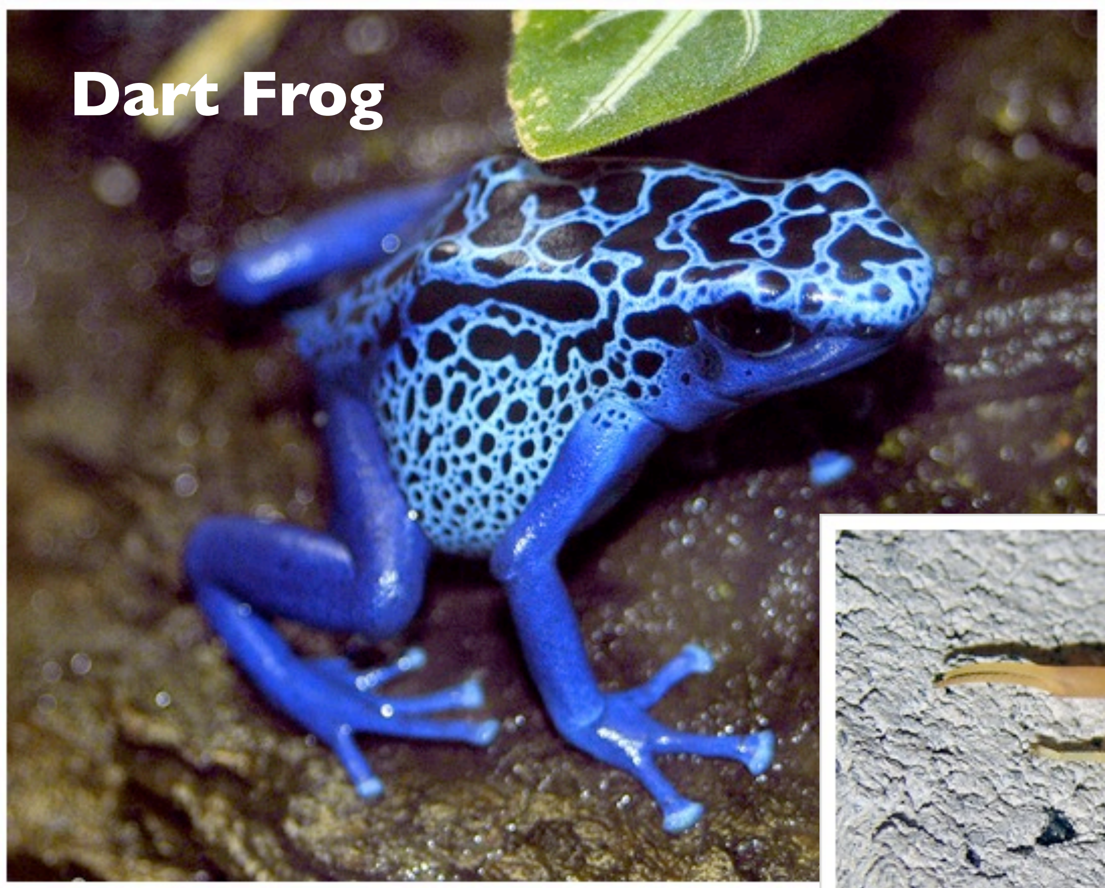

#3
Taipan

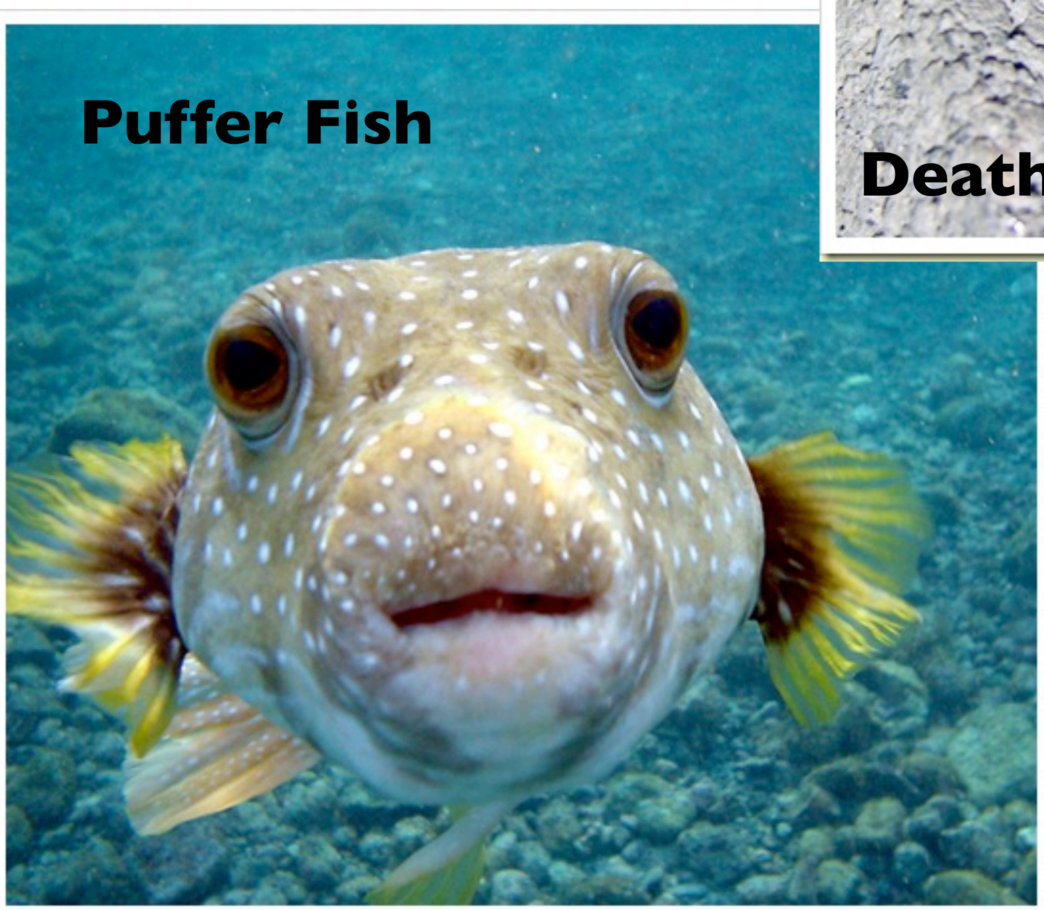

#5
Stonefish


#2
Brazilian Wandering Spider


#4
Blue Ringed Octopi

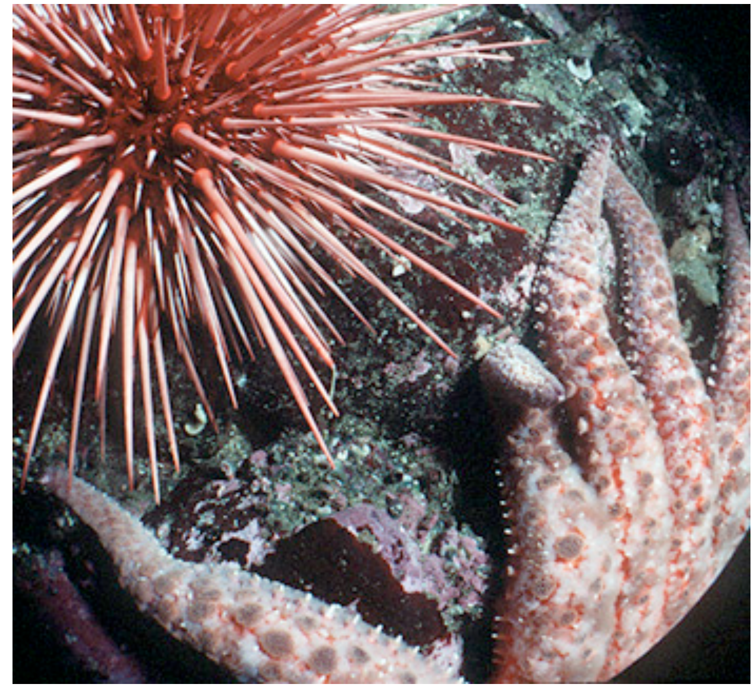
Should have made the list?





Most Poisonous Plants

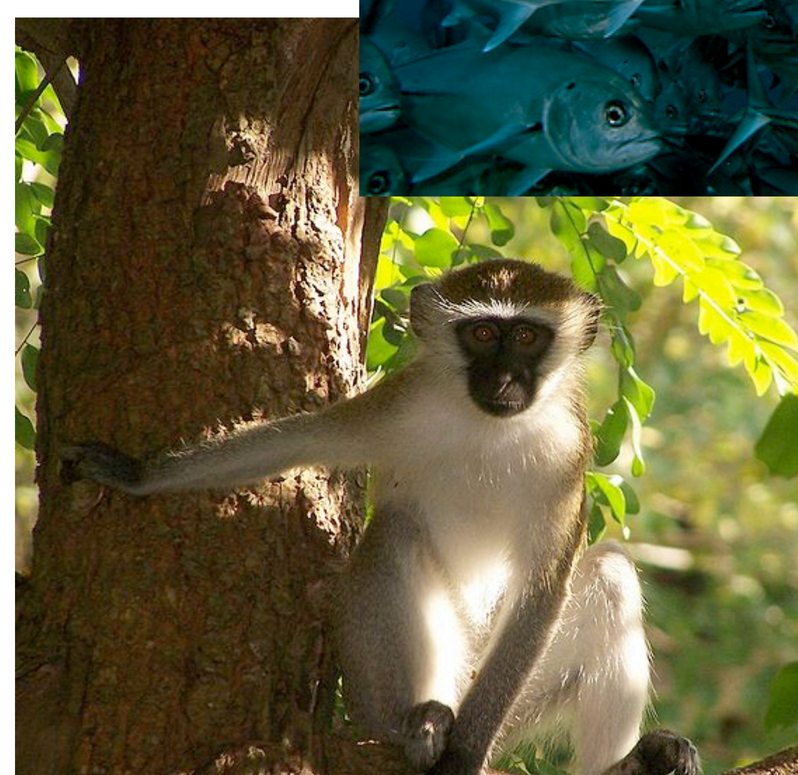
Spines



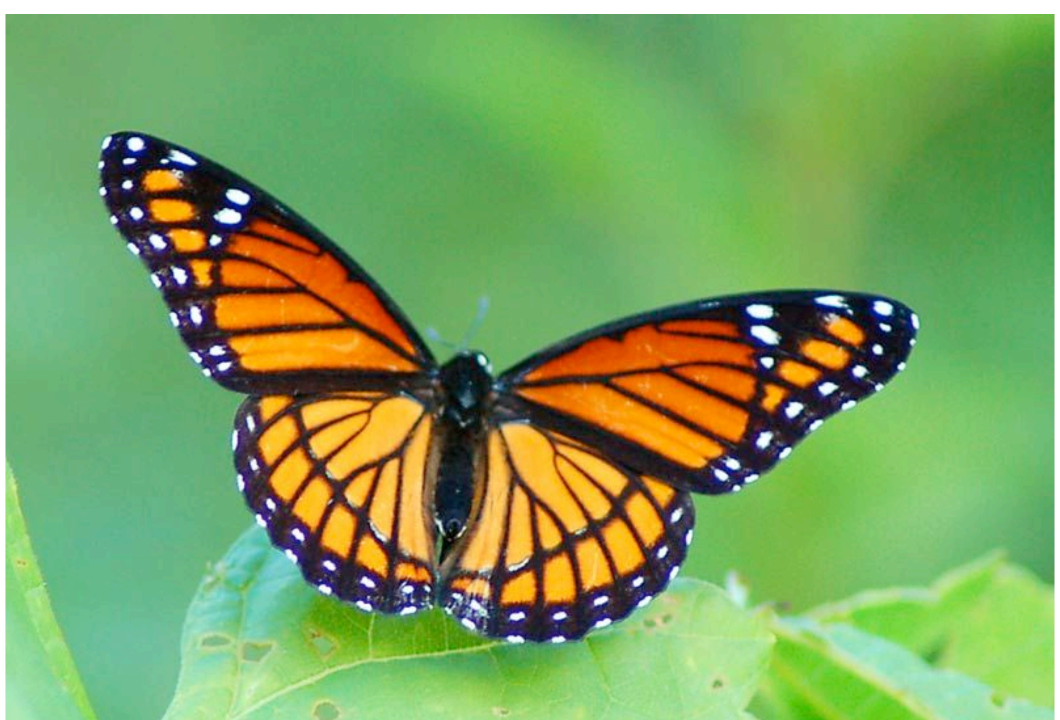
Thorns

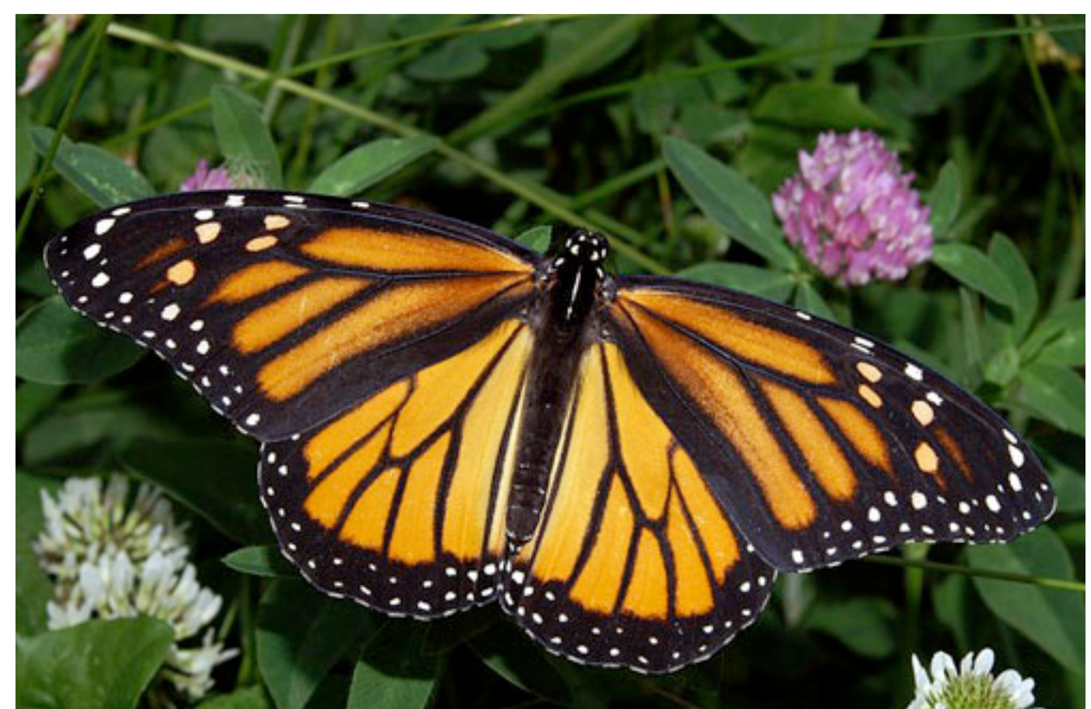
Alarm Calls, Herds & Schools



- **Batesian Mimicry:** a harmless/palatable species copying a harmful/unpalatable species

- **Mullerian Mimicry:** two or more harmful/unpalatable species resembling each other





Herbivory (+/-)

- Natural selection has fine tuned herbivores (and the plants) with remarkable adaptations.
  - **Herbivores**:
    - insects can detect toxic chemicals with their feet
    - mammals
      - use smell to assess plants,
      - mammals also have specialized teeth (molars) for grinding plant matter,
      - mammals have specialized digestive tracts to breakdown cellulose
  - **Plants**:
    - Spines and Thorns
    - Toxins: strychnine, nicotine, selenium, peppermint, cloves,

Parasitism (+/-)

- *Parasites* are organisms that derive nourishment from a host, the *host* is the organism that is harmed in the process.
  - Endoparasites feed/live within their host (tapeworms)
  - Ectoparasites feed/live on their host (ticks)

1.1

Parasitism

- ***Parasitism** is a relationship where one organism lives ON or INSIDE OF another. The other organism is called the HOST. The parasite receives a benefit (e.g. food/shelter, etc..) from the host, but the host is harmed by the relationship.*

- While parasites DO harm their hosts, they rarely cause the death of the host. This distinguishes parasitism from predation (predators HUNT and KILL their prey).

- Some examples of parasitism include…
  - Fleas/ticks on mammals
  - Intestinal tapeworms
  - Mosquitos biting warm-blooded animals
  - Malarial infections in humans

What is the advantage to the parasite in NOT killing the host organism?

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Lone Star ticks (*Amblyomma americanum*) are common in the South. They are aggressive and bite humans, causing many diseases

Mutualism (+/+)

- These interactions benefit both species involved.
- Many important mutualistic relationships exist in nature.
    - ***#1. Nitrogen Fixation (bacteria and plants-legumes)***
    - ***#2. Cellulose Digestion in Ruminants (herbivores and bacteria)***
    - *#3. Mycorrhizae (fungi and plants)*

1.1

Mutualism

- ***Mutualism*** *is a symbiotic relationship between two species where both receive a benefit that results in an increased chance of survival and reproduction*

- Mutualistic relationships are long-term, and both species have evolved traits over many generations that aid the relationship

- Some examples of mutualism include…
  - Ants and acacia trees
  - Lichens
  - Corals
  - Clownfish and sea anemones

Pollination is ALWAYS a mutualistic relationship!

Can you identify the resource each species is receiving in the relationships above? Can you identify if that resource is biotic or abiotic?

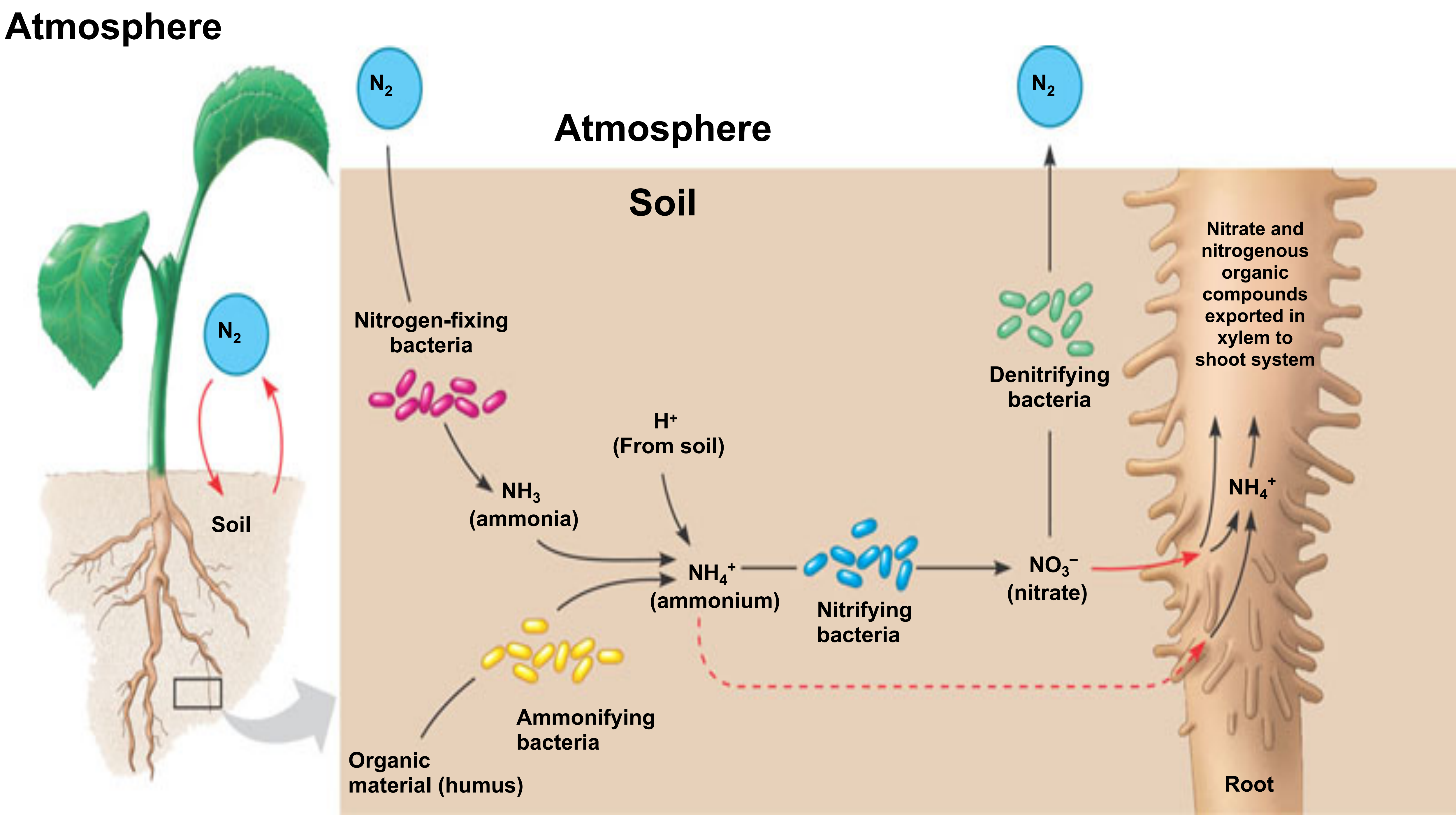
#1. Nitrogen Fixation (bacteria and plants-legumes)

An Introduction

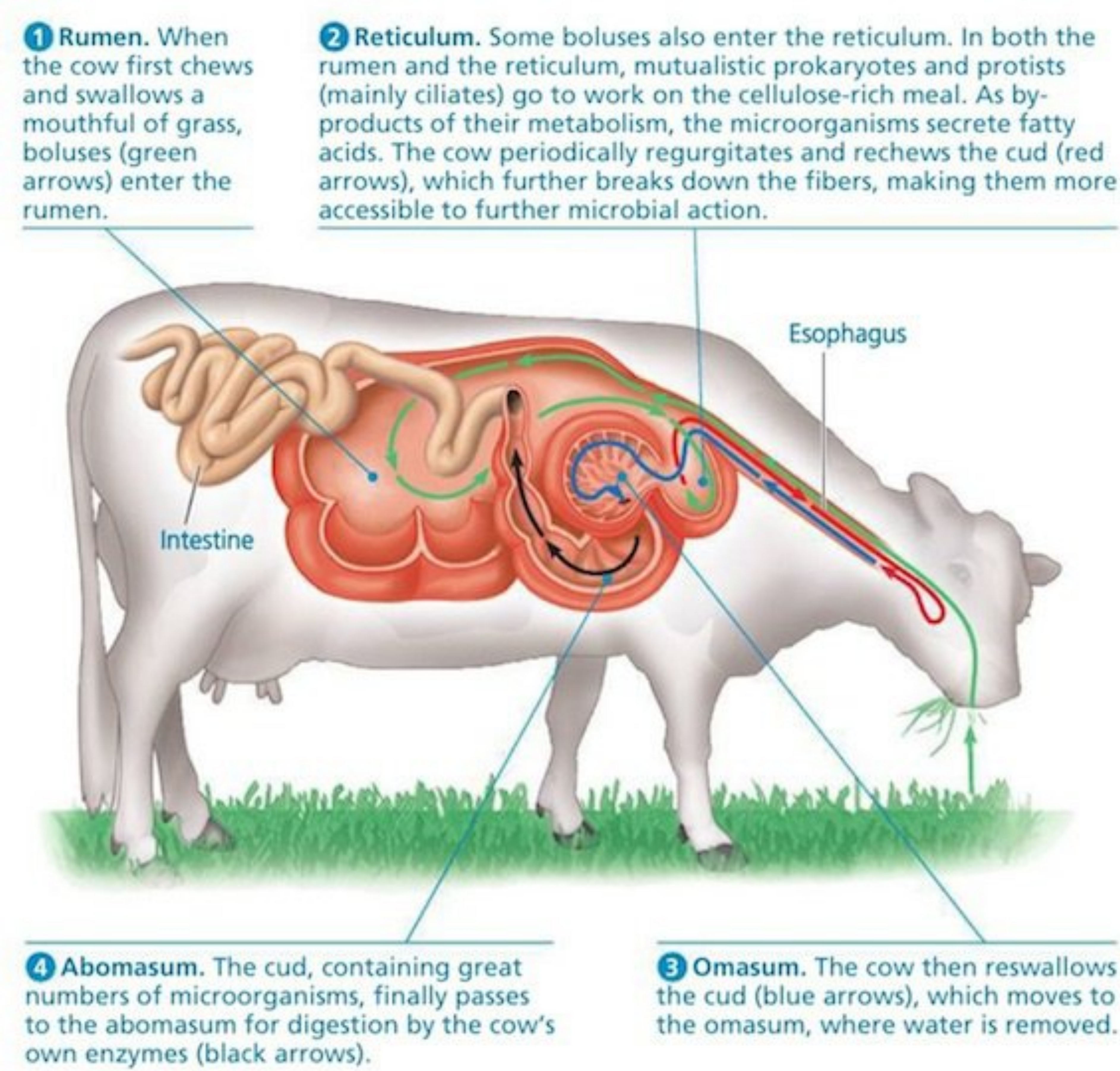
- Atmospheric nitrogen is abundant however it is biologically unavailable. Most organisms are unable to break the triple covalent bonds between nitrogen atoms.
- It is imperative that these bonds are broken because **"life" needs nitrogen atoms** to build amino acids and nucleotides.
- This reaction requires ***nitrogenase*** the enzyme cable of fixing nitrogen gas.
- This reaction is **energetically costly**.

#1. Nitrogen Fixation (bacteria and plants-legumes)

Overview



- ***#2. Cellulose Digestion in Ruminants (herbivores and bacteria)***



Overview

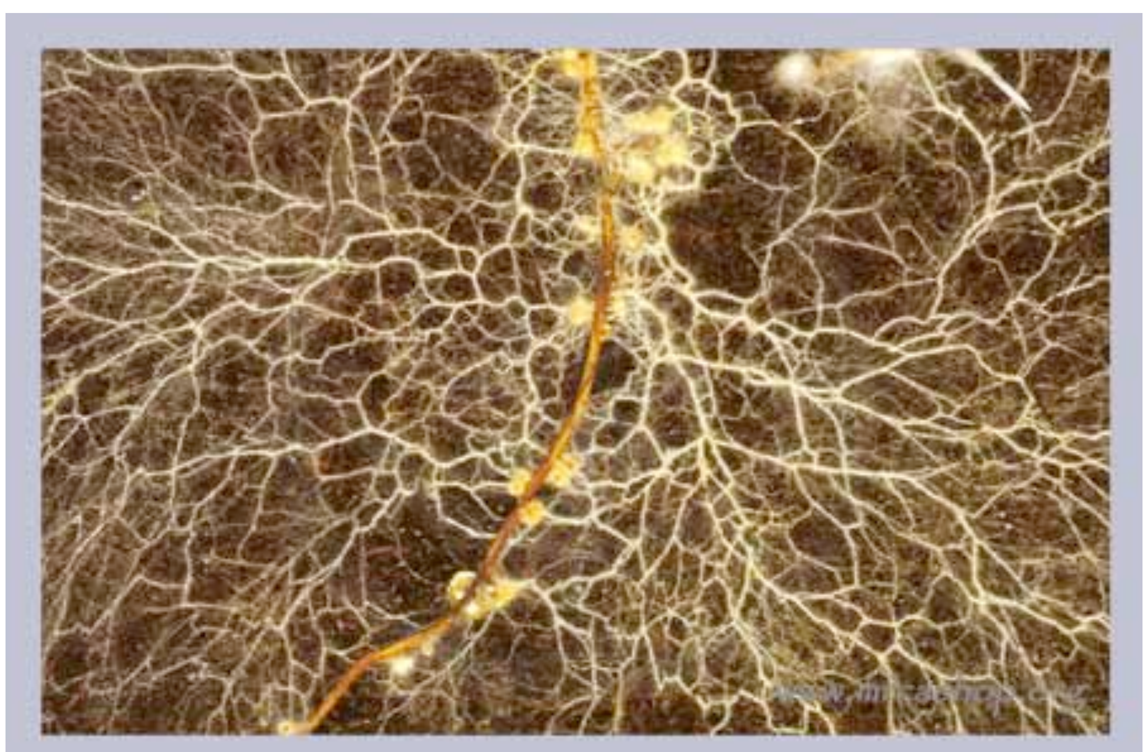
#3. Mycorrhizae (fungi and plants)

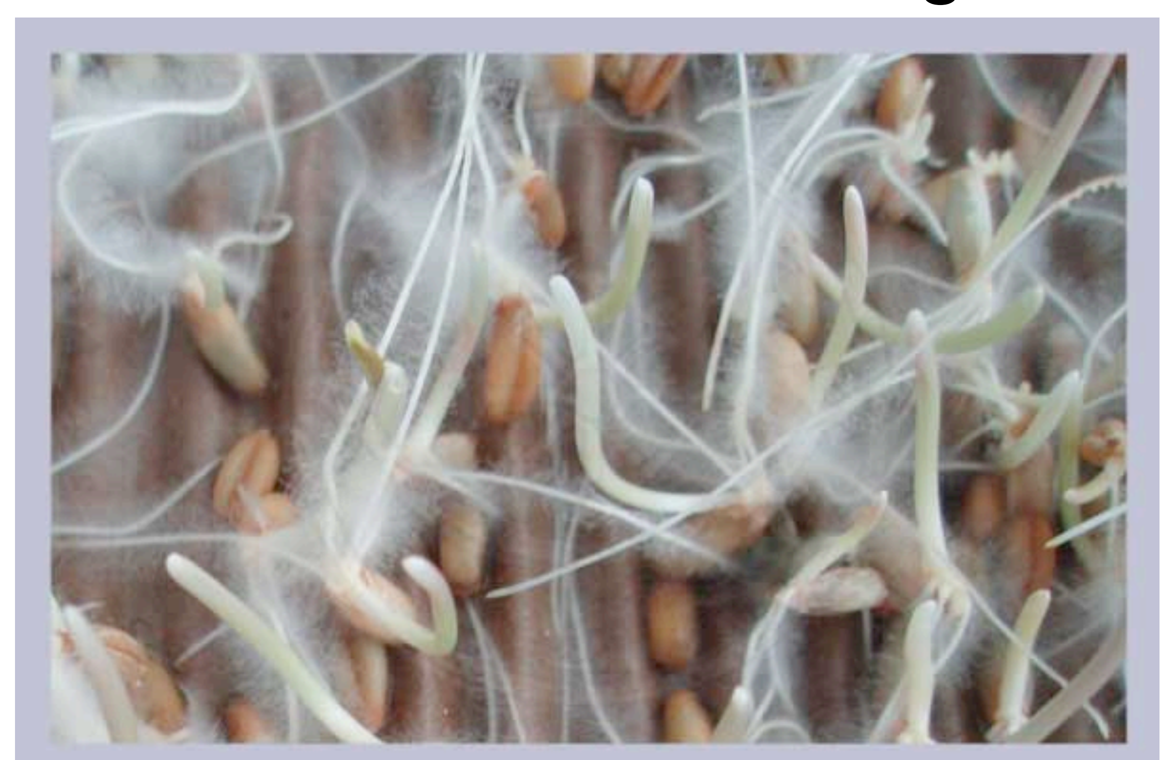
Overview

- This relationship is both *ancient* and *extensive*. Fossil evidence suggests that this relationship is over 400 million old and may have contributed to plants colonizing land. Furthermore this relationship is found in roughly 80% of all plant species.

- Plants (through photosynthesis) provide fungi a constant supply of sugar (food) while the fungi provides plants with increased water and mineral absorption (through their vast surface area and unique cell chemistry).

- Mycorrhizal plants are more resistant to disease, toxins and drought.





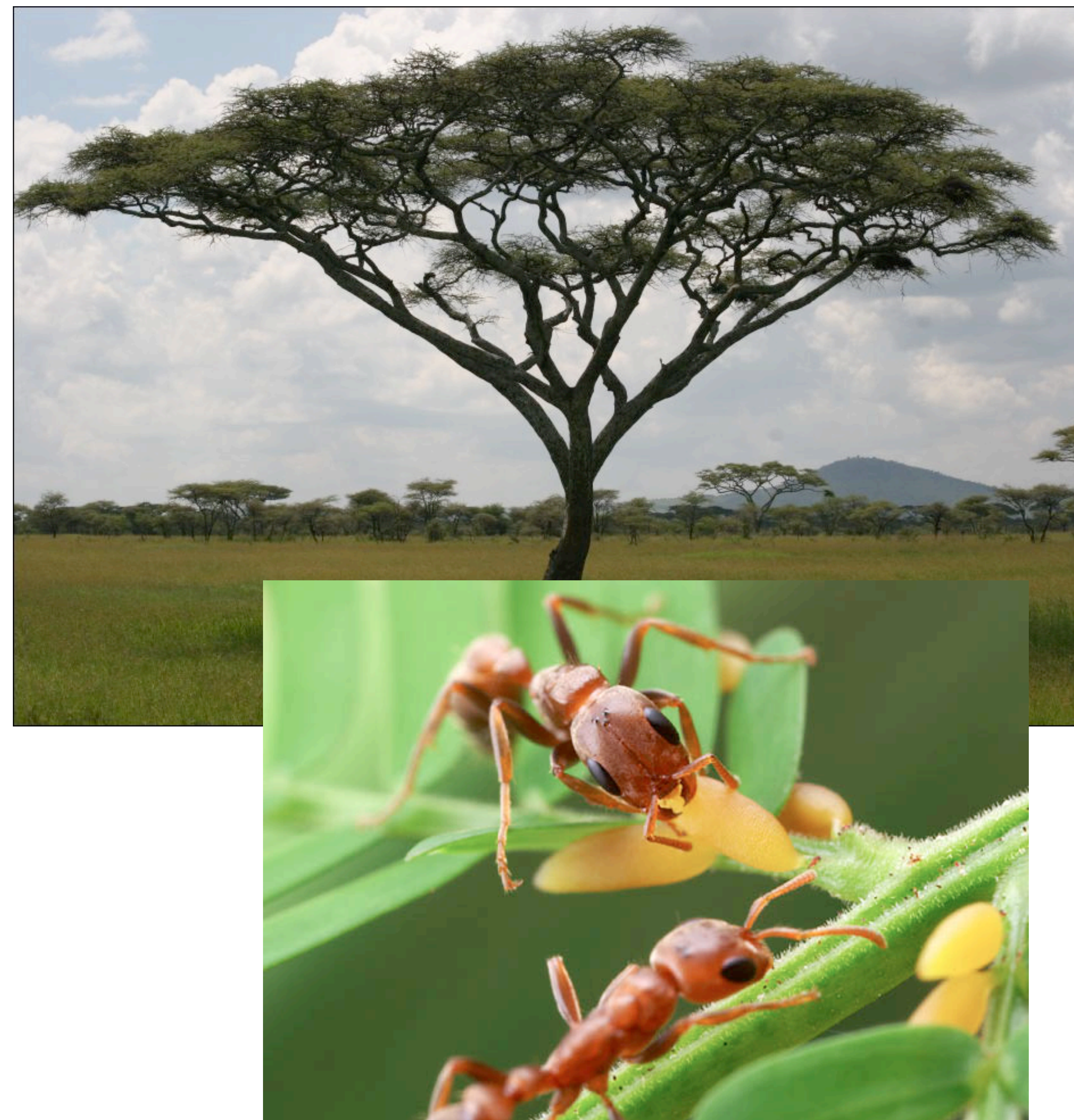
Commensalism (0/+)

- These interactions benefit one species and the other is effected no way positive or negative. Some argue that this can not exist, that all interactions have some effect no matter how small.
  - *ex.* barnacles on whales, algae on turtle shells

What do you think? Can argue both ways?

Homework / Classwork

On your own checkout the story of the Honey Badgers & Honey Guides.
As well as the relationship between the Acacia and Ants



1.1

Mutualistic Relationships - Practice

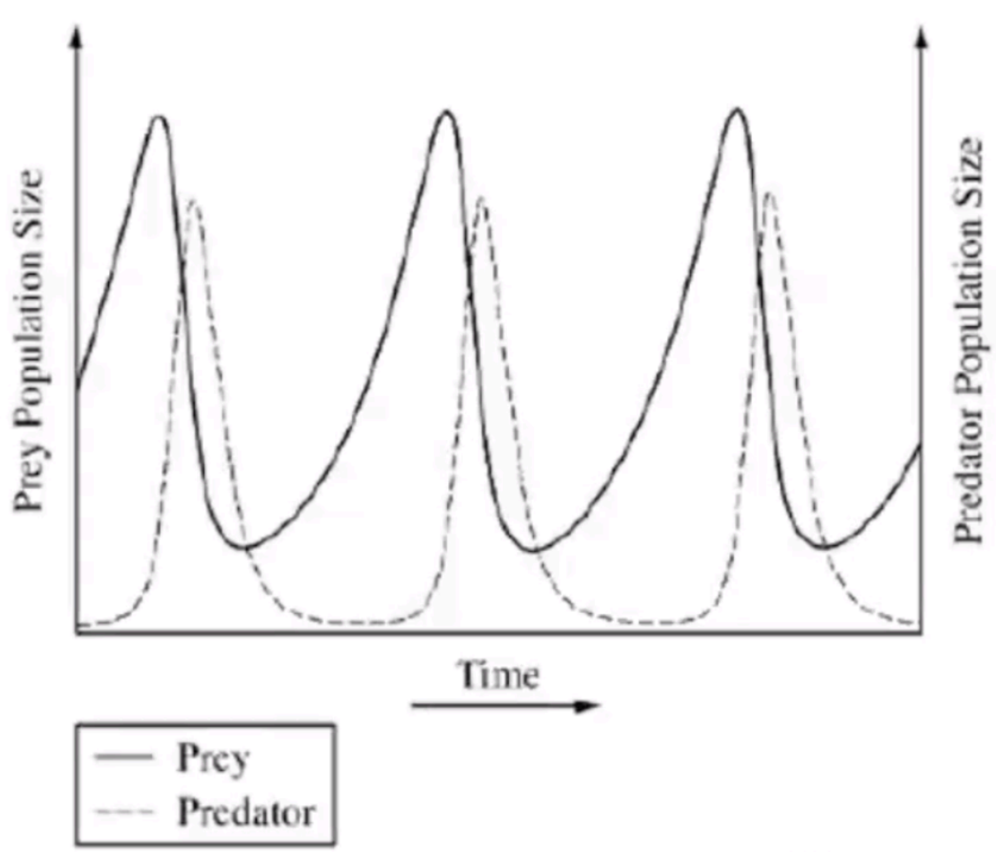
Identify the resource(s) gained for each species in the scenarios below. Is the resource biotic or abiotic?

1) Oxpeckers are birds that are commonly found on the sub-Saharan African savanna. They can often be seen sitting on buffalo, giraffes, impalas, and other large mammals. Oxpeckers eat ticks, flies, fleas and other insects. While sitting on large mammals, oxpeckers will give a loud warning call when predators are near.

1.1

- What it the TITLE of the graph?
- What is the X axis? The Y axes?
- *Describe* the trends in the populations over time. What do you observe here?

Science Practice 1.A:
Describe environmental concepts and processes



"Source: Released AP Exam. Taken from: AP Classroom."

TOPIC 1.2

Terrestrial Biomes

Required Course Content

ENDURING UNDERSTANDING

ERT-1

Ecosystems are the result of biotic and abiotic interactions.

LEARNING OBJECTIVE

ERT-1.B

Describe the global distribution and principal environmental aspects of terrestrial biomes.

ESSENTIAL KNOWLEDGE

ERT-1.B.1

A biome contains characteristic communities of plants and animals that result from, and are adapted to, its climate.

ERT-1.B.2

Major terrestrial biomes include taiga, temperate rainforests, temperate seasonal forests, tropical rainforests, shrubland, temperate grassland, savanna, desert, and tundra.

ERT-1.B.3

The global distribution of nonmineral terrestrial natural resources, such as water and trees for lumber, varies because of some combination of climate, geography, latitude and altitude, nutrient availability, and soil.

ERT-1.B.4

The worldwide distribution of biomes is dynamic; the distribution has changed in the past and may again shift as a result of global climate changes.

Ecology/Biosphere

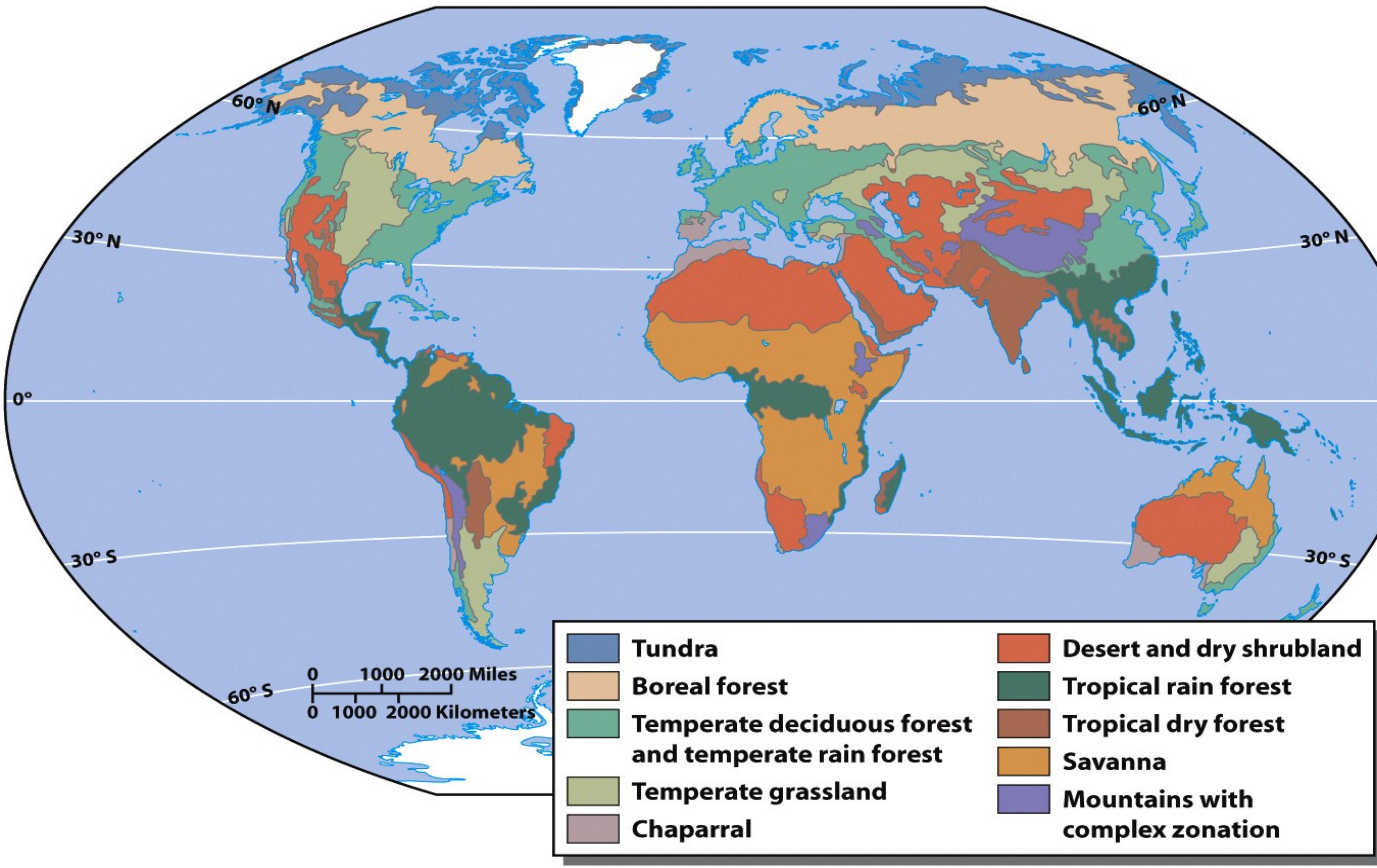
Main Idea: Terrestrial Biomes are major life zones characterized by vegetation.

Main Idea: Climate effects the type a vegetation that will grow in area.

Main Idea: Climate therefore plays an important role in the distribution of biomes around the globe

Can you give any examples of biome and its climate?

Terrestrial Biomes



Terrestrial Biomes

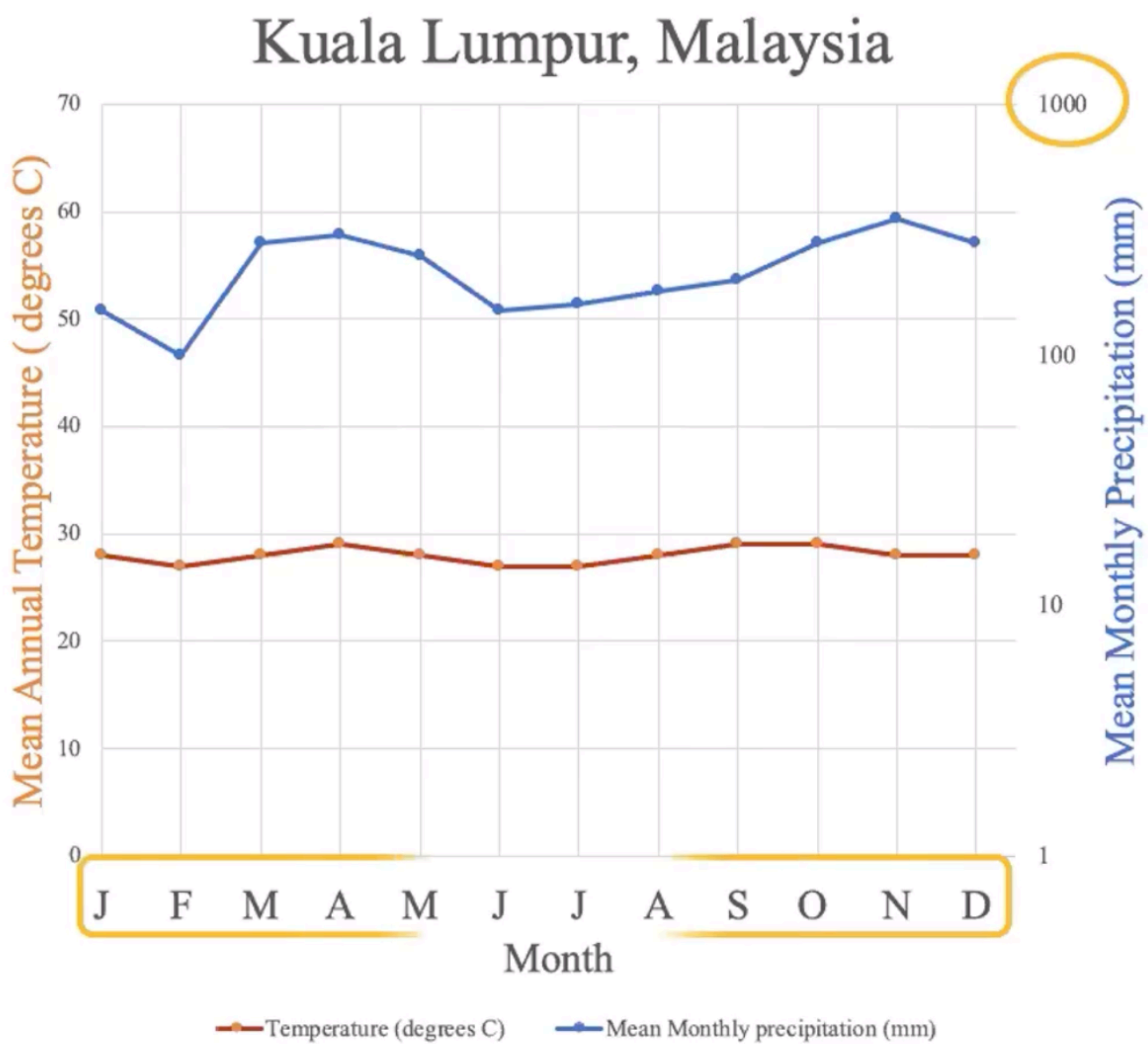
- Have their own climates
- Have their own unique composition of species from microorganisms to mammals
- Have vertical layering, providing different habitats
- They do not have distinct divisions, instead “gray” areas called ecotones divide one biome from another

STRUCTURE AND DISTRIBUTION OF TERRESTRIAL BIOMES

Climate & Terrestrial Biomes

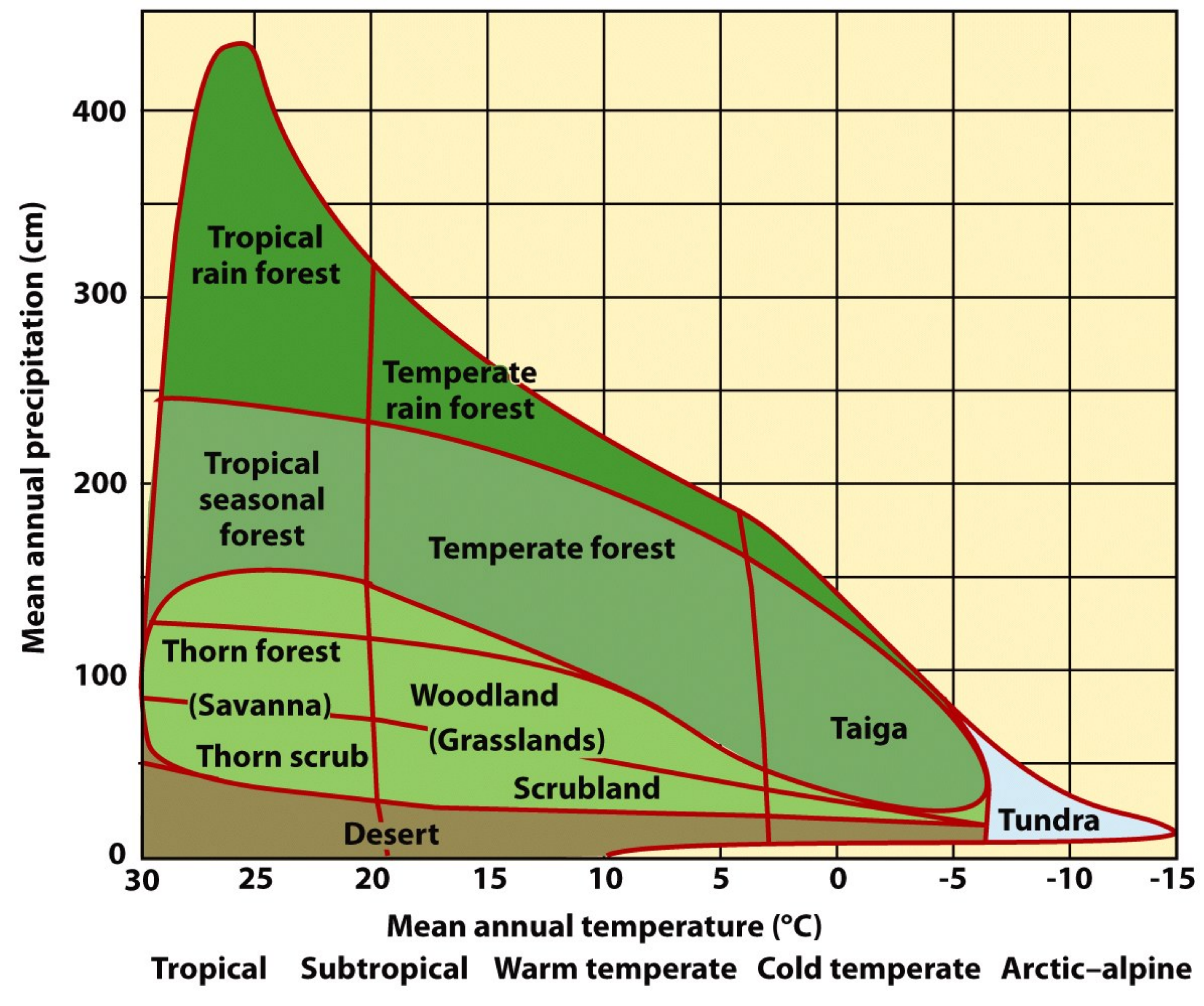
- General: Terrestrial Biomes are correlated with *latitude*
- Specifically: Terrestrial Biomes are very much dependent on *Temperature and Precipitation* (see climograph)

1.2

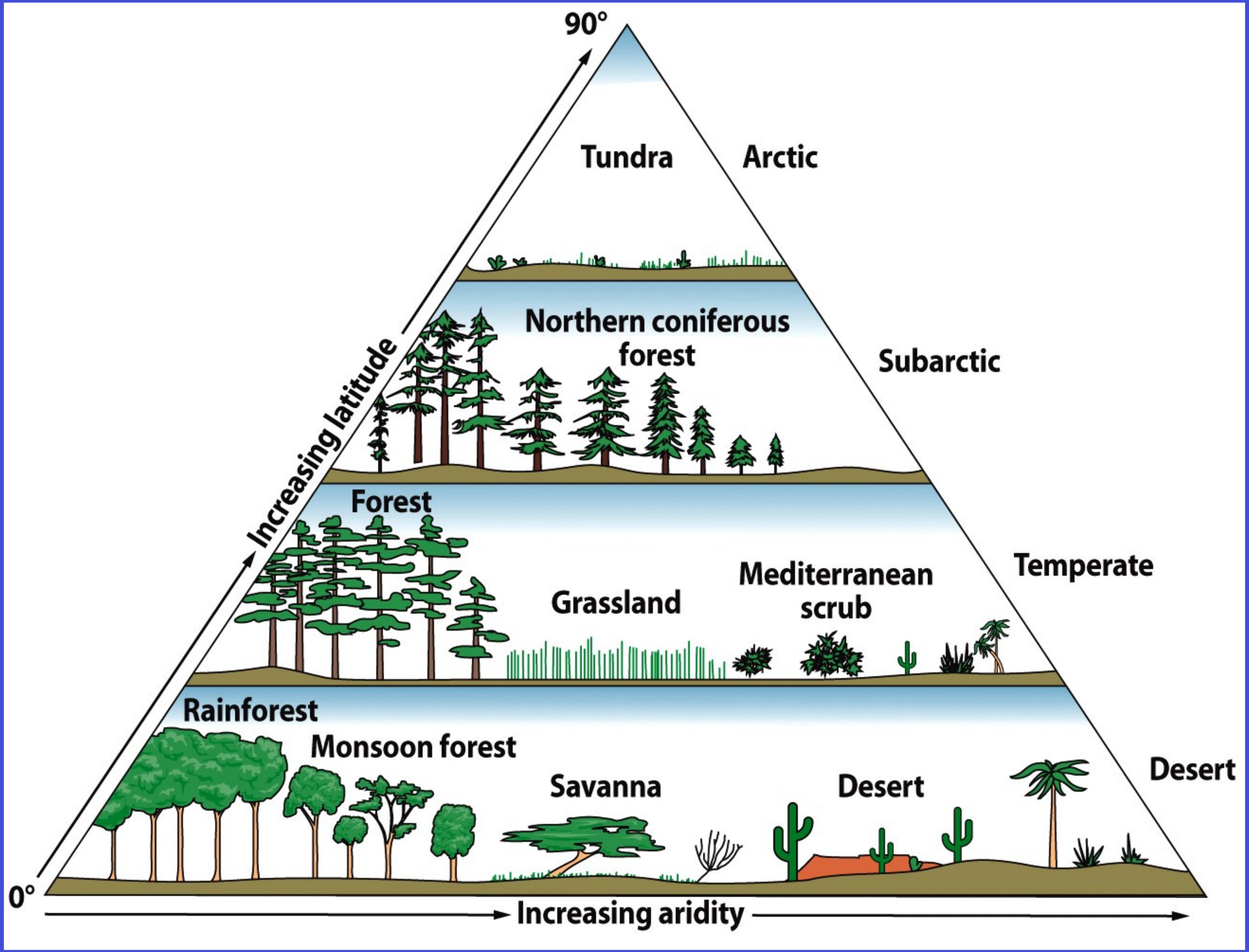


Tropical Rain Forest

- Above freezing year round
- Notice the change in scale in precipitation
- When precipitation is *above* temperature = *moist* conditions



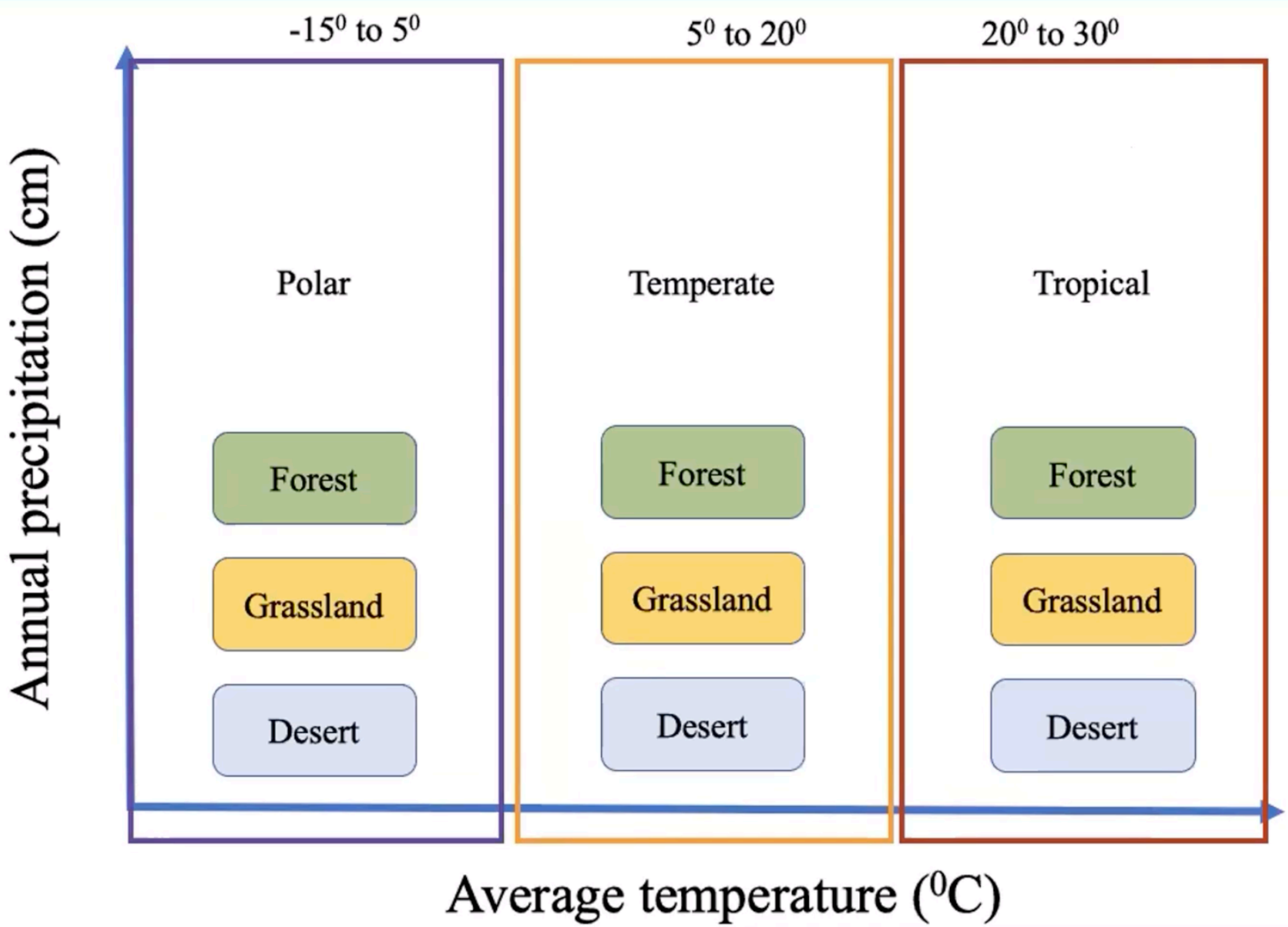
400
300
200
100
0
Mean annual precipitation (cm)
Tropical rain forest
Temperate rain forest
Tropical seasonal forest
Temperate forest
Thorn forest
(Savanna)
Woodland
(Grasslands)
Thorn scrub
Scrubland
Taiga
Tundra
Desert
30
25
20
15
10
5
0
-5
-10
-15
Mean annual temperature (°C)
Tropical
Subtropical
Warm temperate
Cold temperate
Arctic–alpine


90°
Tundra
Arctic
Northern coniferous forest
Subarctic
Increasing latitude
Forest
Grassland
Mediterranean scrub
Temperate
Rainforest
Monsoon forest
Savanna
Desert
Desert
0°
Increasing aridity

Earth's Terrestrial Biomes

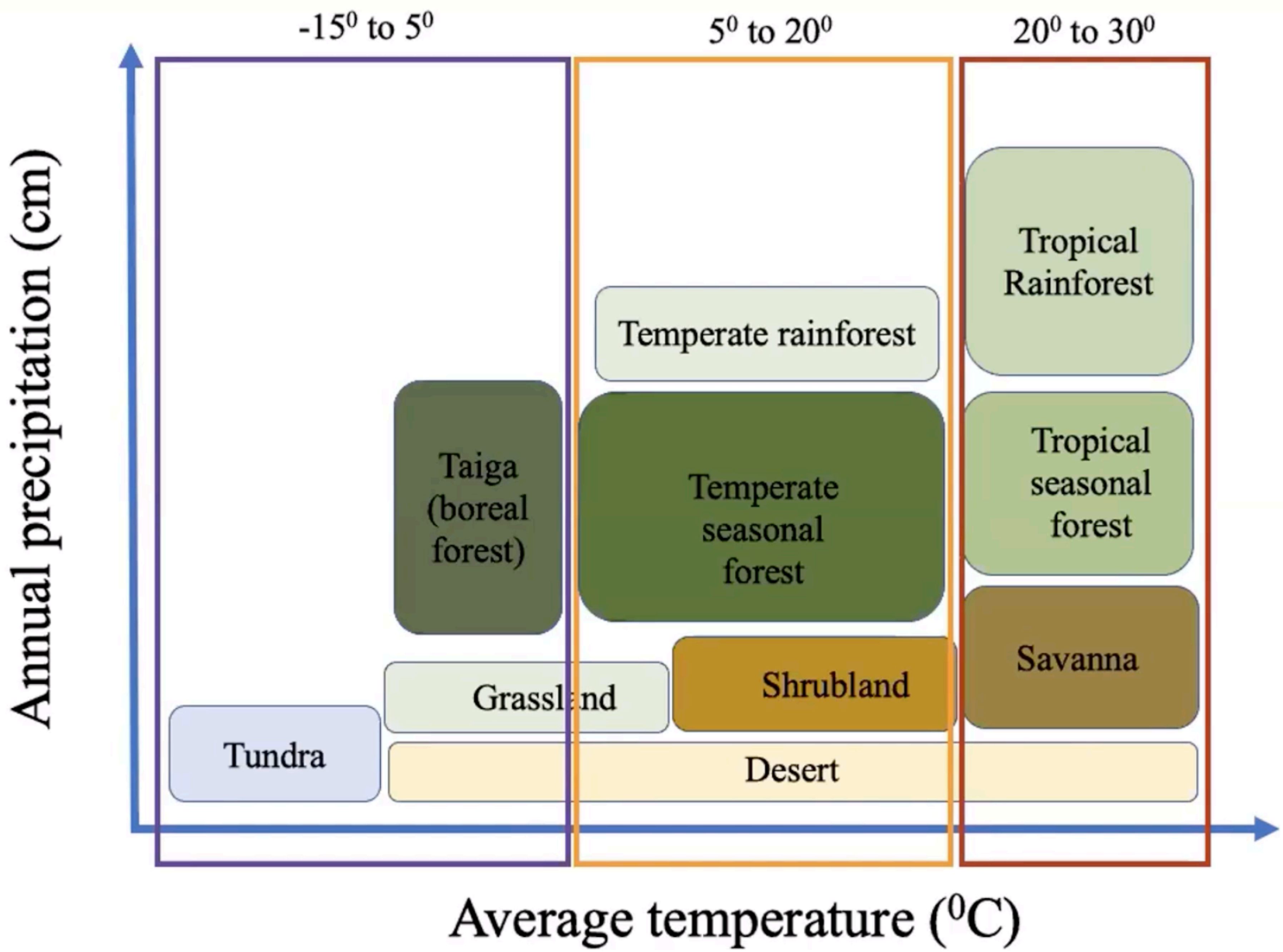
- **Biological diversity varies among biomes**
  - **Generally declines with increasing latitude**
  - **The more favorable the temperature and precipitation for life the more diversity.**

1.2



-15⁰ to 5⁰
5⁰ to 20⁰
20⁰ to 30⁰
Annual precipitation (cm)
Polar
Temperate
Tropical
Forest
Forest
Forest
Grassland
Grassland
Grassland
Desert
Desert
Desert
Average temperature (⁰C)

1.2



-15⁰ to 5⁰
5⁰ to 20⁰
20⁰ to 30⁰
Annual precipitation (cm)
Tropical Rainforest
Temperate rainforest
Taiga (boreal forest)
Temperate seasonal forest
Tropical seasonal forest
Savanna
Shrubland
Grassland
Tundra
Desert
Average temperature (⁰C)

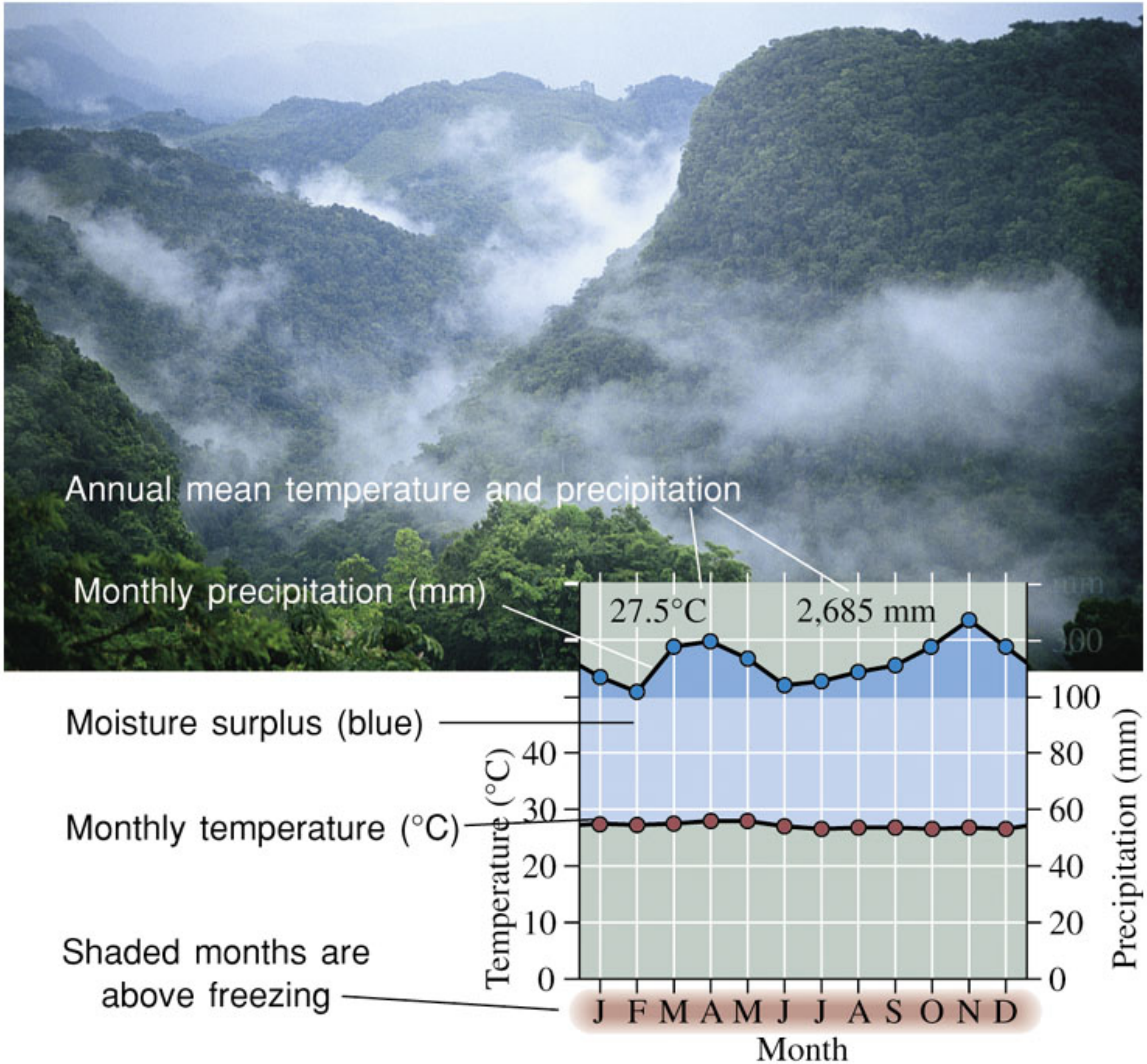
Terrestrial Biomes: A closer Look

1.2

TERRESTRIAL BIOMES

- Characteristics vary with temperature, precipitation, and latitude.
- Hot, humid regions have greater primary productivity and thus greater biodiversity than cold or dry regions.
- Climate graphs are used to describe and compare precipitation and temperature in different biomes.

Tropical Rain Forests



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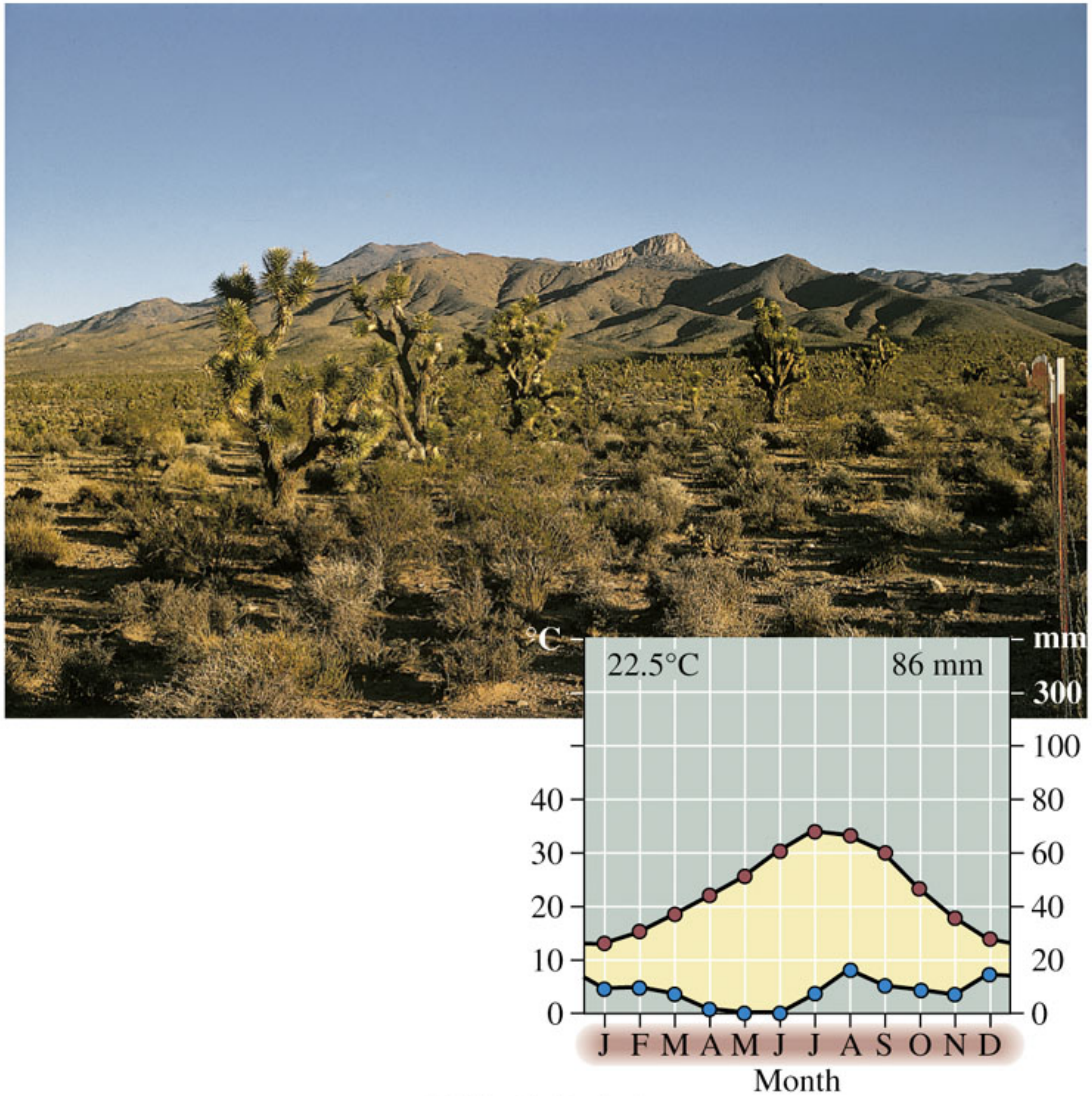
TROPICAL RAIN FOREST

- Distribution: equatorial and subequatorial
- Precipitation: abundant and constant
- Temperature: high and little variation
- Plants: broadleaf evergreens, epiphytes, tremendous layering
- Animals: mammals, birds, reptiles, amphibians, insects, highest biodiversity
- Human Impact: deforestation
- Point of Interest: very poor soil, high turnover rate / decomposition, 50-65% of all terrestrial species live here

TROPICAL RAIN FOREST

DESERTS



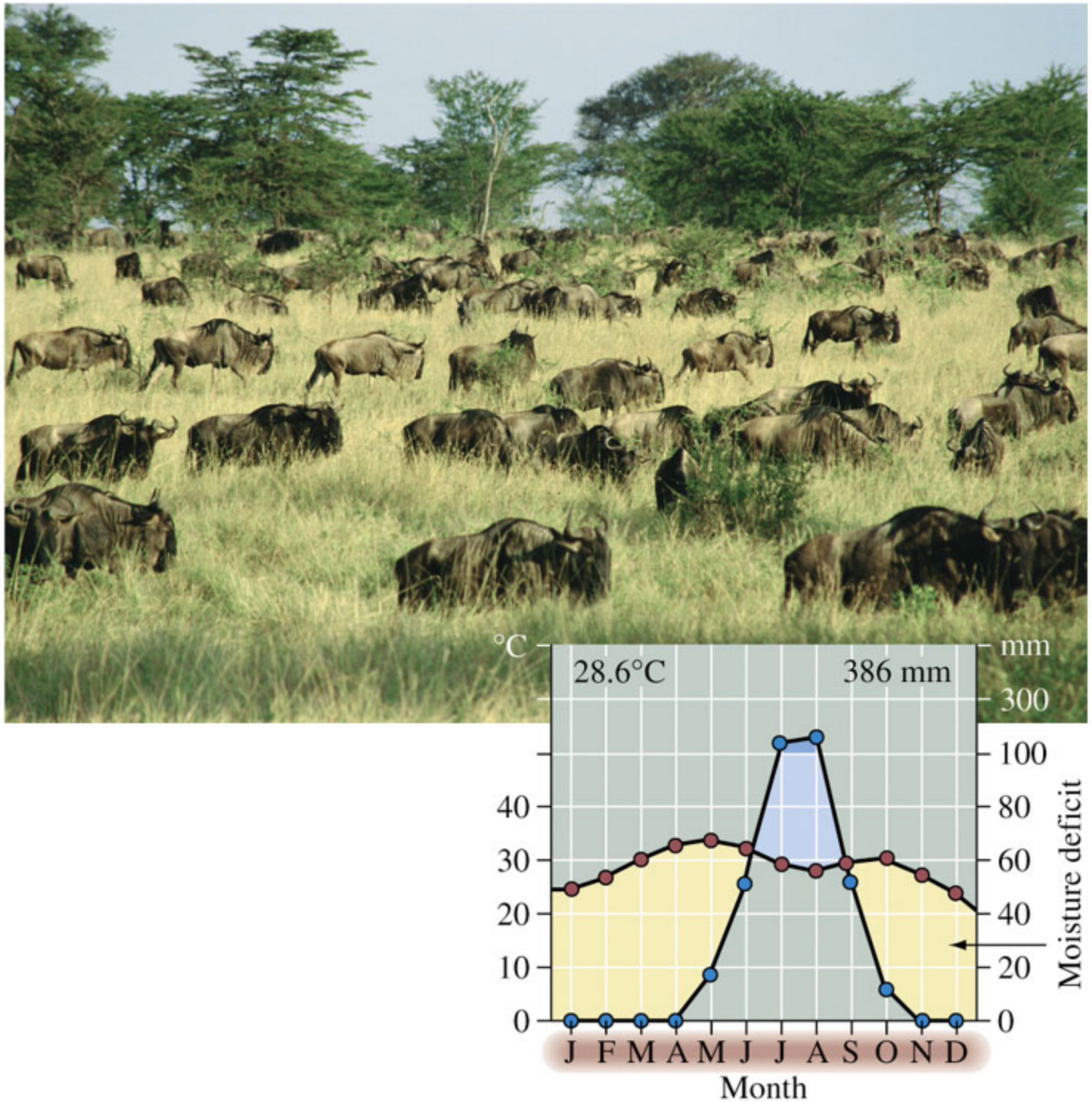
© William P. Cunningham

DESERT

- Distribution: 30 degrees N and S latitudes, interior of continents
- Precipitation: low and extremely variable
- Temperature: extremely variable both seasonally and daily
- Plants: succulents, shrubs, herbs, adapted to dry conditions
- Animals: snakes, lizards, birds, rodents, scorpions, beetles, adapted to dry conditions, adapted to extreme heat
- Human Impact: reduction in biodivesity
- Point of Interest: deserts are defined by precipitation not temp

DESERT BIOME

SAVANNAS



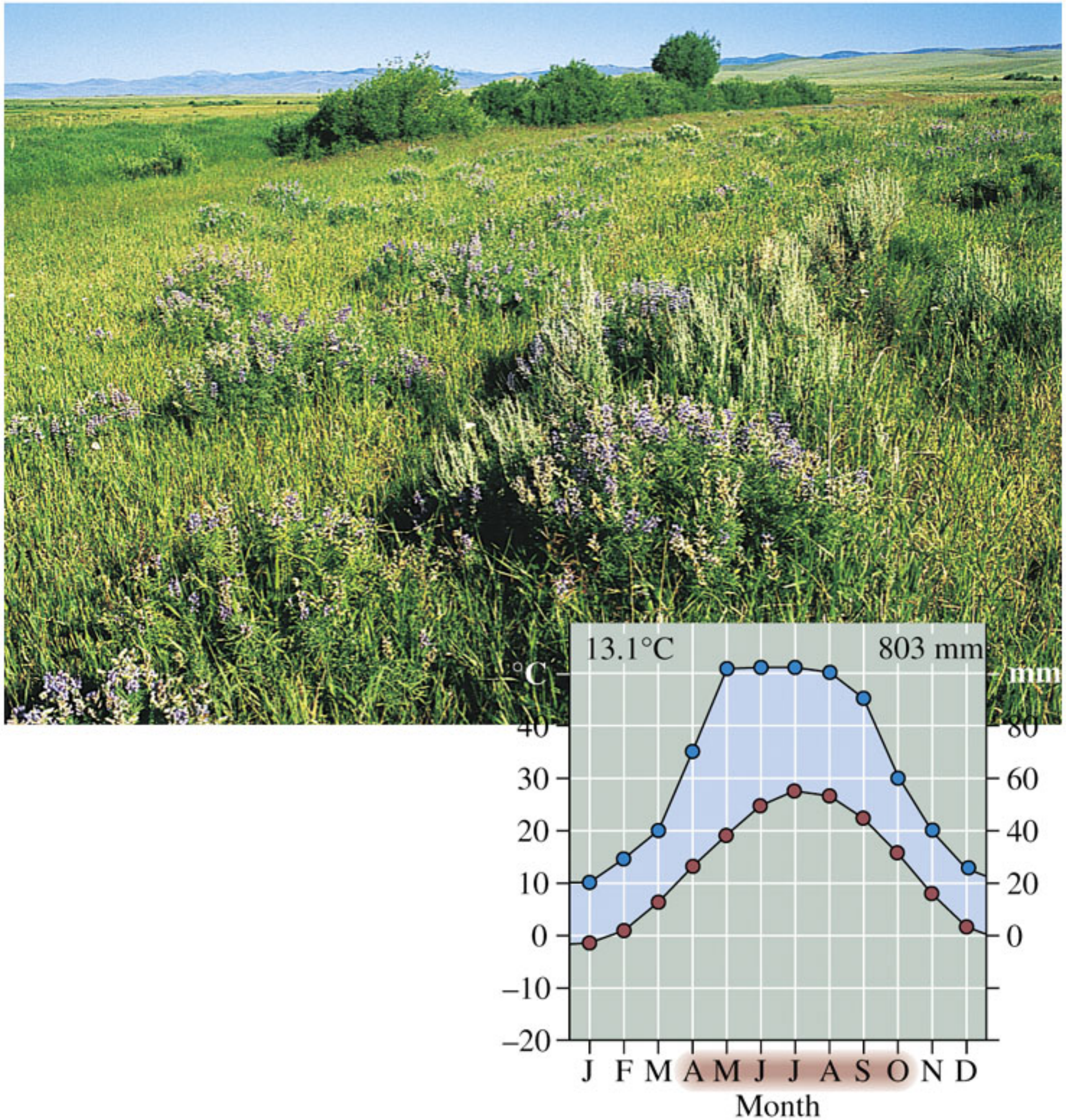
© Vol. 6/Corbis

SAVANNA

- Distribution: equatorial and subequatorial
- Precipitation: low and seasonal
- Temperature: warm year round (somewhat seasonal)
- Plants: grasses, small nonwoody plants, few scattered trees, adapted to dry conditions
- Animals: large herbivores, and their predators, many insects, migratory
- Human Impact: cattle ranching and overhunting
- Point of Interest: earliest human civilizations, fires common

SAVANNA

GRASSLANDS



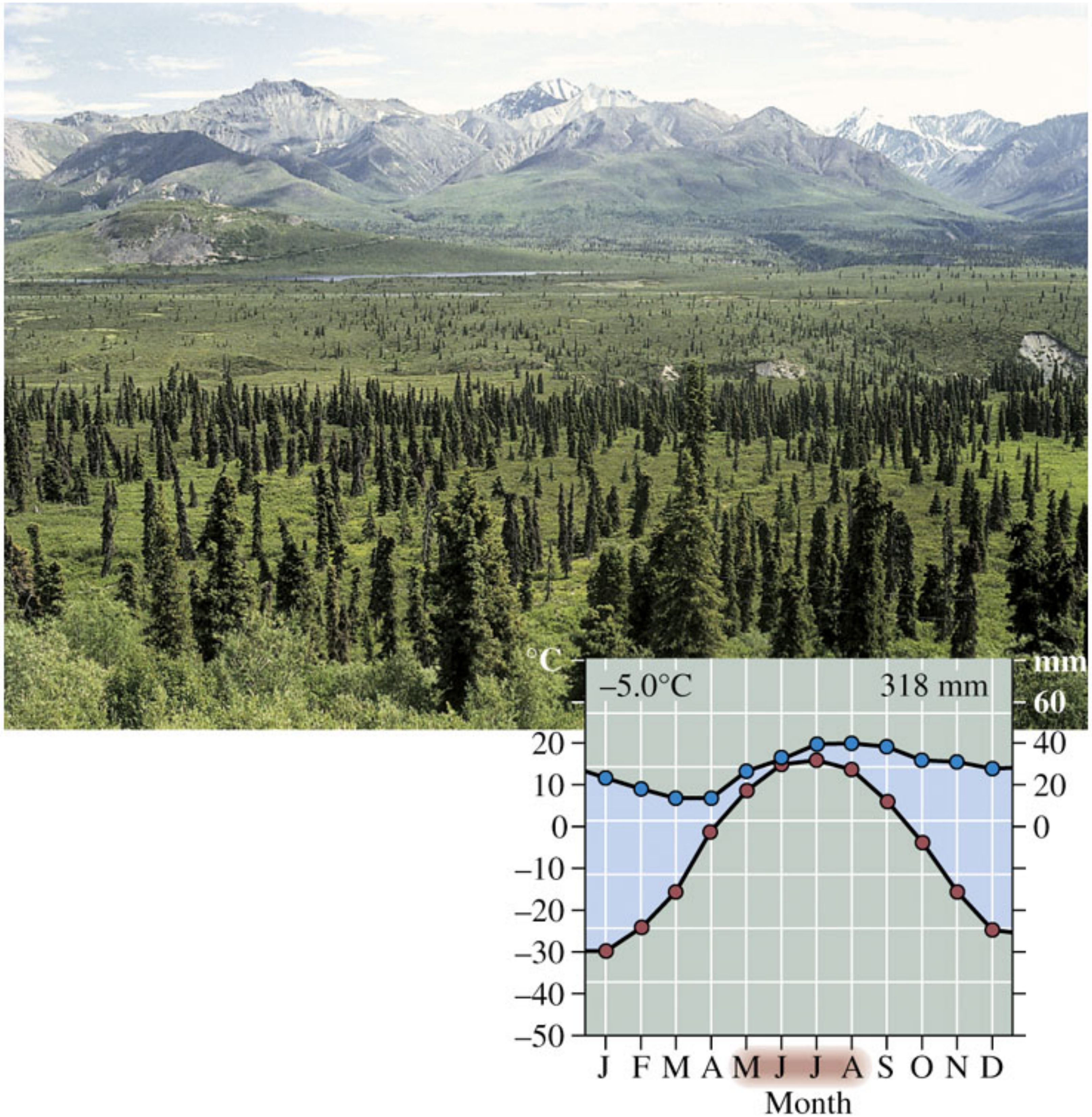
© Mary Ann Cunningham

TEMPERATE GRASSLANDS

- Distribution: s. african (veldts), s. american (pampas), russian (steppes) n. american (plains and prairies)
- Precipitation: low to moderate, highly seasonal
- Temperature: very cold winters and very hot summers
- Plants: grasses and small nonwoody plants, adapted to droughts and fires
- Animals: large grazers and burrowing animals
- Human Impact: very fertile soil much has been converted to agriculture and even into deserts
- Point of Interest: most fertile soil on earth, produces most food


Temperate Grasslands

TAIGA / BOREAL FOREST

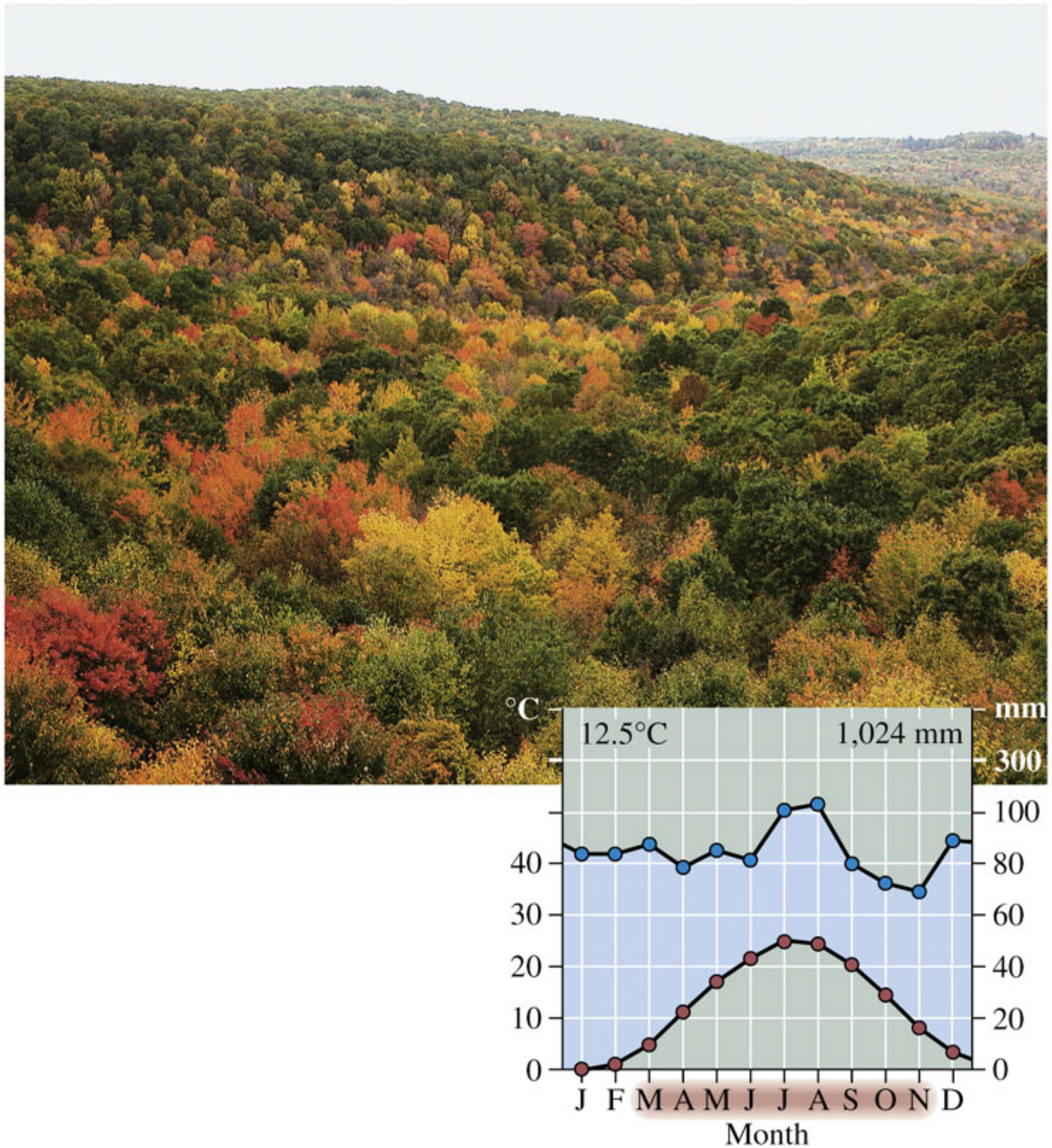


TAIGA / BOREAL FOREST

- Distribution: northern north america and eurassia
- Precipitation: moderate, periodic droughts
- Temperature: usually cold, summers may get hot in the day
- Plants: conifers (evergreens with cones and needles), shrubs, herbs
- Animals: moose, bear, tigers, migratory birds, insects
- Human Impact: logged at an alarming rate
- Point of Interest: largest of all biomes, low biodiversity

TAIGA / BOREAL BIOME

TEMPERATE DECIDUOUS FORESTS



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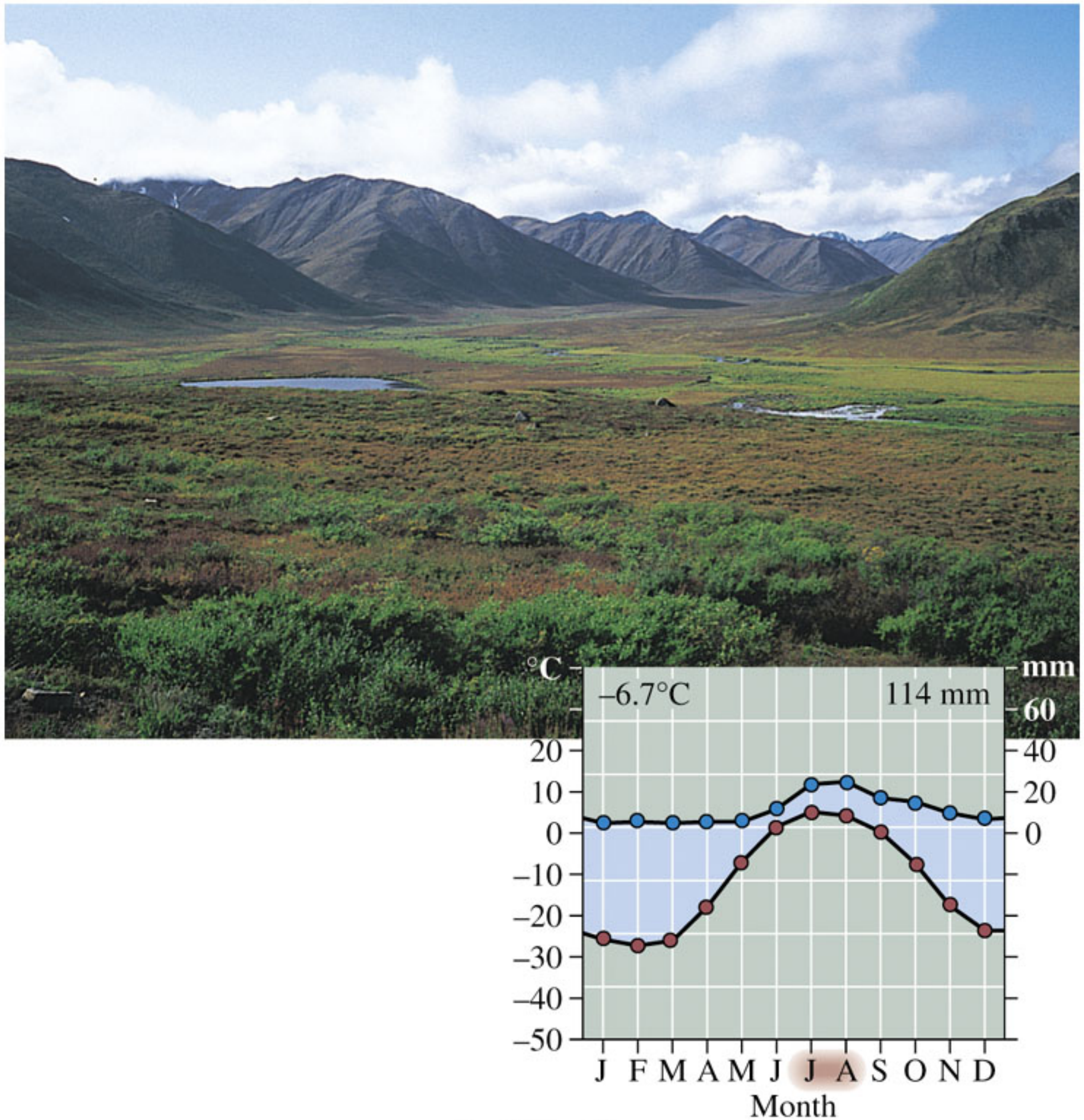
TEMPERATE BROADLEAF FOREST

- Distribution: midlatitudes of the northern hemisphere
- Precipitation: moderate to high, fairly constant
- Temperature: variable, cold winters and hot summers
- Plants: deciduous trees, shrubs, herbs, layered
- Animals: hibernating mammals, migratory birds, insects
- Human Impact: heavily settled, was completely wiped out in the U.S. but now making a comeback
- Point of Interest: forest that gives us the beautiful colors of fall

TEMPERATE DECIDUOUS FOREST

TUNDRA



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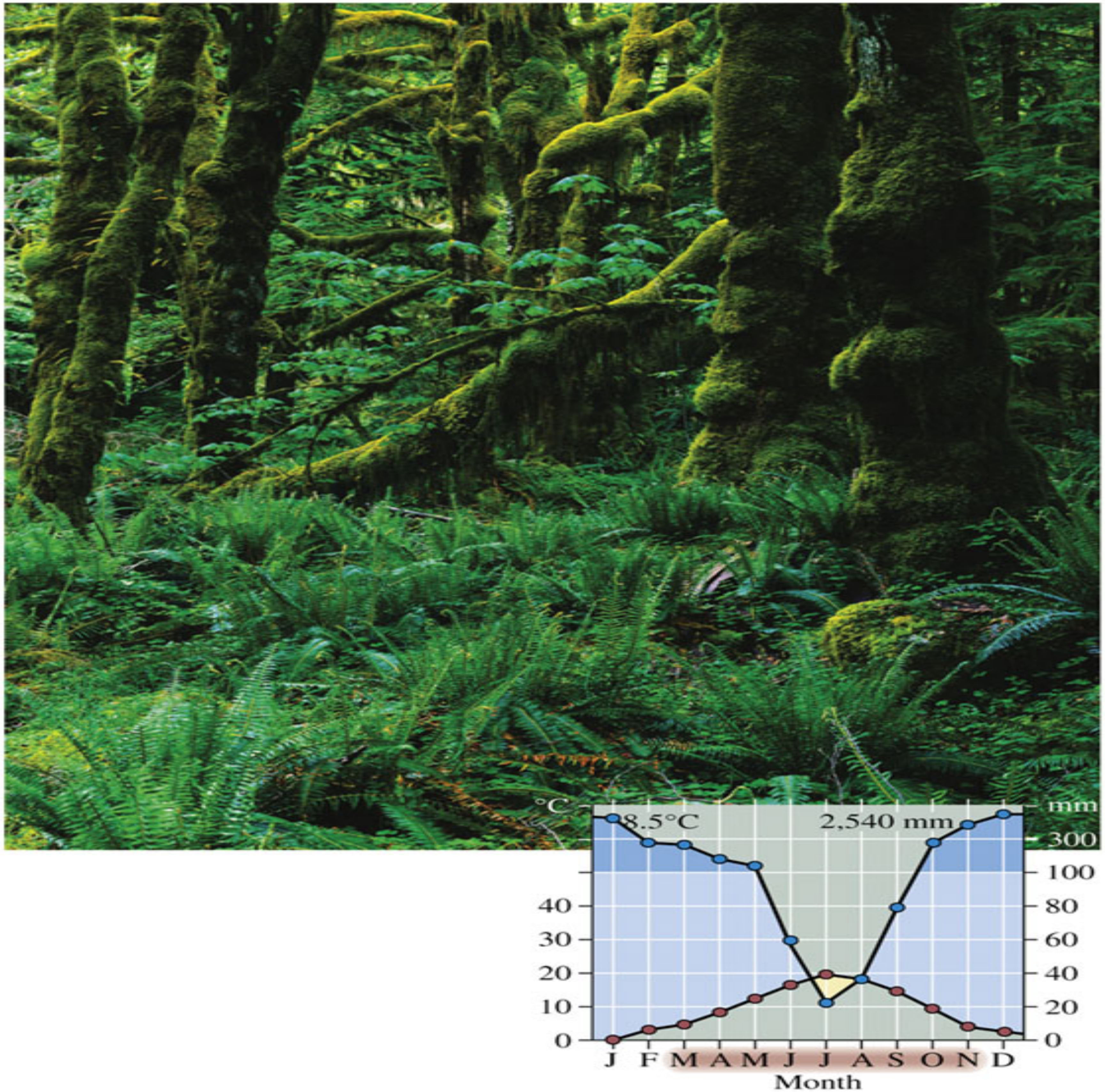
TUNDRA

- Distribution: arctic and high mountain tops
- Precipitation: low in arctic, moderate in mountains
- Temperature: very cold, windy
- Plants: moss, lichens, grass, small shrubs
- Animals: oxen, caribou, reindeer, bears, wolves, foxes, migratory birds
- Human Impact: mineral and oil extraction
- Point of Interest: permafrost; ground is frozen solid, least distrurbed

Tundra Biome

TEMPERATE RAIN FOREST



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TEMPERATE RAIN FORESTS

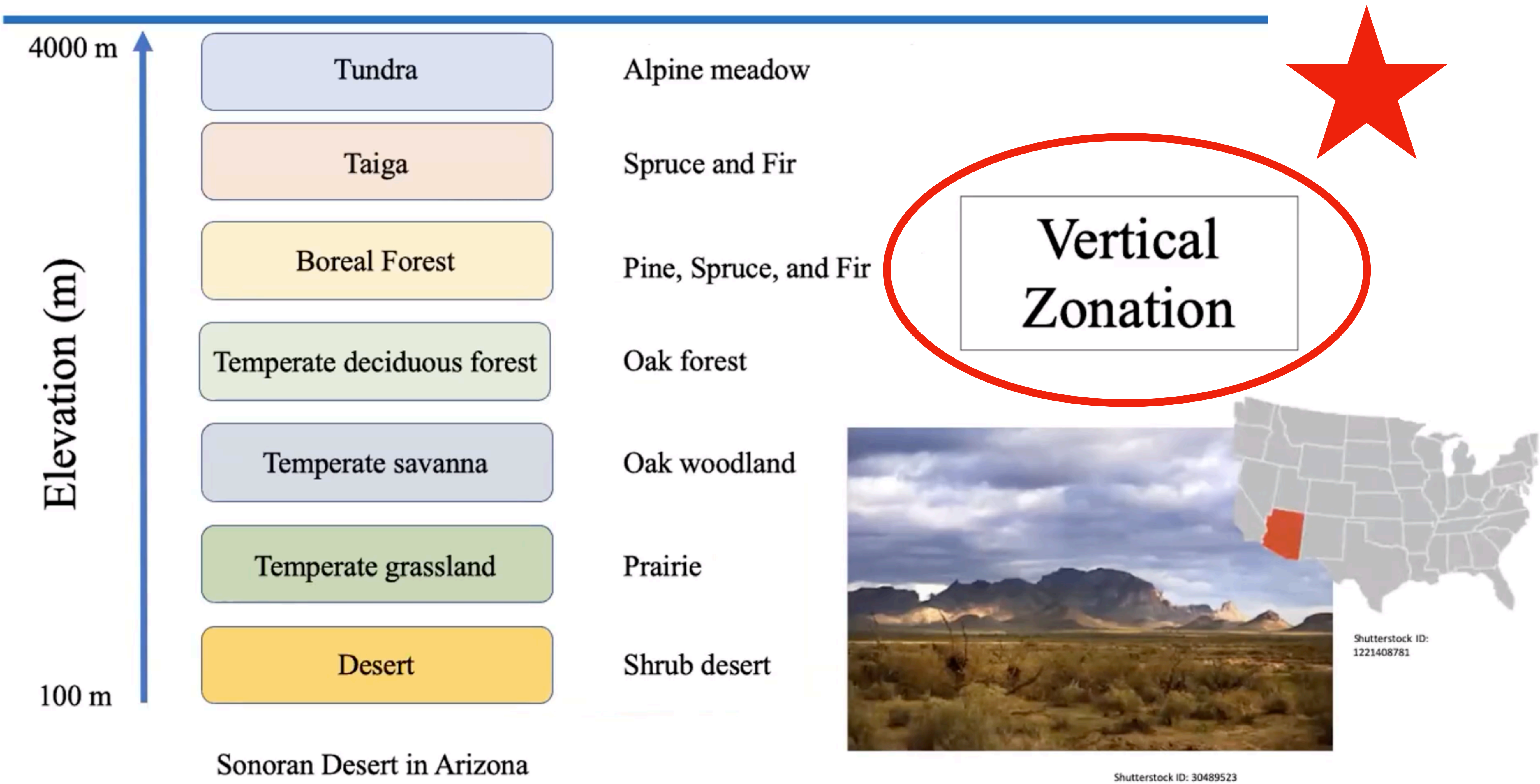
- Distribution: Pacific west coast from California to Alaska
- Precipitation: abundant
- Temperature: mild and cool, very humid
- Plants: conifers, redwoods, giant sequias
- Animals: bears, birds, insects
- Human Impact: battles continue over these "old growth" forests
- Point of Interest: contain world's tallest, largest and oldest trees

Temperate Rain Forest

ADDITIONAL BIOMES

- Temperate Shrublands (Chaparral)
- Temperate Woodlands
- Tropical Dry Forests
- Tropical Seasonal Forests
- Cloud Forests

1.2



4000 m
100 m
Elevation (m)
Tundra
Alpine meadow
Taiga
Spruce and Fir
Boreal Forest
Pine, Spruce, and Fir
Temperate deciduous forest
Oak forest
Temperate savanna
Oak woodland
Temperate grassland
Prairie
Desert
Shrub desert
Sonoran Desert in Arizona
Vertical Zonation
Shutterstock ID: 1221408781
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Disturbances & Biomes

- Biomes are dynamic, stability is the exception
  - Fire, storms and human activity are constantly changing the resource availability and community structure

How are fires beneficial to ecosystems?

Answer: Fire ecology differs in each biome. In general fires will destroy build up of underbrush making large fires less likely, they are necessary for some seeds to germinate, they help recycled nutrients back into the soil, encourage succession, change soil properties, etc

Can you name this tune? Who was the original singer?

"Ring of Fire" By: Adam Lambert Johnny Cash!

These remarkable trees below the Sequoia and Redwood are the largest (and very old) trees on the planet. They are found in area where forest fires are common and necessary for their survival. Examine the pictures below.

What adaptations might explain how these trees are fire tolerant?

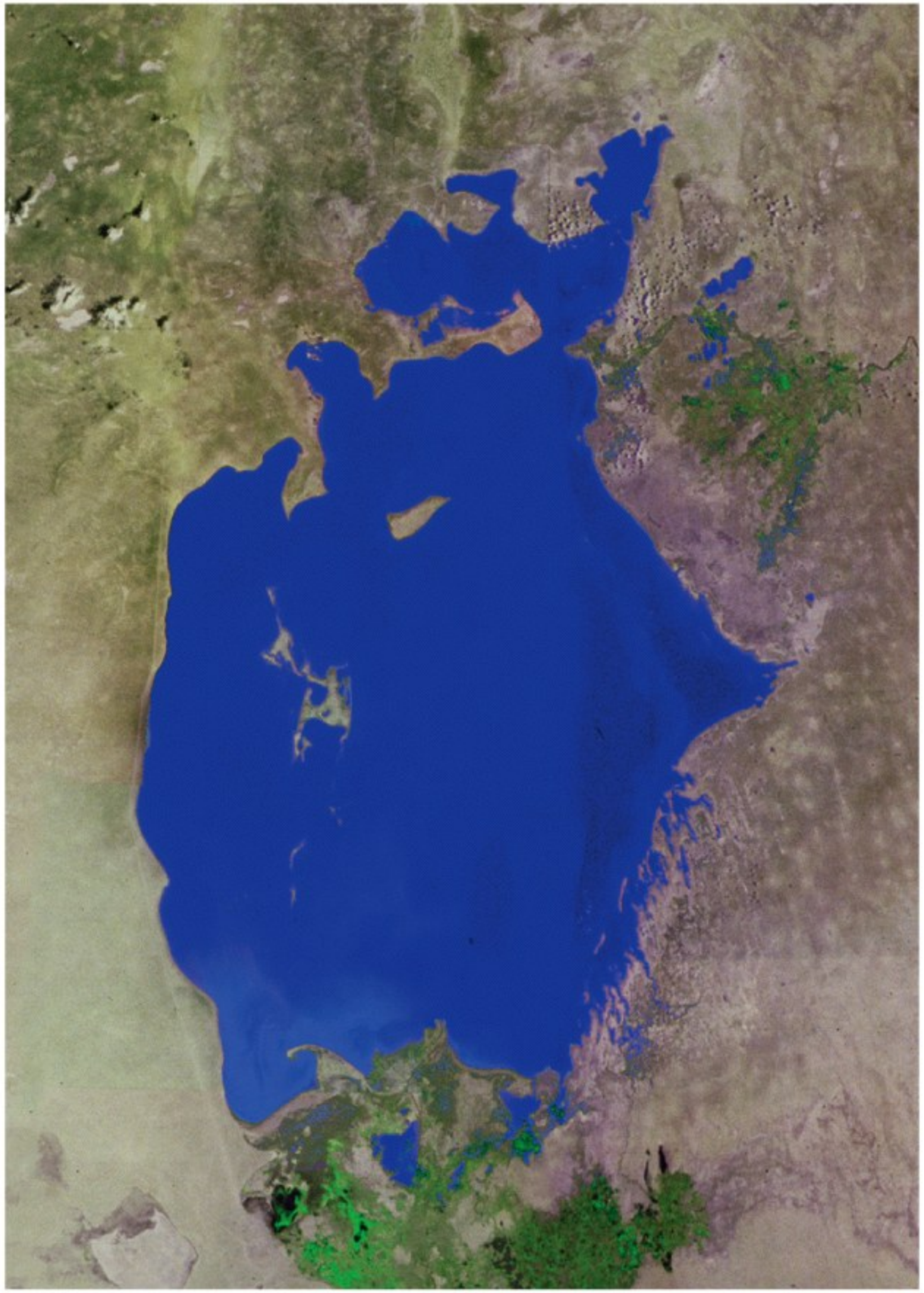
Thick bark & Check out the height of the first branches

- *Sadly human activity is severely changing our distribution of biomes*
  - Boreal Deforestation (1million acres are logged annually in canada alone)
  - Desertification (land the size of Rhode Island annually turning into deserts)
  - Wetlands (221 million acres in colonial times...today only 104 million acres)
  - Coral reefs (25% of reefs worldwide are damaged and seriously threatened)
  - Tropical Deforestation (a century ago these forests covered a land area about the size of the United States...today less than 50% remain. The net loss per year is occurring a rate of a football field in size per second!)
  - Aquatic Biomes (see picture of the Aral sea on the next slide)

What are the downsides to this destruction?

loss of biodiversity, loss of potential medicines, loss of carbon sinks, loss food, loss of fertile soil, increased soil erosion, sediment pollution in rivers, changing rain patterns, floods, droughts

Aral Sea



(a) 1976

(b) 2008

1.2

HUMAN DISTURBANCE

Broadleaf Temperate Forest	Eastern N. America and Europe	Logging and habitation
Shrubland	Mediterranean	Habitation and favorable climate
Temperate grassland	American "cornbelt"	Agriculture
Tundra	Canada and Russia	Harsh climate and poor soils
Taiga	Canada and Russia	Logging, tar sands, and natural gas
Tropical rainforests	Amazon and Congo	Remain mostly intact
Tropical rainforests	West Africa, SE Asia, Brazil, and Malaysia	Timber, palm oil, soy bean, cattle grazing

Human Disturbance

TABLE 5.1

Human Disturbance

Biome	Total Area (10^6 km^2)	% Undisturbed Habitat	% Human Dominated
Temperate broad-leaf forests	9.5	6.1	81.9
Chaparral	6.6	6.4	67.8
Temperate grasslands	12.1	27.6	40.4
Temperate rainforests	4.2	33.0	46.1
Tropical dry forests	19.5	30.5	45.9
Mixed mountain systems	12.1	29.3	25.6
Mixed island systems	3.2	46.6	41.8
Cold deserts/semideserts	10.9	45.4	8.5
Warm deserts/semideserts	29.2	55.8	12.2
Moist tropical forests	11.8	63.2	24.9
Tropical grasslands	4.8	74.0	4.7
Temperate coniferous forests	18.8	81.7	11.8
Tundra and arctic desert	20.6	99.3	0.3

Note: Where undisturbed and human-dominated areas do not add up to 100 percent, the difference represents partially disturbed lands.

Source: Hannah, Lee, et al., "Human Disturbance and Natural Habitat: A Biome Level Analysis of a Global Data Set," in *Biodiversity and Conservation,* 1995, Vol. 4:128–55.

TOPIC 1.3

Aquatic Biomes

Required Course Content

ENDURING UNDERSTANDING

ERT-1

Ecosystems are the result of biotic and abiotic interactions.

LEARNING OBJECTIVE

ERT-1.C

Describe the global distribution and principal environmental aspects of aquatic biomes.

ESSENTIAL KNOWLEDGE

ERT-1.C.1

Freshwater biomes include streams, rivers, ponds, and lakes. These freshwater biomes are a vital resource for drinking water.

ERT-1.C.2

Marine biomes include oceans, coral reefs, marshland, and estuaries. Algae in marine biomes supply a large portion of the Earth's oxygen, and also take in carbon dioxide from the atmosphere.

ERT-1.C.3

The global distribution of nonmineral marine natural resources, such as different types of fish, varies because of some combination of salinity, depth, turbidity, nutrient availability, and temperature.

Ecology/Biosphere

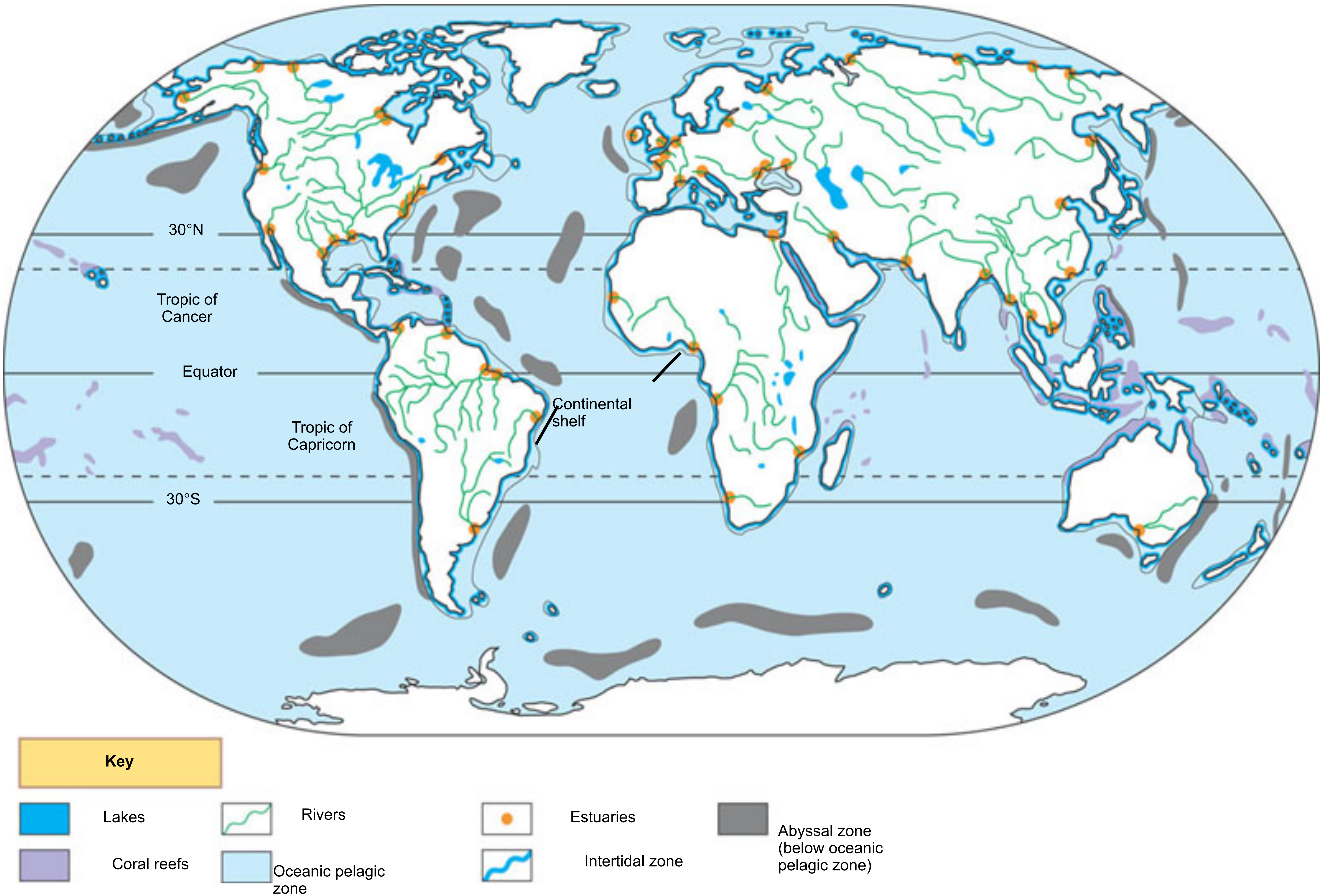
Main Idea: Aquatic biomes show little latitudinal correlation instead they are characterized by their physical factors

Can you give any examples of physical factors that are important in these biomes? What do think will be the most important one?

MARINE & FRESHWATER BIOMES

- **Light and Nutrients are the most important abiotic factors; effecting the distribution and abundance of living organisms in an aquatic biome**
- Water evaporated from oceans provides most of the earth's rain
- Ocean temperatures effect global climate
- Marine algae & photosynthetic bacteria provide most of the world's oxygen and consume most carbon dioxide

Marine & Freshwater Biomes



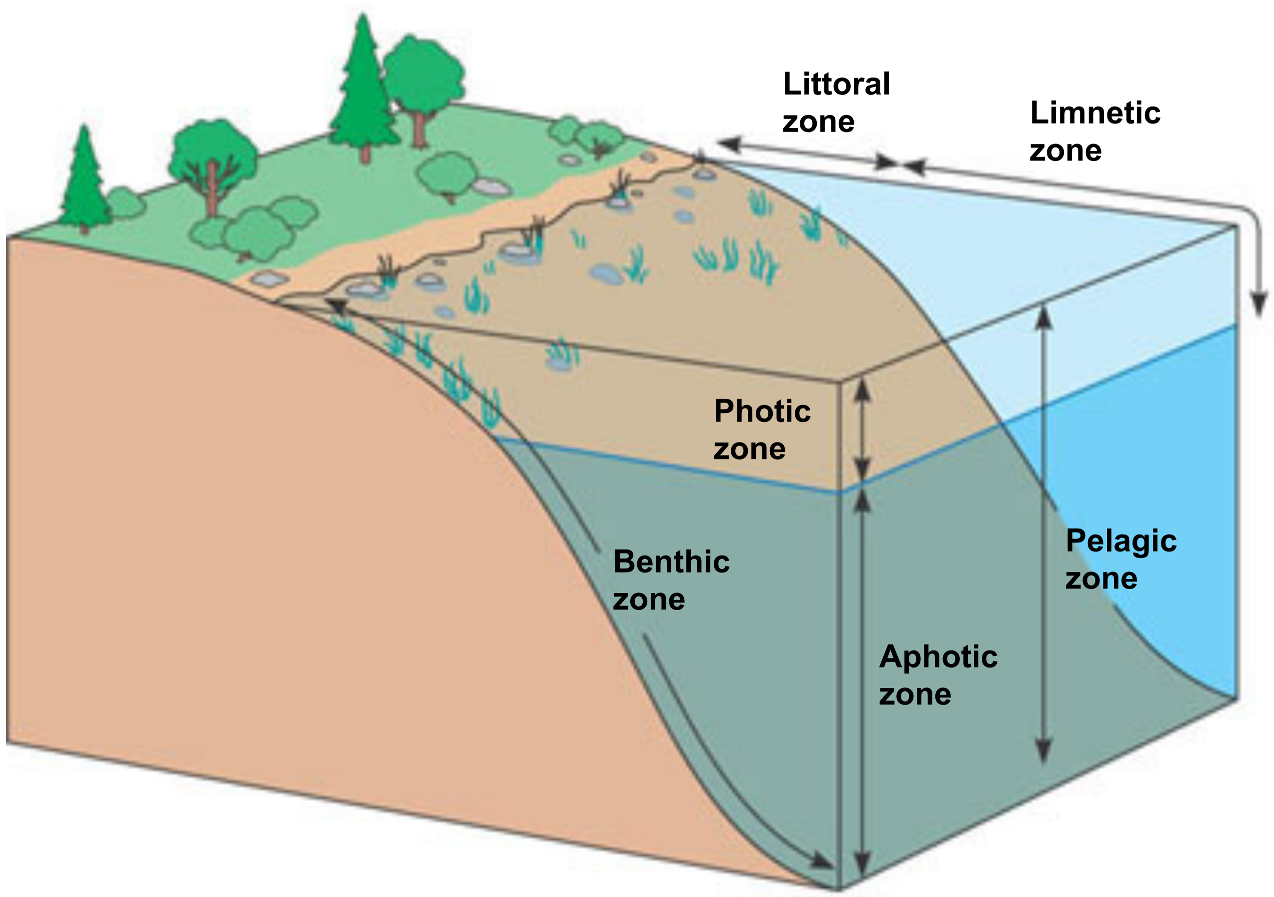
Aquatic Biome Zones

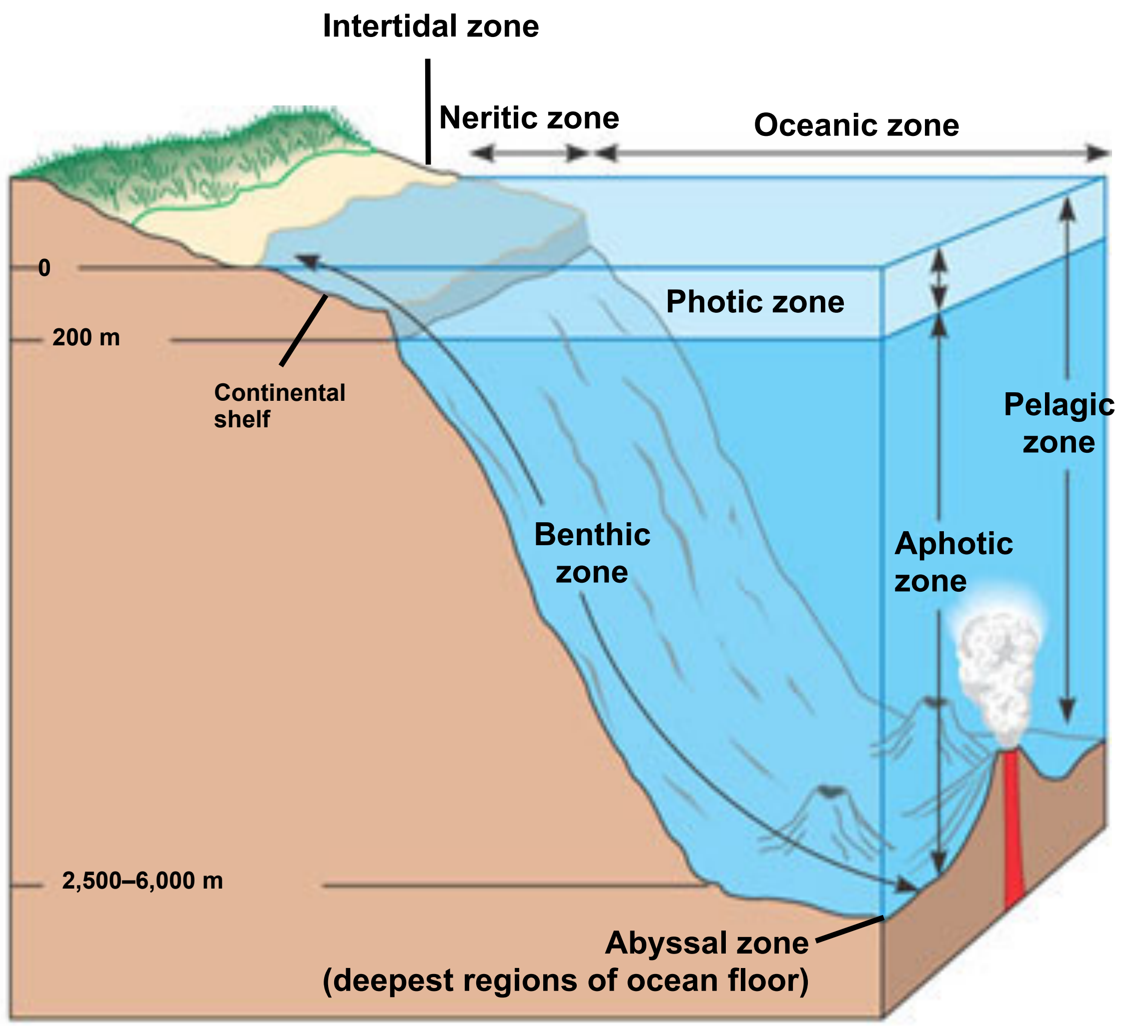
- Key Aquatic Biome Zones
- Pelagic = open water
    - Photic = light penetration
    - Aphotic = no/little light penetration
    - Benthic = the bottom; shallow or deep (like the soil!)

Aquatic life is distributed according to the *water depth, light penetration, distance from the shore,* and whether they are found in *open water* or *at the bottom.*

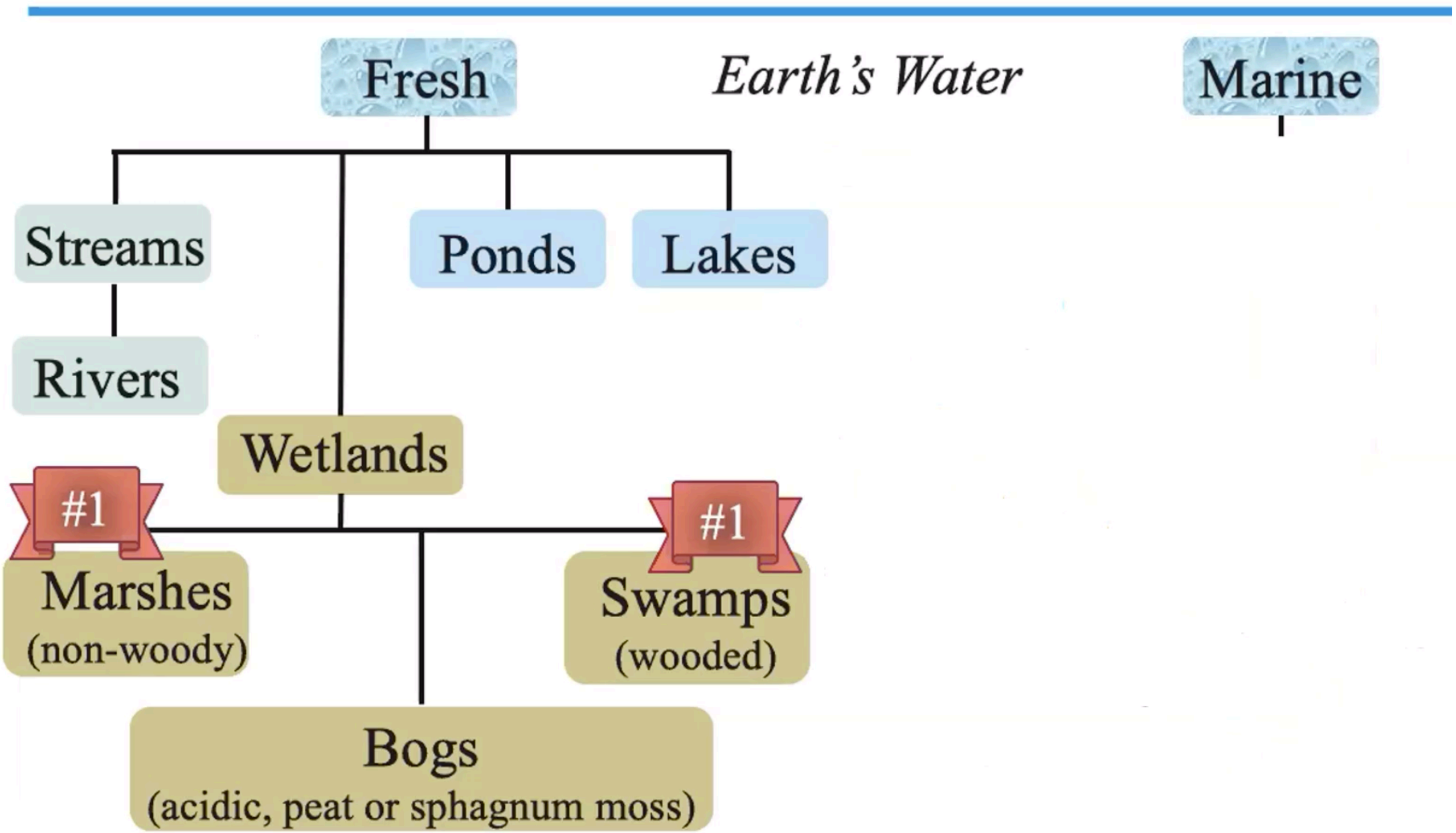
Aquatic Biome Zones

- Aquatic Biomes are layered by their physical and chemical properties
- They are stratified vertically and horizontally





1.3


Fresh
Earth's Water
Marine
Streams
Ponds
Lakes
Rivers
Wetlands
#1
#1
Marshes
(non-woody)
Swamps
(wooded)
Bogs
(acidic, peat or sphagnum moss)

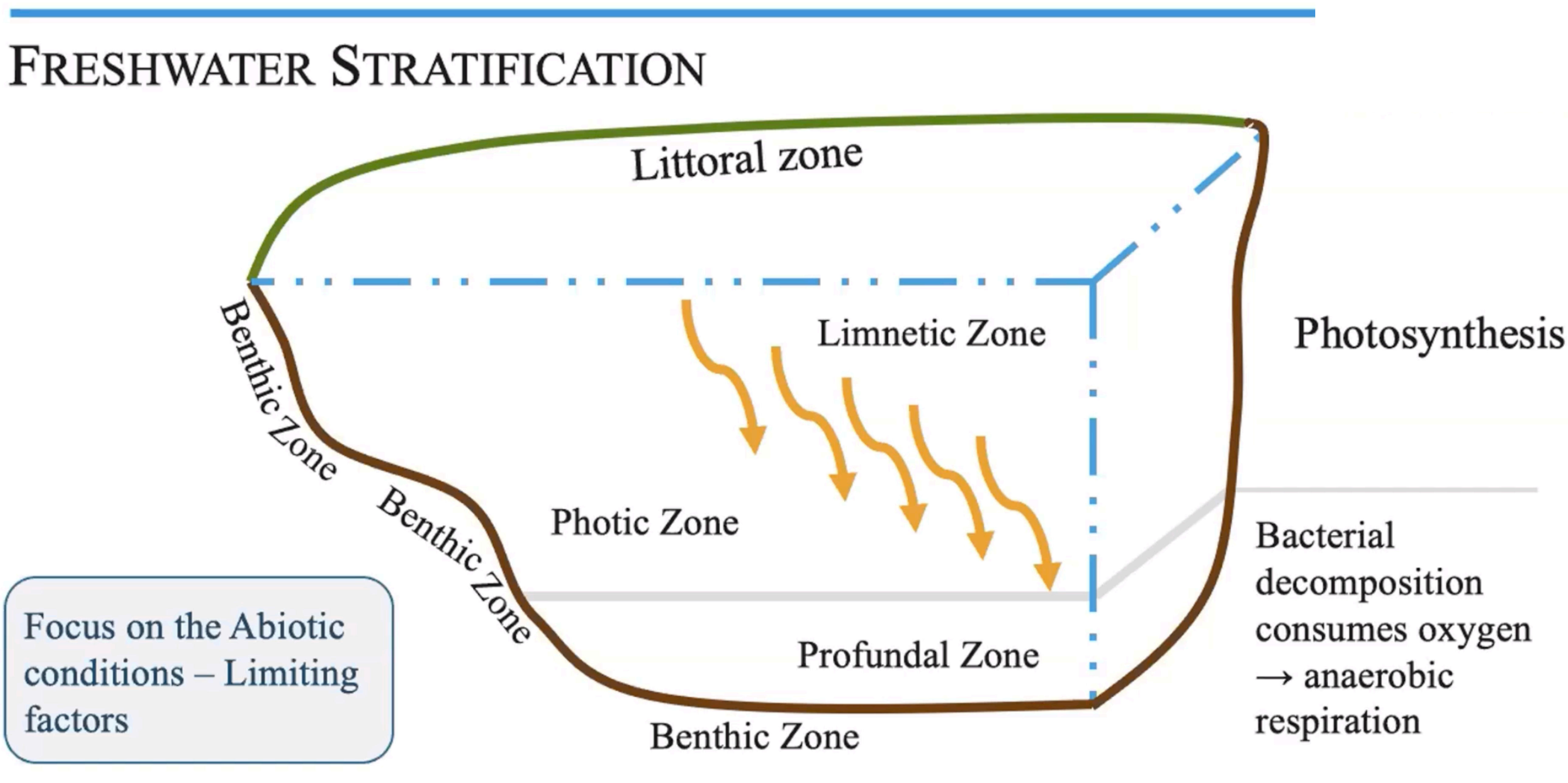
1.3

Abiotic Conditions in Aquatic vs. Terrestrial

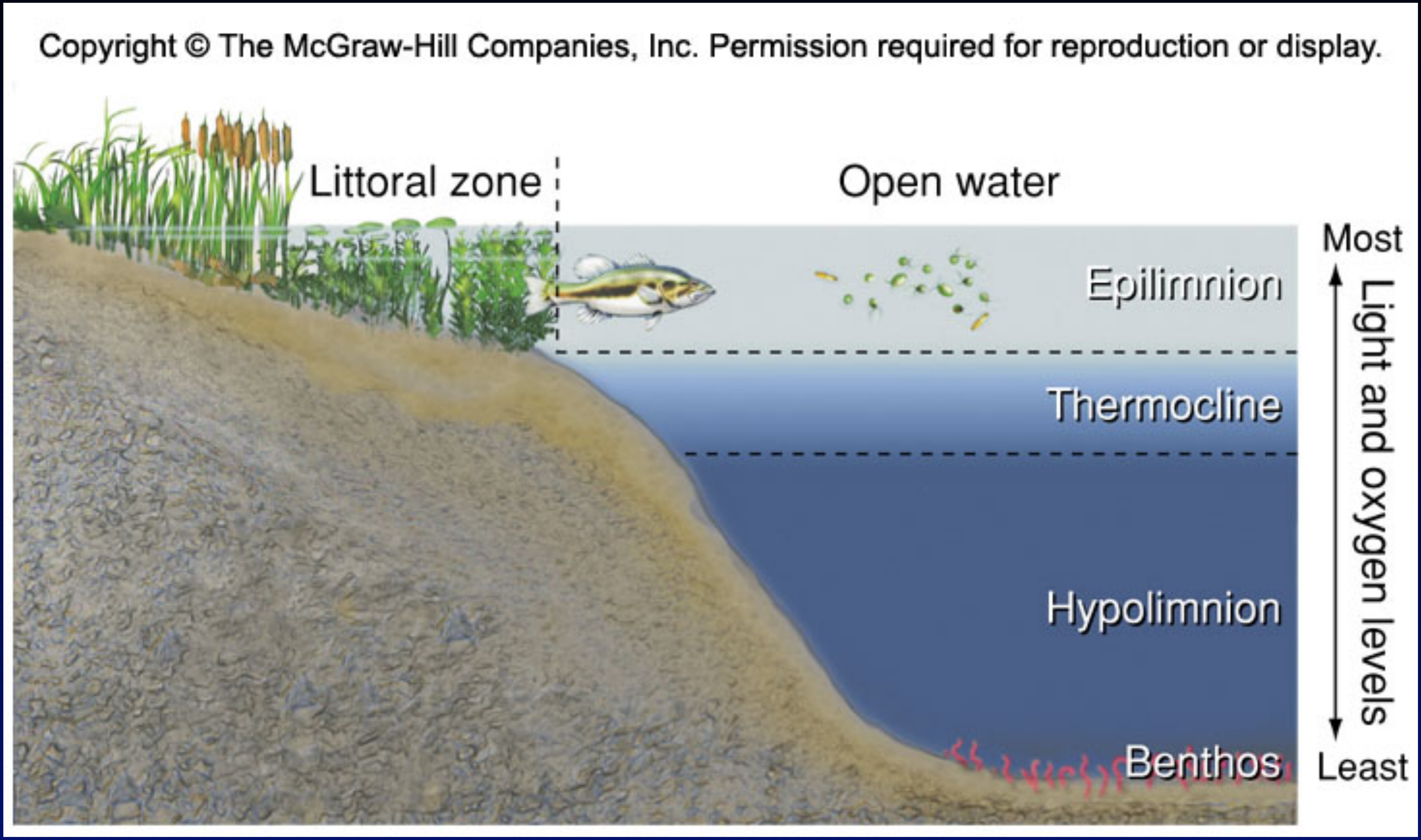
- Depth
- ✅ **Light**
- **Temperature**
- *Velocity (currents)*
- Salinity
- Oxygen
- Nutrients: nitrates and phosphates
- Suspended matter (*silt*)
- Bottom substrate (*muddy, sandy, rocky*)

- Annual average precipitation
- Annual average temperature
- *Latitude* and *Altitude*
- Soil type
- Topography
- Wind speed

1.3

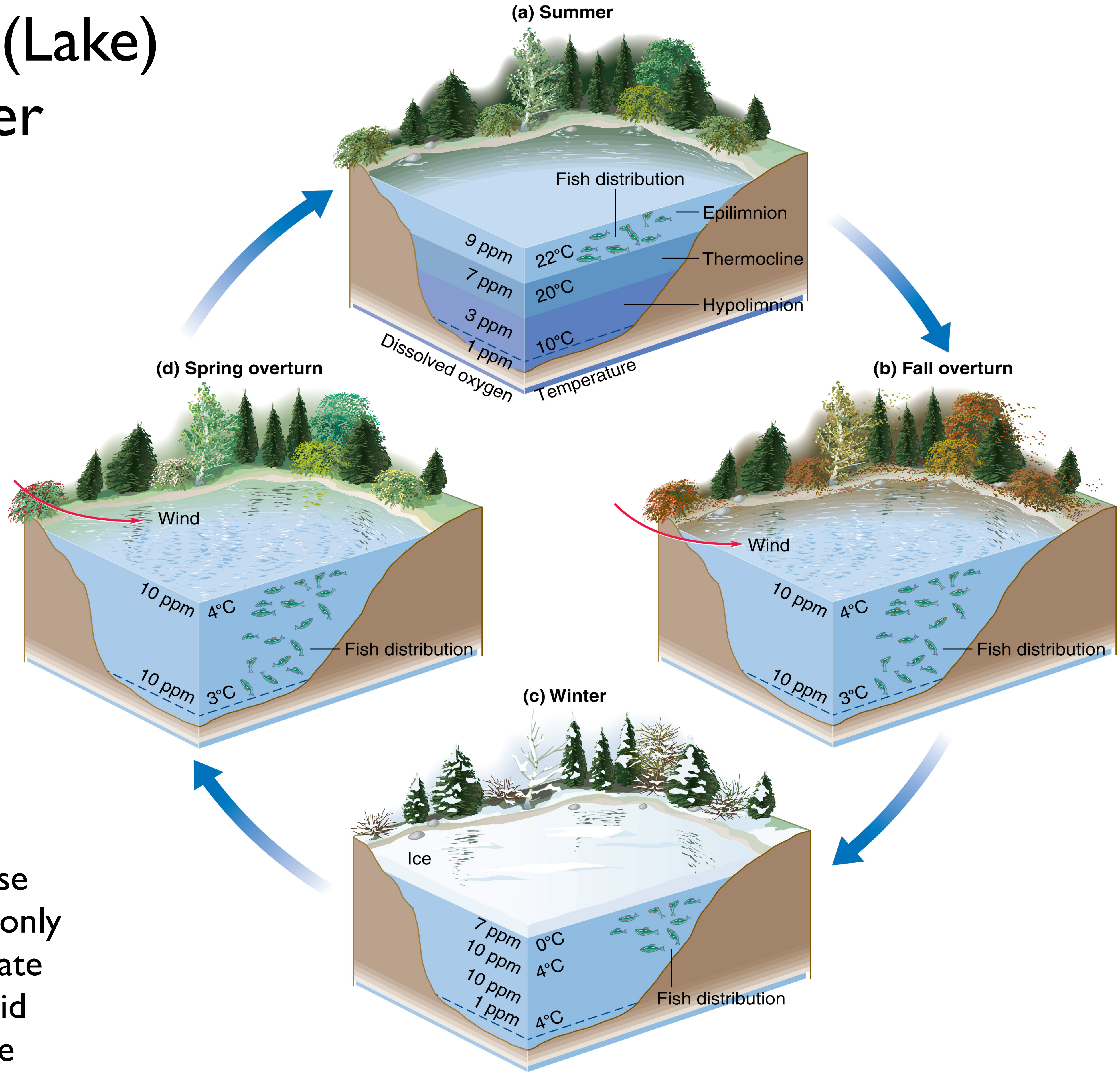

FRESHWATER STRATIFICATION
Littoral zone
Limnetic Zone
Photosynthesis
Benthic Zone
Benthic Zone
Photic Zone
Bacterial decomposition consumes oxygen → anaerobic respiration
Profundal Zone
Benthic Zone
Focus on the Abiotic conditions – Limiting factors

Layers of a Lake



Freshwater (Lake) Turnover

- Seasonal mixing of oxygen and nutrients in lake



Note: Water is most dense of 4 degrees Celcius. The only substance whose liquid state is more dense than its solid state. This explains why ice floats.

Aquatic Biomes:
A Closer Look @
Freshwater

WETLANDS

(a) Swamp, or wooded wetland
Trees © Vol. 16/PhotoDisc

(b) Marsh
No Trees © Vol. 16/PhotoDisc

(c) Coastal saltmarsh
No Trees © William P. Cunningham

WETLANDS

- Physical Environment: habitat inundated with water all of the time or some of the time
- Chemical Environment: high nutrients, low oxygen
- Geological Features: different types exists but n/a
- Photosynthetic Organisms: lilies, cattails, woody plants (in swamps), mosses (in bogs), most have adaptations for living in saturated soil
- Heterotrophs: birds, alligators, insects, otters, frogs, herons, crustaceans, dragonflies
- Human Impact: high capacity to filter pollutants and nutrients, among the most productive biomes on earth

WETLANDS

OLIGOTROPHIC LAKES / PONDS

OLIGOTROPHIC LAKES / PONDS

- Physical Environment: standing bodies of water lakes (large), ponds (smaller), rocky bottoms, cold, clear

- Chemical Environment: low nutrients, high oxygen, low decomposition rates

- Geological Features: become eutrophic over time, less surface area relative to their depth

- Photosynthetic Organisms: littoral zone has rooted and floating plants, limnetic zone has a variety of phytoplankton and cyanobacteria

- Heterotrophs: zooplankton, invertebrates, fish

- Human Impact: fertilizer run off and waste dumping causing algal blooms, oxygen depletion and fish kills

- Point of Interest: n/a

OLIGOTROPHIC LAKES / PONDS

EUTROPHIC LAKES / PONDS

EUTROPHIC LAKES / PONDS

- Physical Environment: standing bodies of water lakes (large), ponds (smaller), muddy bottoms, warm, murky
- Chemical Environment: high nutrients, low oxygen, high decomposition rates
- Geological Features: more surface area relative to their depth
- Photosynthetic Organisms: littoral zone has rooted and floating plants, limnetic zone has a variety of phytoplankton and cyanobacteria
- Heterotrophs: zooplankton, invertebrates, fish
- Human Impact: fertilizer run off and waste dumping causing algal blooms, oxygen depletion and fish kills
- Point of Interest: cultural eutrophication often shows up on AP exam

EUTROPHIC LAKES / PONDS

STREAMS / RIVERS

STREAMS / RIVERS

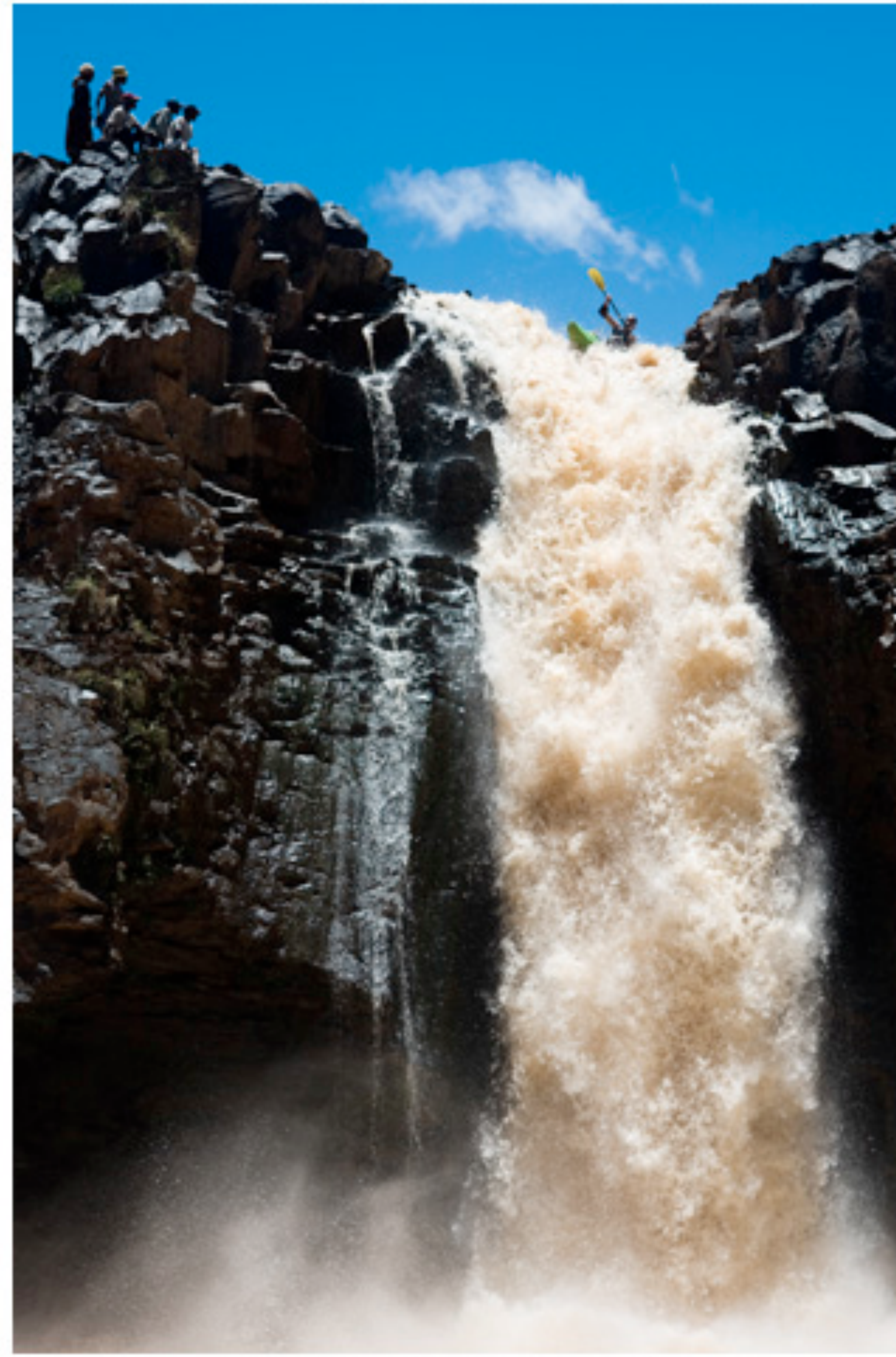
- Physical Environment: currents are most prominent feature, headwaters: cold, clear, turbulent, swift; tributaries: warmer, turbid, slow
- Chemical Environment: salt and nutrients increase moving away from headwaters, oxygen generally decreases
- Geological Features: headwaters: narrow with rocky bottoms and alternating depths, tributaries: wide with sediment bottoms
- Photosynthetic Organisms: phytoplankton and rooted aquatic plants
- Heterotrophs: fish and invertebrates
- Human Impact: negative impacts from dams and pollution
- Point of Interest: rivers are ranked from 1-6 for rafting difficulty

RIVER Classifications

© by Ian Garcia

Tyler Bradt, 65/70ft Tomata Falls, Rio Alseseca, Mexico.

Tyler Bradt Exclusive Interview kayaksession.com



© Pat Camblin (as seen in portfolio ks28)

Tyler Bradt Mazyfalls Madagascar

World Record...186 feet!

STREAMS / RIVERS

Aquatic Biomes:
A Closer Look @
Salt Water

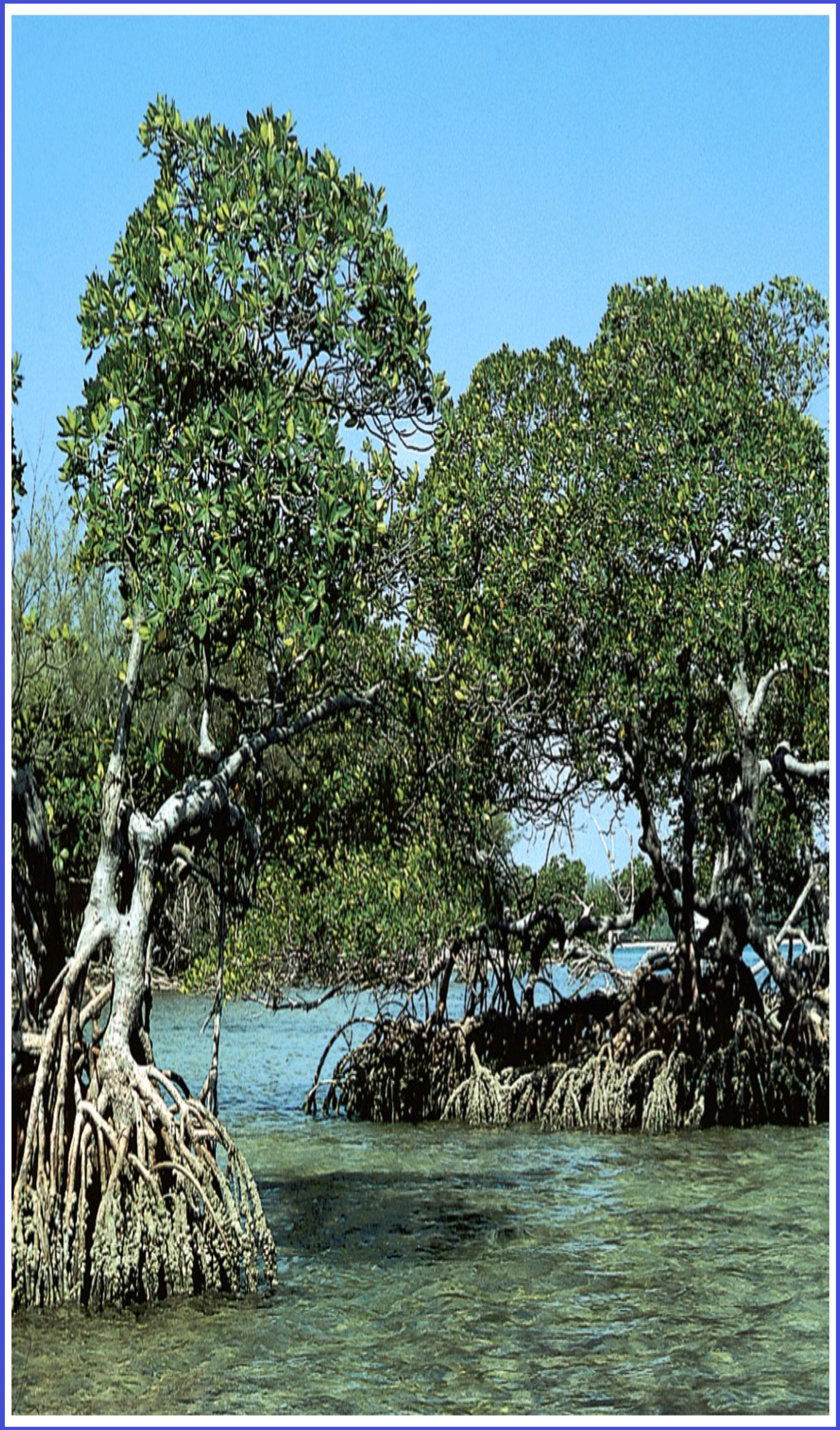
ESTUARIES

© Andrew Martinez/Photo Researchers

ESTUARIES

- Physical Environment: transition between river and sea, higher density sea water on bottom, less dense fresh water on top
- Chemical Environment: salinity varies spatially and temporally
- Geological Features: tidal channels, mud flats, islands, natural levees
- Photosynthetic Organisms: saltmarsh grass, algae, phytoplankton
- Heterotrophs: invertebrates, fish, birds, waterfowl, marine mammals
- Human Impact: filling and dredging for development, pollution
- Point of Interest: highly productive biome, crucial breeding and feeding grounds for many species

ESTUARIES



INTERTIDAL ZONES

INTERTIDAL ZONES

- Physical Environment: periodically submerged and exposed by the tides
- Chemical Environment: oxygen and nutrients generally high
- Geological Features: rocky or sandy substrates, shape of bay or coastline also influences magnitude of tide
- Photosynthetic Organisms: marine algae, sea grass
- Heterotrophs: mollusks, crabs, starfish, crustaceans, sponges, sea anemones, small fish
- Human Impact: oil spills
- Point of Interest: Bay of Fundy has a tidal range of 55 feet

INTERTIDAL ZONES

OCEAN PELAGIC ZONE

OCEAN PELAGIC ZONE

- Physical Environment: open blue water
- Chemical Environment: high oxygen, low nutrients, thermally stratified
- Geological Features: covers 70% of earth's surface, ave. depth 4000m
- Photosynthetic Organisms: phytoplankton, photosynthetic bacteria
- Heterotrophs: zooplankton, krill, jellies, invertebrates, fish, mammals, sea turtles, squid
- Human Impact: over fishing and pollution
- Point of Interest: photosynthetic plankton account for over 50% of photosynthetic activity on earth

OCEAN PELAGIC ZONE

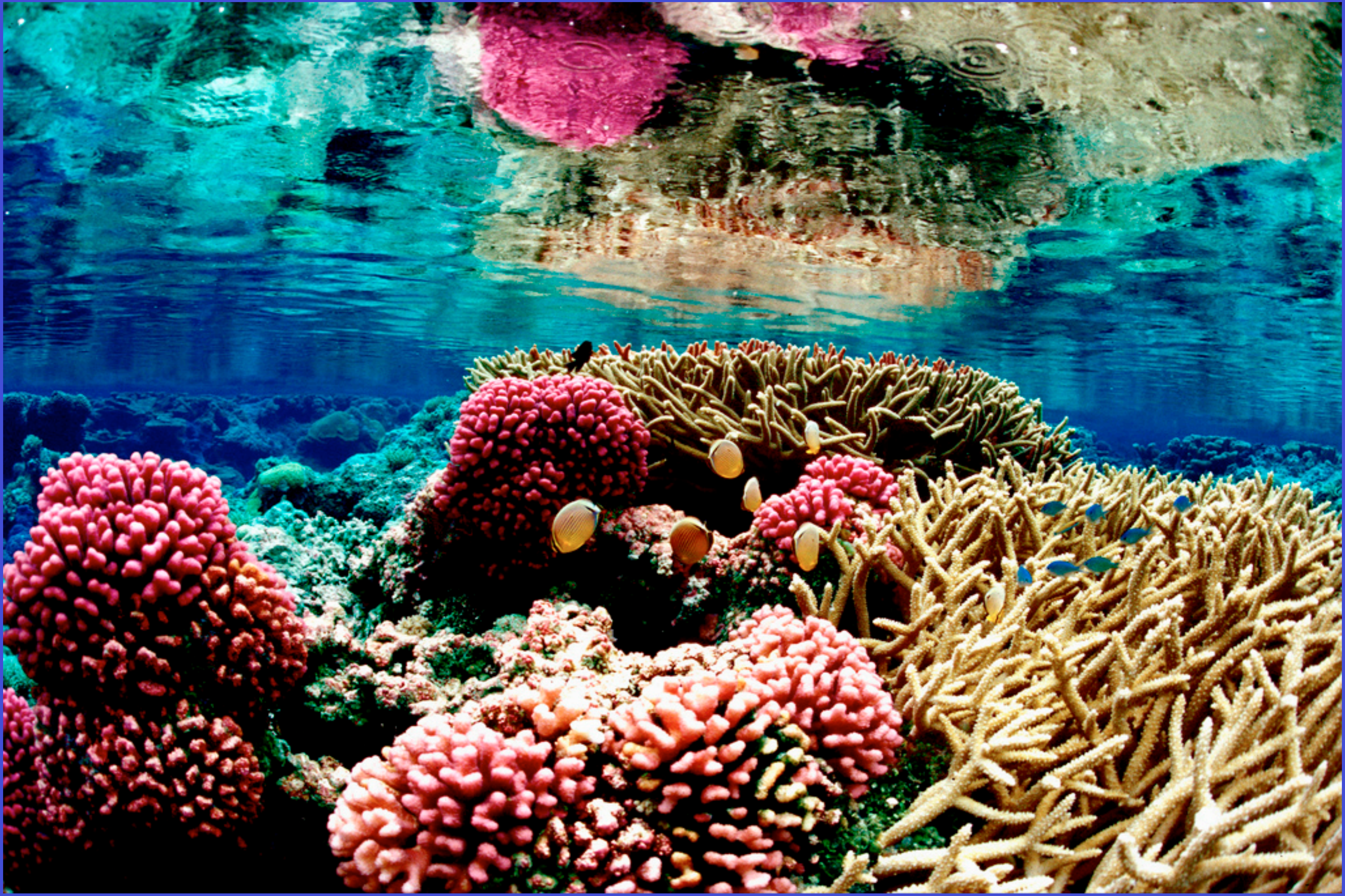
CORAL REEFS

© Vol. 89/PhotoDisc/Getty RF

CORAL REEFS

- Physical Environment: photic zone of stable tropical marine environments, high clarity water, calcium carbonate skeletons
- Chemical Environment: require high oxygen concentrations
- Geological Features: solid substrates required for attachment
- Photosynthetic Organisms: unicellular algae living mutualistically with the corals, also red algae, green algae
- Heterotrophs: corals, invertebrates, fish, high biodiversity
- Human Impact: over fishing and coral bleaching
- Point of Interest: see next page for different coral formations, Charles Darwin was of the scientists to explain reef formations

CORAL REEFS

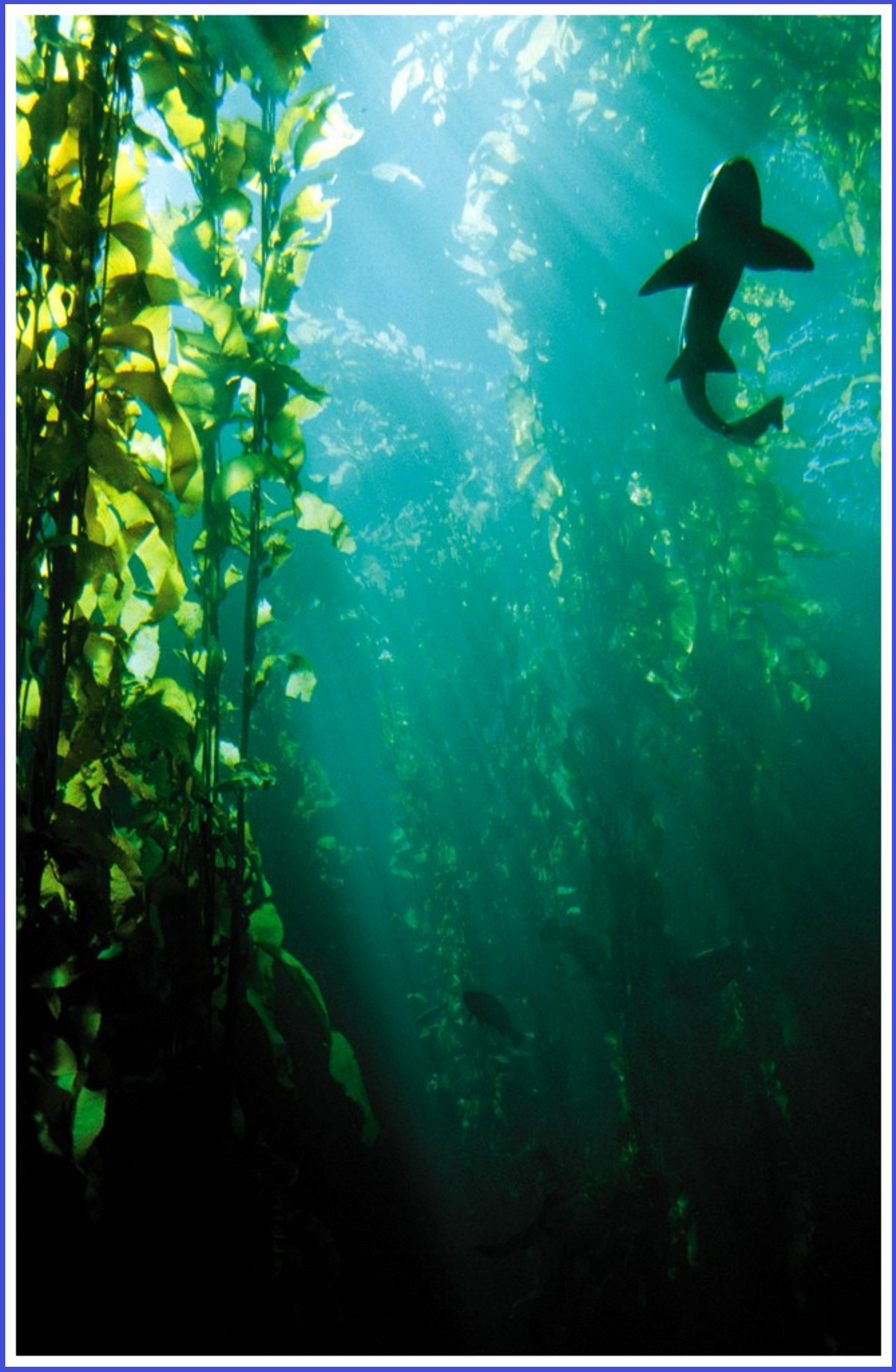


MARINE BENTHIC ZONE

MARINE BENTHIC ZONE

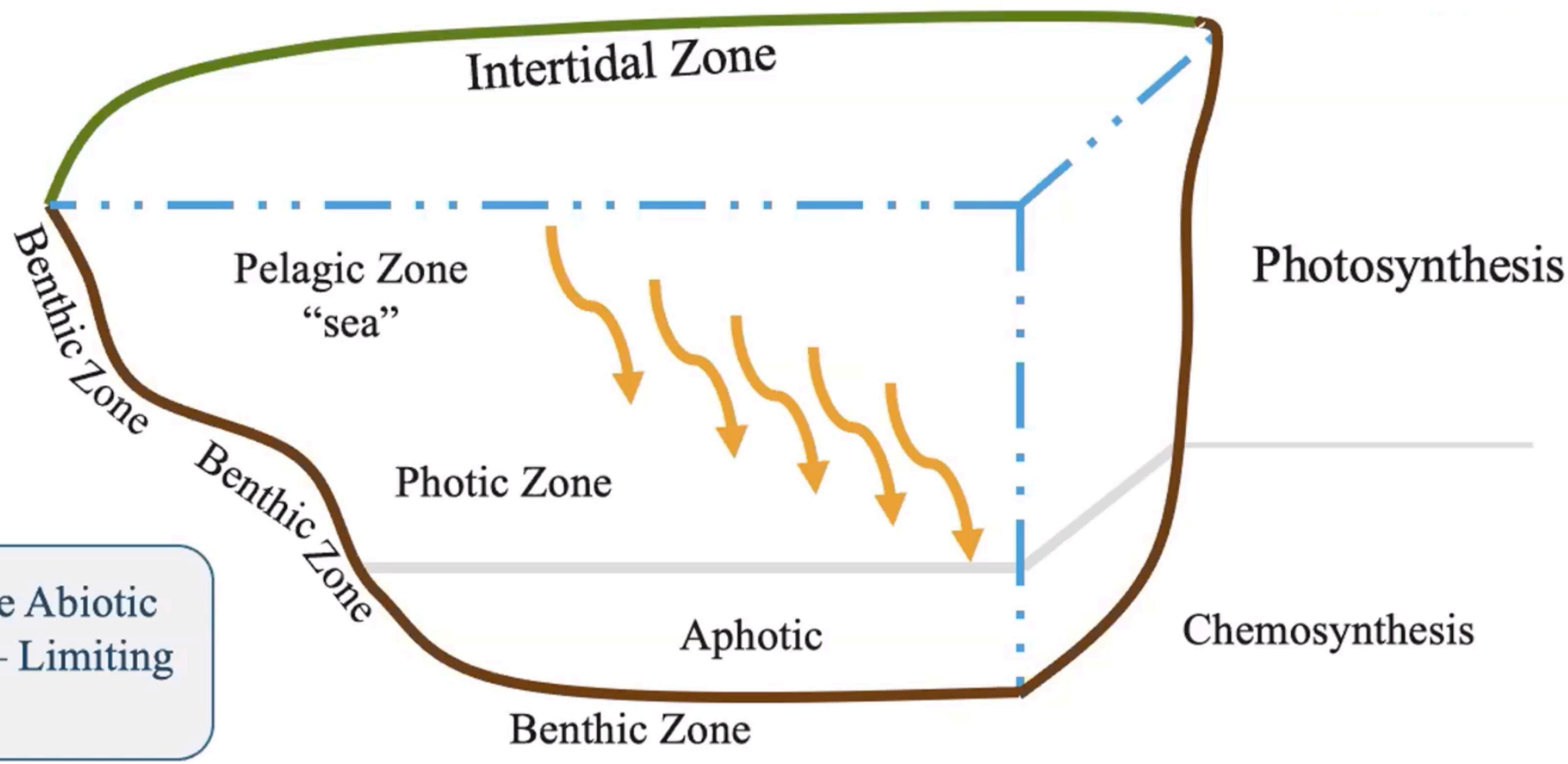
- Physical Environment: seafloor (shallow or deep), most is deep with no light, high pressure and very cold
- Chemical Environment: sufficient oxygen
- Geological Features: mostly soft sediments, a few places are rocky
- Photosynthetic Organisms: seaweeds and filamentous algae, deep benthic communities near geothermal vents have chemoautotrophic bacteria
- Heterotrophs: invertebrates, tube worms, fish, arthropods, echinoderms
- Human Impact: over fishing and pollution
- Point of Interest: the first cell may have originated in this zone (bya)

MARINE BENTHIC ZONE



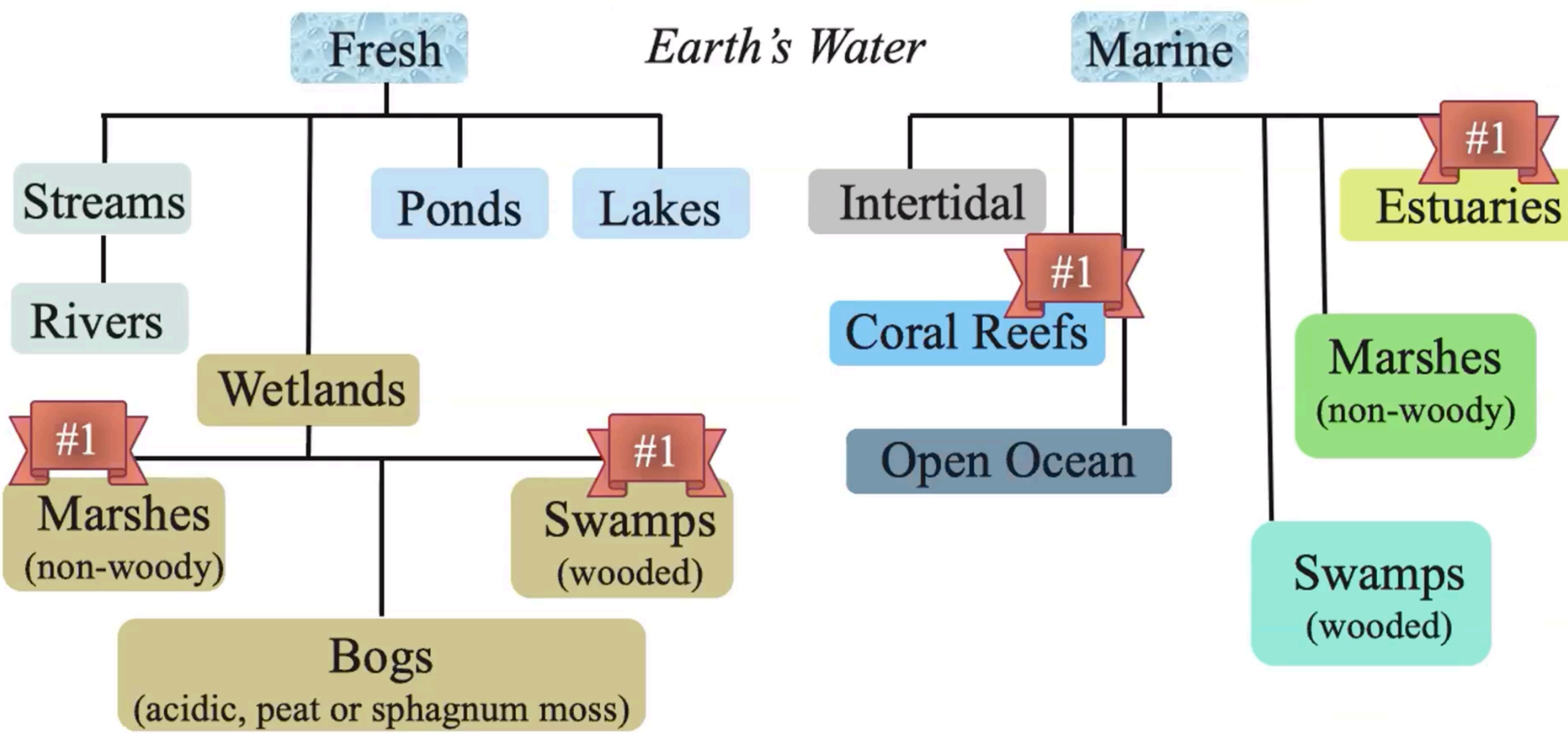
1.3

MARINE STRATIFICATION



Focus on the Abiotic conditions – Limiting factors

1.3



Earth's Water
Fresh
Streams
Rivers
Ponds
Lakes
Wetlands
#1
Marshes
(non-woody)
#1
Swamps
(wooded)
Bogs
(acidic, peat or sphagnum moss)
Marine
Intertidal
#1
Coral Reefs
Open Ocean
#1
Estuaries
Marshes
(non-woody)
Swamps
(wooded)

1.3

MARINE ECOSYSTEMS

Vary with *depth*, *temperature*, and *salinity*.

Coral reefs and estuaries are the biomes with the highest **primary productivity** and **biodiversity**. (topic 1.8 and topic 2.1)

Nitrogen and phosphorus nutrient amounts are greater along the coastlines as a result of runoff into rivers and eventually estuaries.

1.3

Marine Ecosystems

Upwellings also bring **nutrients** from the depths of the ocean to the surface for **phytoplankton**

As organisms die, the *biomass* sinks to the bottom of the ocean where *decomposers* utilize the nutrients. Compare this to the decomposers on the the forest floor with leaf litter.

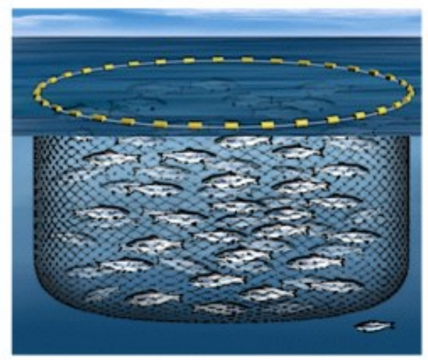
Secondary Productivity can also be high in cold water where there is an increase of dissolved oxygen present

Nonpoint Source Pollution (runoff from land)
Example: Agricultural runoff (fertilizers, pesticides, and livestock wastes) pollutes water.

Invasive Species
Example: Release of ships' ballast water, which contains foreign crabs, mussels, worms, and fishes.

Overfishing
Example: The populations of many commercial fish species are severely depleted.

Bycatch
Example: Fishermen unintentionally kill dolphins, sea turtles, and seabirds.



Aquaculture
Example: Produces wastes that can pollute ocean water and harm marine organisms.

Point Source Pollution
Example: Passenger cruise ships dump sewage, shower and sink water, and oily bilge water.

Coastal Development
Example: Developers destroy important coastal habitat, such as salt marshes and mangrove swamps.

Habitat Destruction
Example: Trawl nets (fishing equipment pulled along the ocean floor) destroy habitat.

Climate Change
Example: Coral reefs and polar seas are particularly vulnerable to increasing temperatures.

Stop and Think

What biomes would expect to be most challenging for organisms?

Can you think of any general or specific adaptations found in each biome?

Mammals generally get larger as move towards the poles can you guess why?

Can name any animals that live in high elevations? Can guess what adaptations they might have that allow them to be successful in this niche?

If you were drifting in life boat and needed to catch a fish for food. Would it be wiser to drop you only bait deep into the ocean or drag it on the surface? Why?

Introduction to BioGeoChemical Cycles

Conservation of Matter

- The **law of conservation of mass**, also known as **principle of mass/matter conservation** is that the mass of a closed system (in the sense of a completely isolated system) will remain constant over time. A similar statement is that mass cannot be created/ destroyed, although it may be rearranged in space, and changed into different types of particles.

- In other words: all of earth's "stuff" is constant, it is simply recycled and moved around through time

Conservation of Mass

- **Law of Conservation of Mass**: like energy, matter can not be created or destroyed.
  - Very little matter enters earth from space.
  - Thus the matter on *earth* is constant. Matter has been, is and will continue to be recycled over time.
  - Be Careful! Matter can be gained and lost from *ecosystems* themselves.

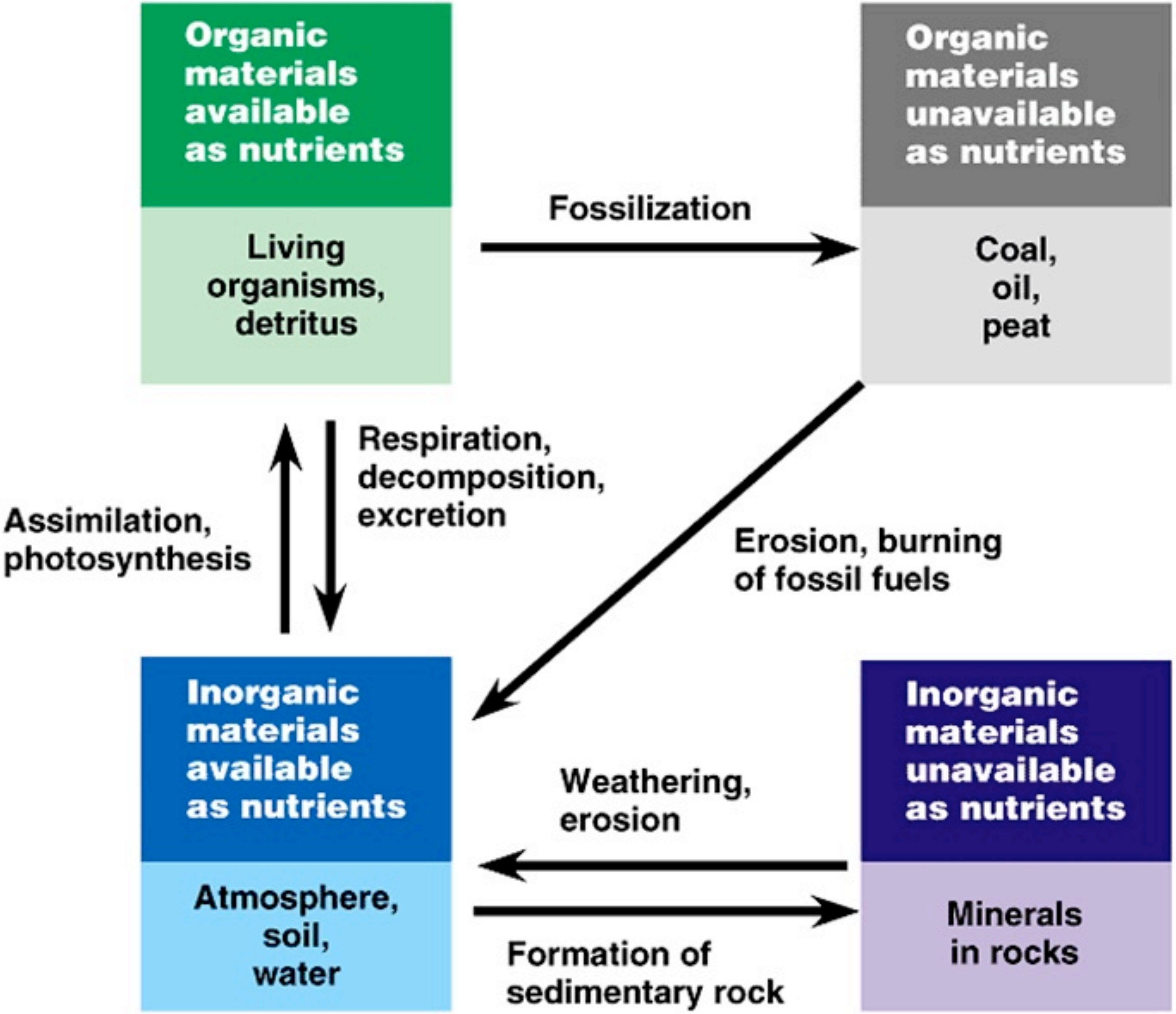
Biogeochemical Cycles

- These cycles occur on both on a local and global level.
- **A general look at cycles finds two key components:**
  - **A *Reservoir* (the location of the element)**
  - **A *Process* (the means of moving the element)**

Biogeochemical Cycles

- Reservoirs.
  - Atmosphere
  - Hydrosphere
  - Lithosphere
  - Biosphere

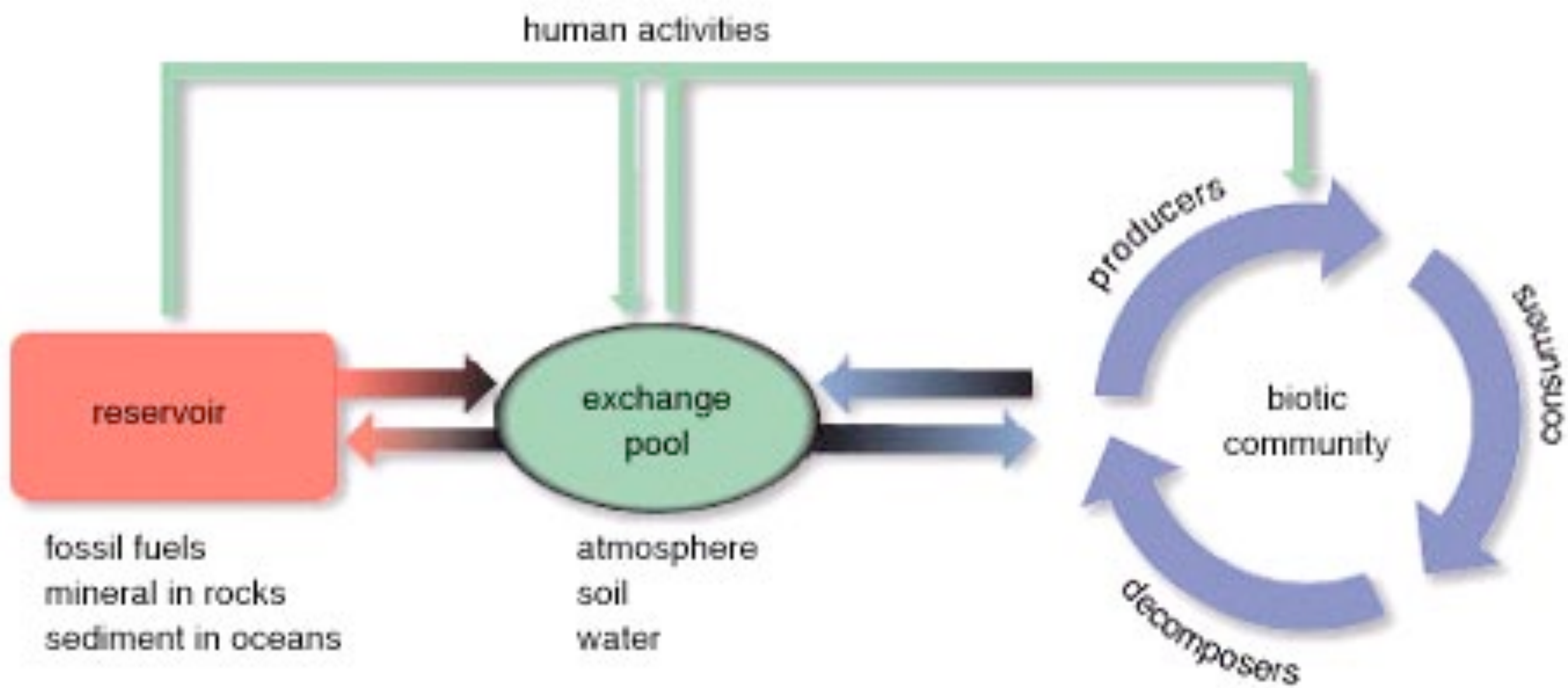
- Chemicals in these reservoirs have different average storage times
  - Long in lithosphere (rocks)
  - Short in the atmosphere
  - Intermediate in the hydrosphere and biosphere



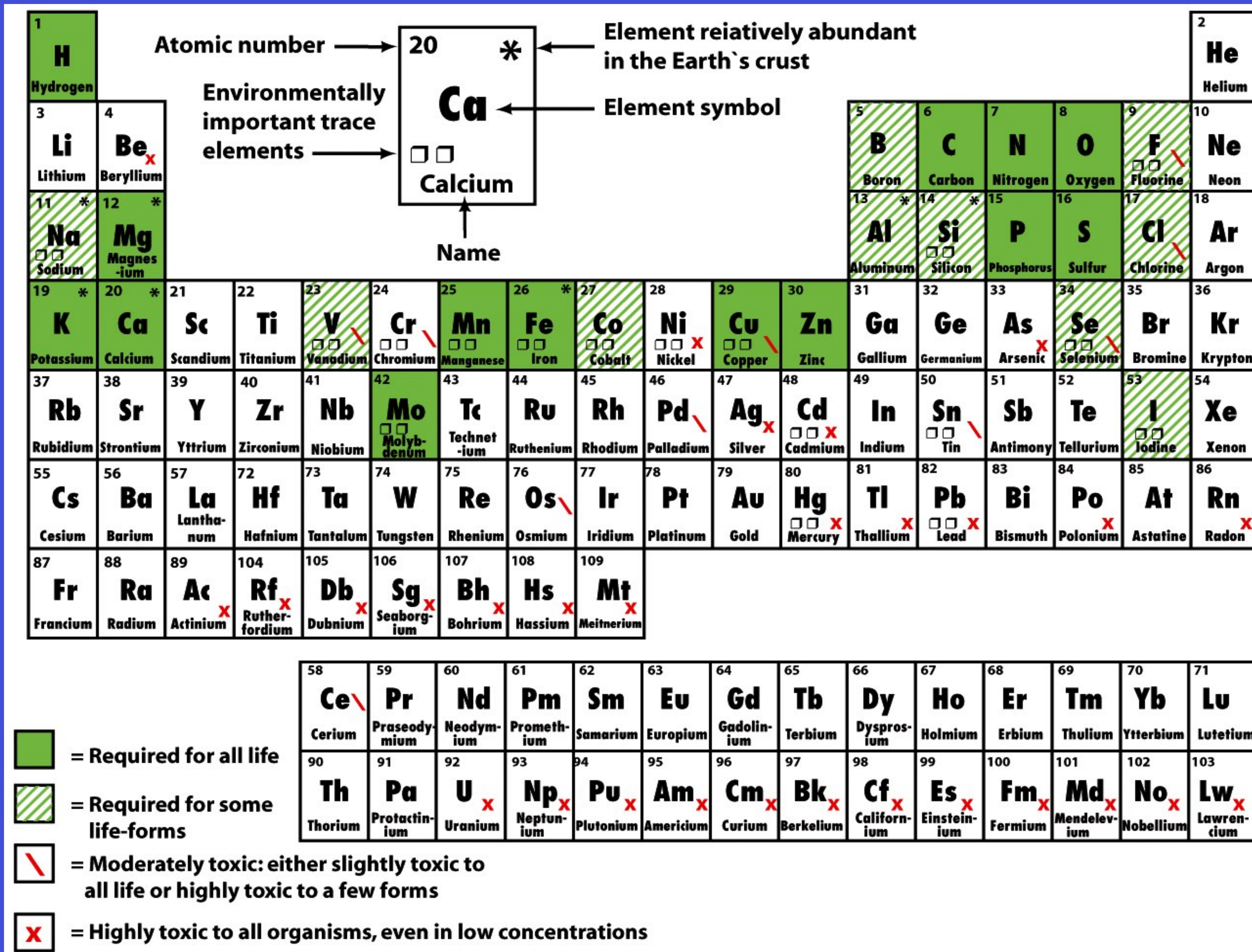
Can you match these reservoirs using the terms on the previous slide?

Simplified Version

A closer look!



kinda cool periodic table...



TOPIC 1.4

The Carbon Cycle

Required Course Content

ENDURING UNDERSTANDING

ERT-1

Ecosystems are the result of biotic and abiotic interactions.

LEARNING OBJECTIVE

ERT-1.D

Explain the steps and reservoir interactions in the carbon cycle.

ESSENTIAL KNOWLEDGE

ERT-1.D.1

The carbon cycle is the movement of atoms and molecules containing the element carbon between sources and sinks.

ERT-1.D.2

Some of the reservoirs in which carbon compounds occur in the carbon cycle hold those compounds for long periods of time, while some hold them for relatively short periods of time.

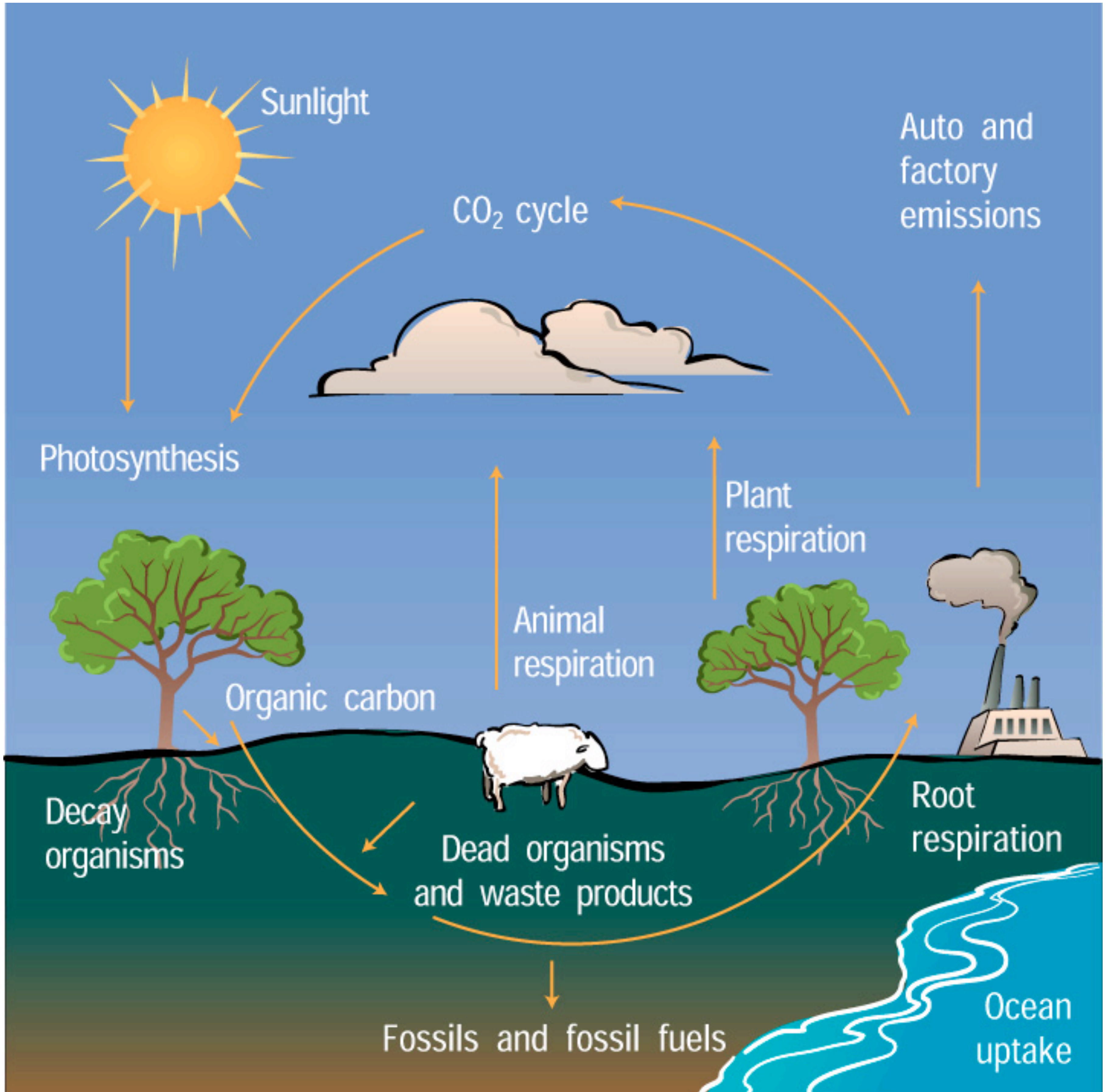
ERT-1.D.3

Carbon cycles between photosynthesis and cellular respiration in living things.

ERT-1.D.4

Plant and animal decomposition have led to the storage of carbon over millions of years. The burning of fossil fuels quickly moves that stored carbon into atmospheric carbon, in the form of carbon dioxide.

CARBON CYCLE



BIOLOGICAL IMPORTANCE

- Carbon is the backbone of all organic compounds essential for life.

FORMS AVAILABLE TO LIFE

- CO_2 used by autotrophs, many other organic forms used by the rest of life.

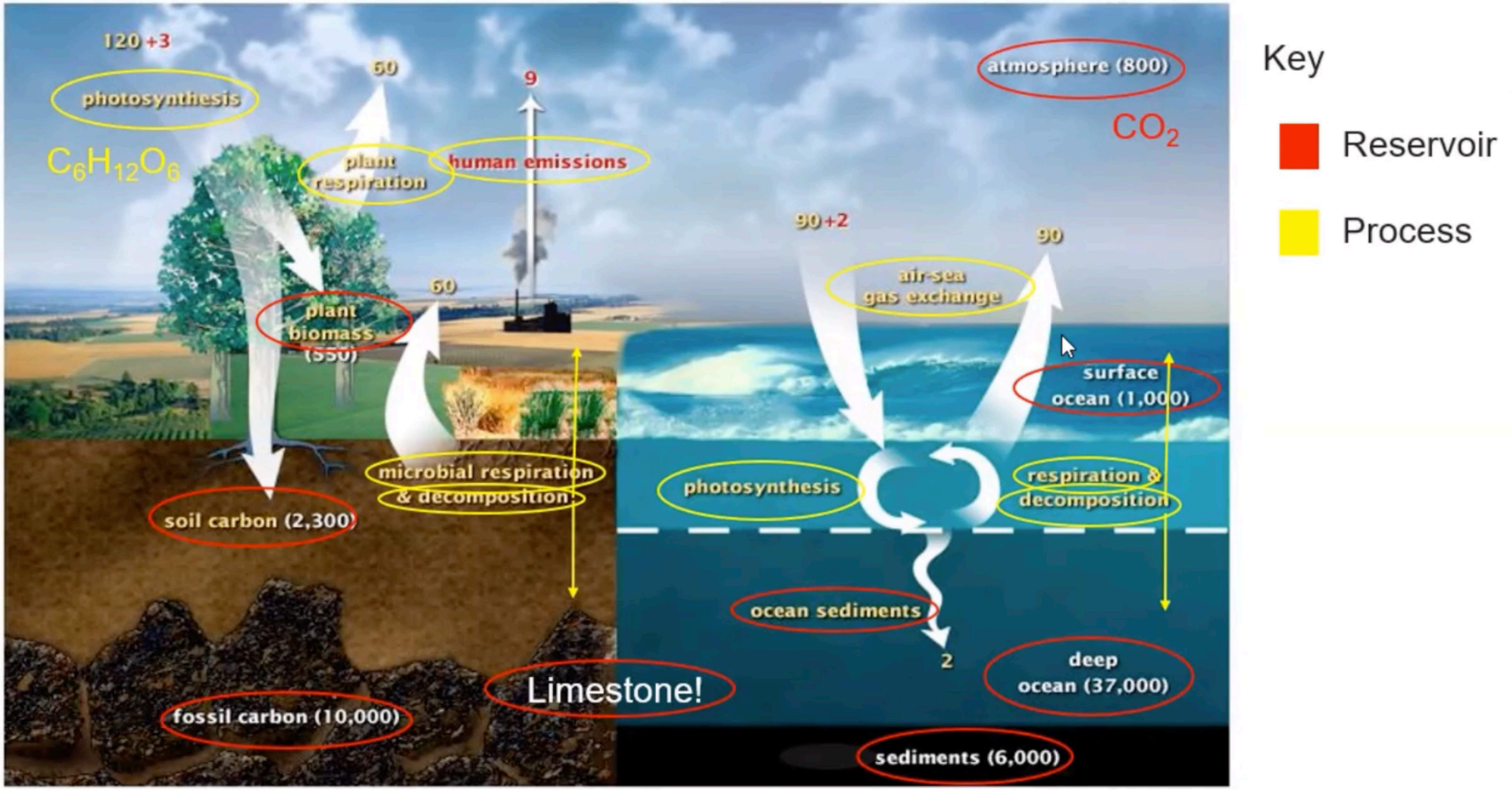
RESERVOIRS

- Fossil fuels, sediments of aquatic ecosystems, dissolved carbon in oceans, plant/animal biomass, atmosphere, sedimentary rocks (the largest)

KEY PROCESSES

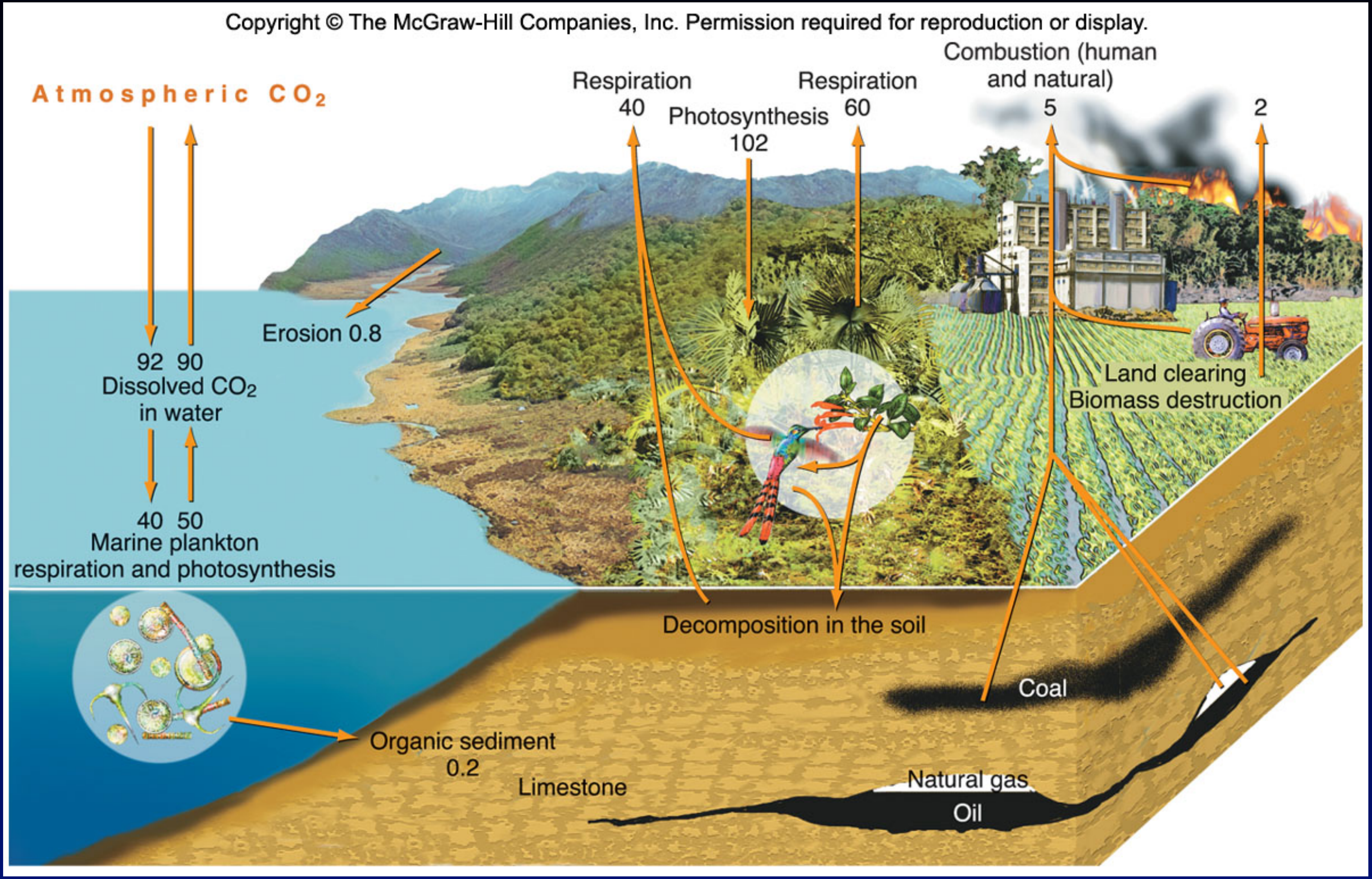
- Mainly photosynthesis and cellular respiration, burning of fossil fuels, volcanoes

1.4



https://earthobservatory.nasa.gov/features/CarbonCycle

Carbon Cycle



1.4

The Carbon Cycle

- The carbon cycle is the movement of atoms and molecules containing the element carbon between sources and sinks
- Some cycling of carbon happens quickly…other types of cycling take millions of years!
- The carbon cycle is a **biogeochemical cycle**, which is a self-regulating, naturally-occurring movement of chemical molecules through various sources and sinks (reservoirs).
- These cycles help stabilize and regulate the flow of matter through ecosystems
- Biogeochemical cycles can be disrupted by human activity

1.4

Quick Check Questions

- **Identify** a carbon sink that holds carbon for a long period of time
- **Identify** a carbon sink that hold carbon for a short period of time
- **Identify** one process that removes CO_2 from the atmosphere
- **Identify** one process that returns CO_2 to the atmosphere

Be sure to watch the second Carbon Cycle video for AP-style practice questions!

1.4

Fast Carbon Cycling

- Fast carbon cycling is largely the movement of carbon compounds through the **biosphere**-- the living organisms on Earth
- This type of cycling is driven by the cellular metabolism of **producers** in ecosystems
- The main biological processes involved in fast carbon cycling are **photosynthesis** and **cellular respiration**
- For fast carbon cycling, the primary carbon reservoir is the **atmosphere**
- The length of time a carbon compound spends in the atmosphere is relatively brief

photosynthesis $$6CO_2 + 6H_2O \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

cellular respiration $$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

1.4

Other Processes

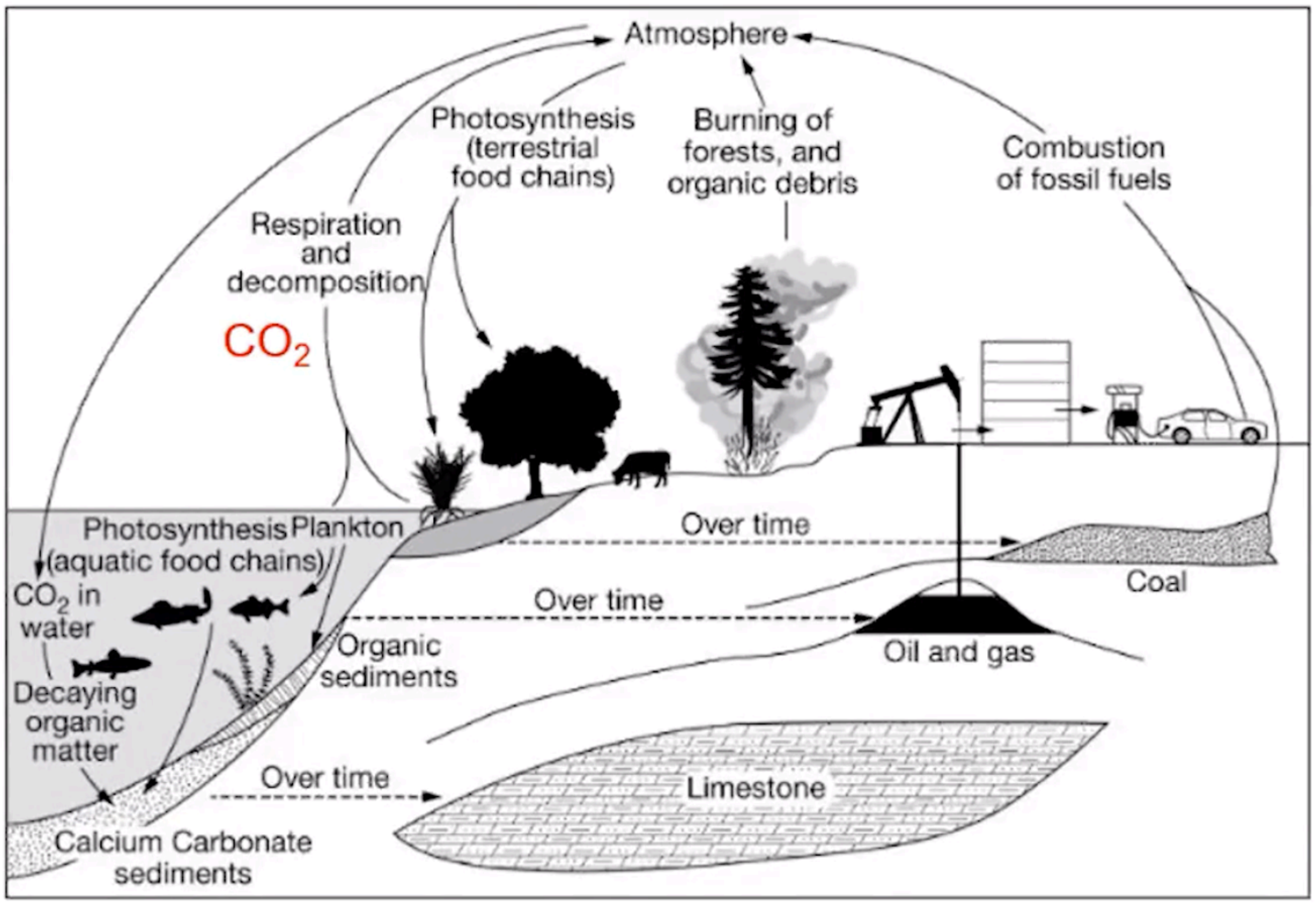
- During the process of **decomposition** of organic material, decomposer organisms help
  - Return CO_2 to the atmosphere through cellular respiration, and
  - Return carbon to the soil or water through breakdown of sugars in the bodies they are decomposing

- **Sedimentation and burial** organic material can result in a MUCH LONGER sequestration of carbon compounds. Once the carbon is buried, it is essentially removed from the fast carbon cycle.

- Remember, deep ocean sediments and fossil carbon (coal, oil, natural gas) are the largest reservoirs of carbon…and these are the result of sedimentation and burial.

- Long-term carbon reservoirs can return to cycling via…
  - Fossil fuel **extraction and combustion** (quick return to cycling)
  - **Uplift and weathering** of limestone (slow return to cycling)

1.4



- **Identify** a process that removes carbon from the atmosphere
- **Identify** a process that sequesters carbon from the atmosphere for a geologic period of time
- **Explain** how the combustion of fossil fuels returns carbon to the atmosphere
- **Explain** the role of decomposition in the carbon cycle

Science Practice 2.B:
Explain relationships between different characteristics of environmental concepts, processes or models represented visually

TOPIC 1.5

The Nitrogen Cycle

Required Course Content

ENDURING UNDERSTANDING

ERT-1

Ecosystems are the result of biotic and abiotic interactions.

LEARNING OBJECTIVE

ERT-1.E

Explain the steps and reservoir interactions in the nitrogen cycle.

ESSENTIAL KNOWLEDGE

ERT-1.E.1

The nitrogen cycle is the movement of atoms and molecules containing the element nitrogen between sources and sinks.

ERT-1.E.2

Most of the reservoirs in which nitrogen compounds occur in the nitrogen cycle hold those compounds for relatively short periods of time.

ERT-1.E.3

Nitrogen fixation is the process in which atmospheric nitrogen is converted into a form of nitrogen (primarily ammonia) that is available for uptake by plants and that can be synthesized into plant tissue.

ERT-1.E.4

The atmosphere is the major reservoir of nitrogen.

1.5

The Importance of Nitrogen

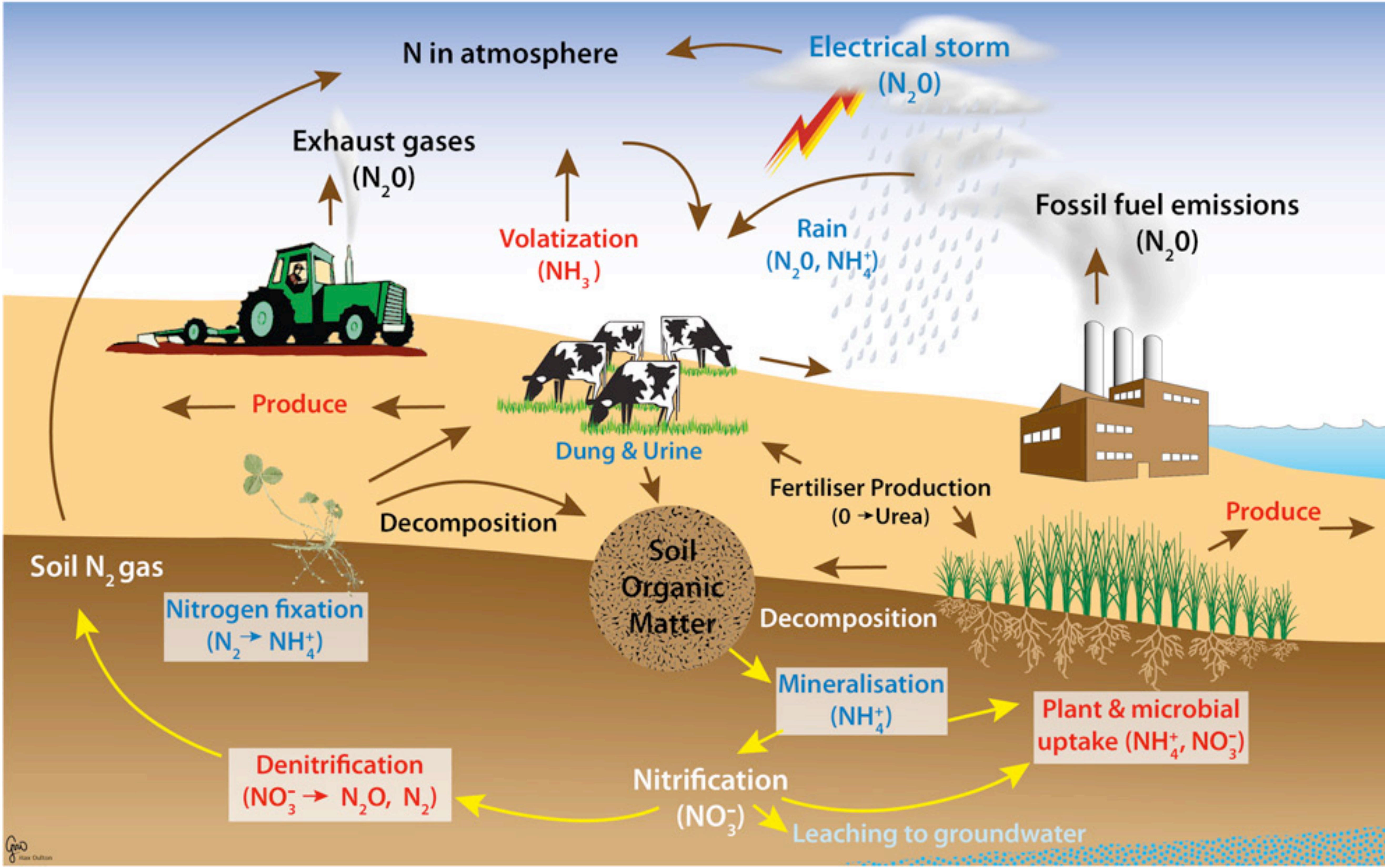
- Nitrogen is vitally important in living things because it is a major component of amino acids (the building block of proteins) and nucleic acids (the building blocks of DNA)

- Nitrogen is a **limiting factor** in ecosystems
  - A limiting factor is a resource that is scarce in an ecosystem, but is vital to its functioning

- Producers are the basis of the trophic structure of ecosystems, and producers need nitrogen to grow
  - Fertilizer contains nitrogen (and other elements) because the addition of nitrogen enhances producer growth!

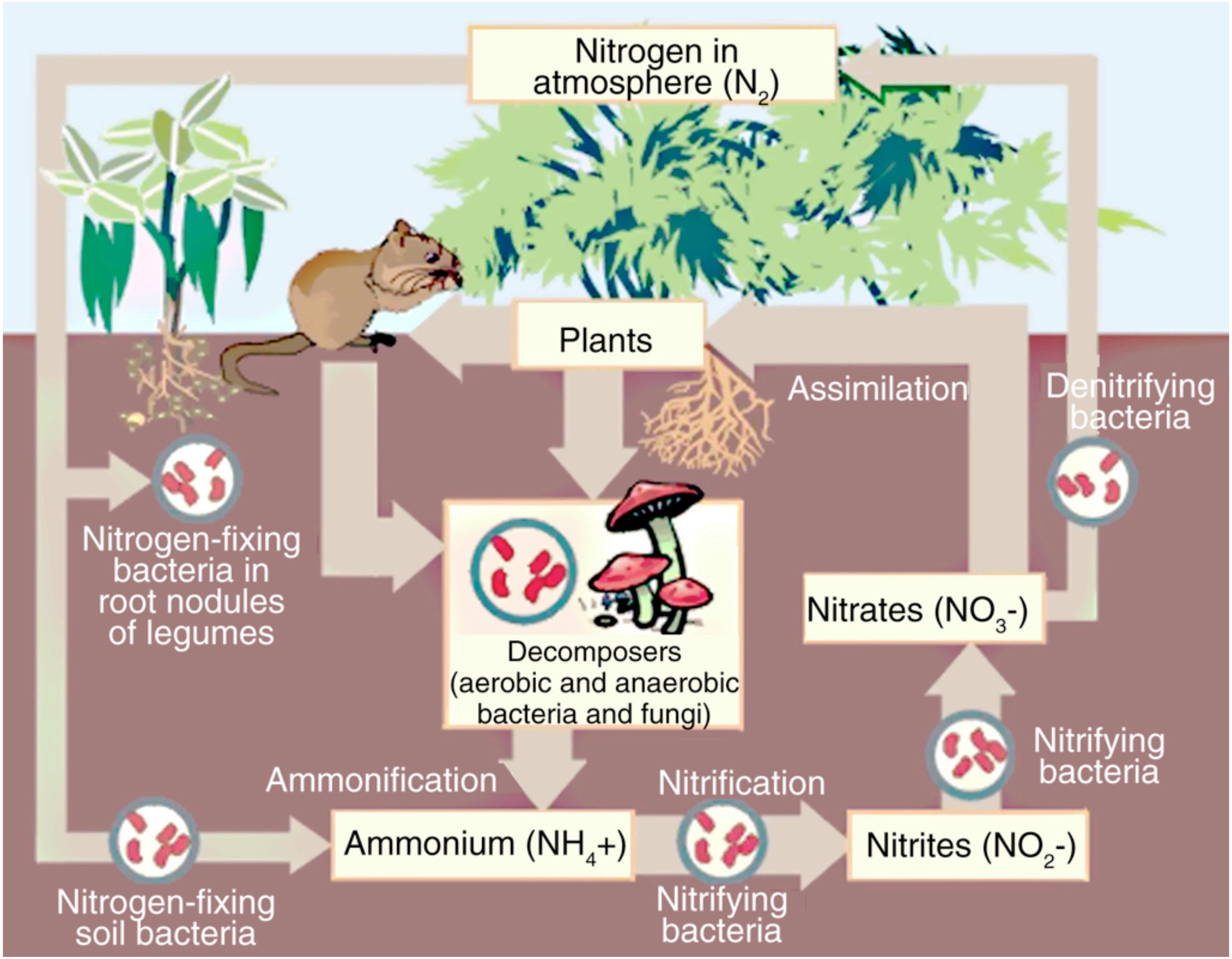
Fotokostic / Shutterstock.com

NITROGEN CYCLE (abiotic +)

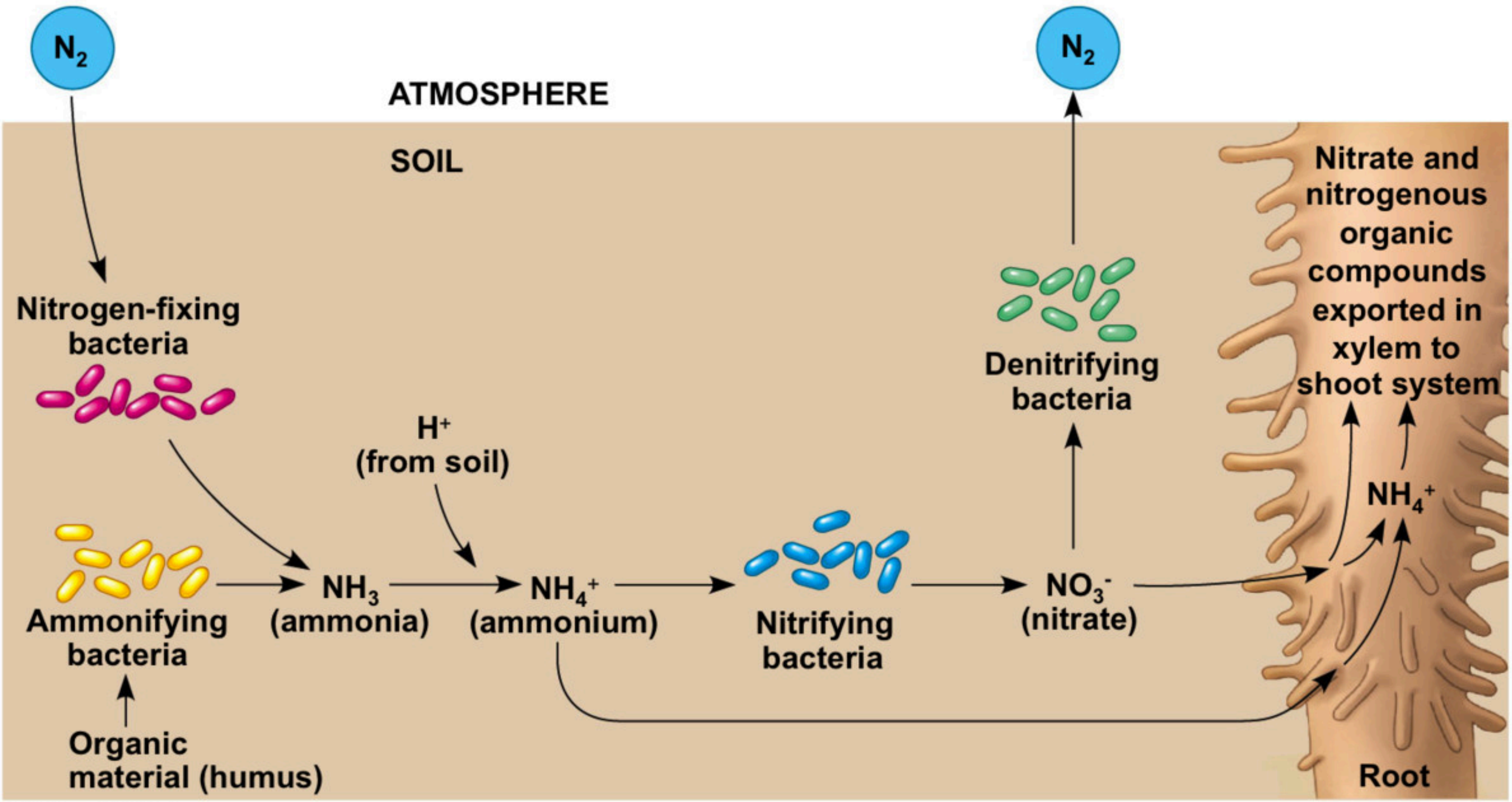


Circle the arrows representing abiotic pathways

NITROGEN CYCLE (biotic focus)



Nitrogen Cycle



1.5

1. **Fixation:** N_2 fixed by lightning (abiotic) or microbes in soil/root nodules (biotic)

2. **Ammonification:** NH_3 converted to NH_4^+ by soil bacteria; NH_3 can also be added by decay of organic material
   - Note: Plants *can* assimilate NH_3/NH_4^+ directly, but they also assimilate NO_3^-

3. **Nitrification:** (2 stages): NH_4^+ converted to NO_2^-, then NO_3^-

4. **Assimilation:** NO_3^- uptaken by plants through roots (then to animals)

5. **Denitrification:** NO_3^- can be converted back to N_2 by soil bacteria

BIOLOGICAL IMPORTANCE

- Nitrogen is an important part of proteins and nucleic acids.

FORMS AVAILABLE TO LIFE

- Bacteria can use ammonium (NH_4^+), nitrates (NO_3^-), nitrites (NO_2^-) and some organic forms. Plants use all of the above except nitrites (NO_2^-). Animals can only use organic forms.

RESERVOIRS

- Atmosphere(the largest), soils, sediments of aquatic ecosystems, dissolved in water and biomass of living organisms

KEY PROCESSES

- Mainly nitrogen fixation, lightning, industrial fertilizers

1.5

The Nitrogen Cycle – Big Picture

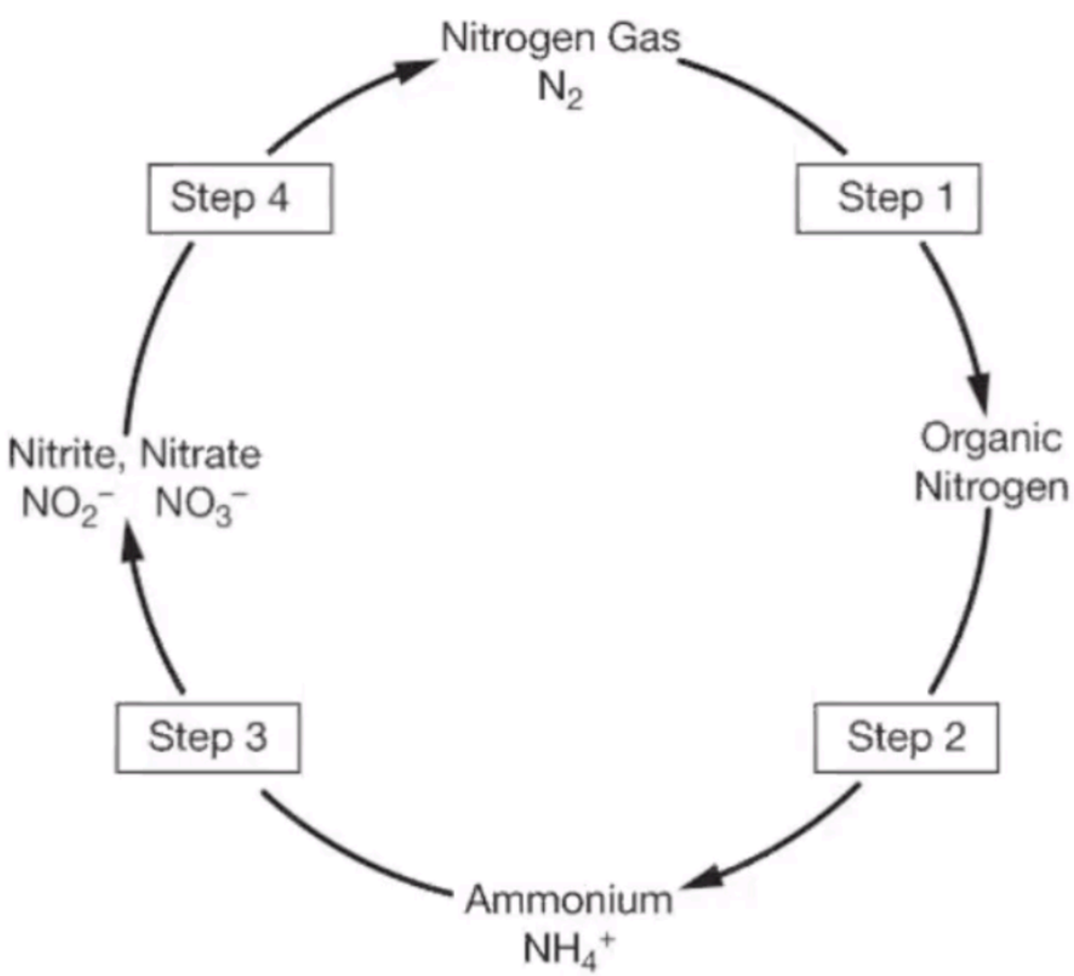
- The **nitrogen cycle** is the movement of atoms and molecules containing the element nitrogen between sources and sinks
- The nitrogen cycle (like the carbon cycle) is a **biogeochemical cycle**, which is a self-regulating, naturally-occurring movement of chemical molecules through various sources and sinks (reservoirs).
- These cycles help stabilize and regulate the flow of matter through ecosystems
- The nitrogen cycle can be disrupted by human activity
    - You'll learn more about nitrogen cycle disruption in Unit 5 and Unit 8!

1.5

Nitrogen Reservoirs

- The nitrogen cycle is primarily driven by **microbial action** (biotic)
- The **atmosphere** is the major reservoir of nitrogen (78% of gases in the troposphere)
- Unlike carbon, most reservoirs of nitrogen store the element for **short periods of time**. There are few substantial geologic stores of nitrogen.

1.5

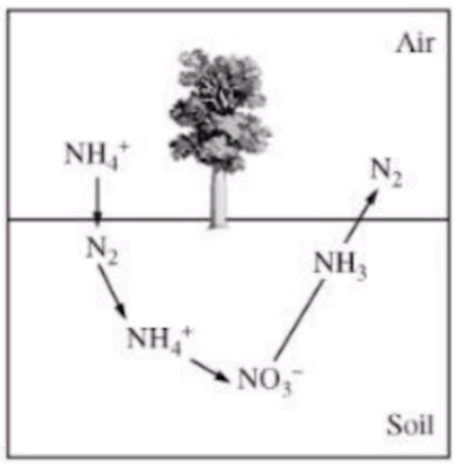


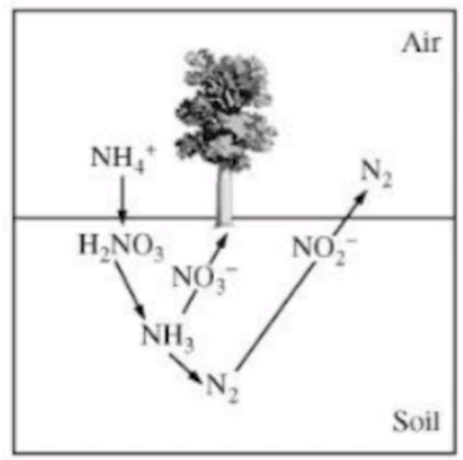
Source: released AP exam. Taken from: AP Classroom

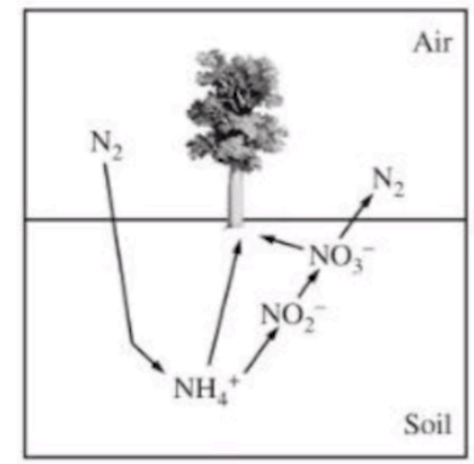
- **Identify** and **describe** a *biotic* process occurring at Step 1
- **Identify** the step that returns nitrogen to its primary reservoir and **identify** the primary reservoir for nitrogen
- A farmer decides to apply an insecticide to his crops. Unfortunately, this chemical is also harmful to soil microorganisms. **Explain** a possible effect of the application of this insecticide on nitrogen cycling in the farmer's field

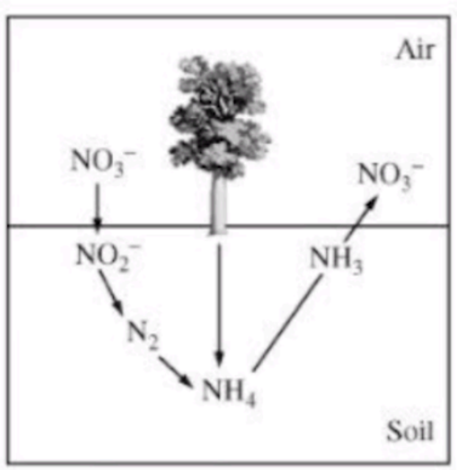
Science Practice 2.B:
Explain relationships between different characteristics of environmental concepts, processes or models represented visually

1.5



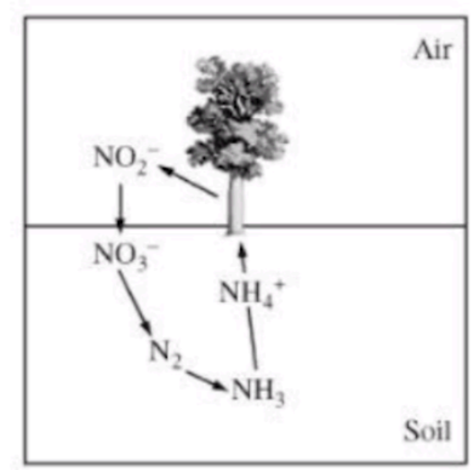






Which of these simplified diagrams correctly depicts the nitrogen cycle?

How did you determine your answer?



Source: released AP exam. Taken from: AP Classroom

Science Practice 2.B:
Explain relationships between different characteristics of environmental concepts, processes or models represented visually

Nitrogen Cycle

- Nitrogen is needed to make proteins and nucleic acids

  - ❖ Nitrogen-fixing bacteria have an enzyme caled nitrogenase that splits the triple covalent bond between the atoms of nitrogen in nitrogen gas.
  - ❖ Higher organisms are therefore dependent on these bacteria to make nitrogen available for their use.

    - Members of the bean family (legumes) have nitrogen-fixing bacteria living in their root tissue.
      - ➢ ex. peas, alfalfa, many beans

Nitrogen nodules on bean plant

© Nigel Cattlin/Visuals Unlimited.

Nitrogen Cycle

- ***Nitrogen and phosphorous*** are most likely to be the “limiting factors” of plant growth.

- Ironic since nearly 80% of the atmosphere is Nitrogen gas!

TOPIC 1.6

The Phosphorus Cycle

Required Course Content

ENDURING UNDERSTANDING

ERT-1

Ecosystems are the result of biotic and abiotic interactions.

LEARNING OBJECTIVE

ERT-1.F

Explain the steps and reservoir interactions in the phosphorus cycle.

ESSENTIAL KNOWLEDGE

ERT-1.F.1

The phosphorus cycle is the movement of atoms and molecules containing the element phosphorus between sources and sinks.

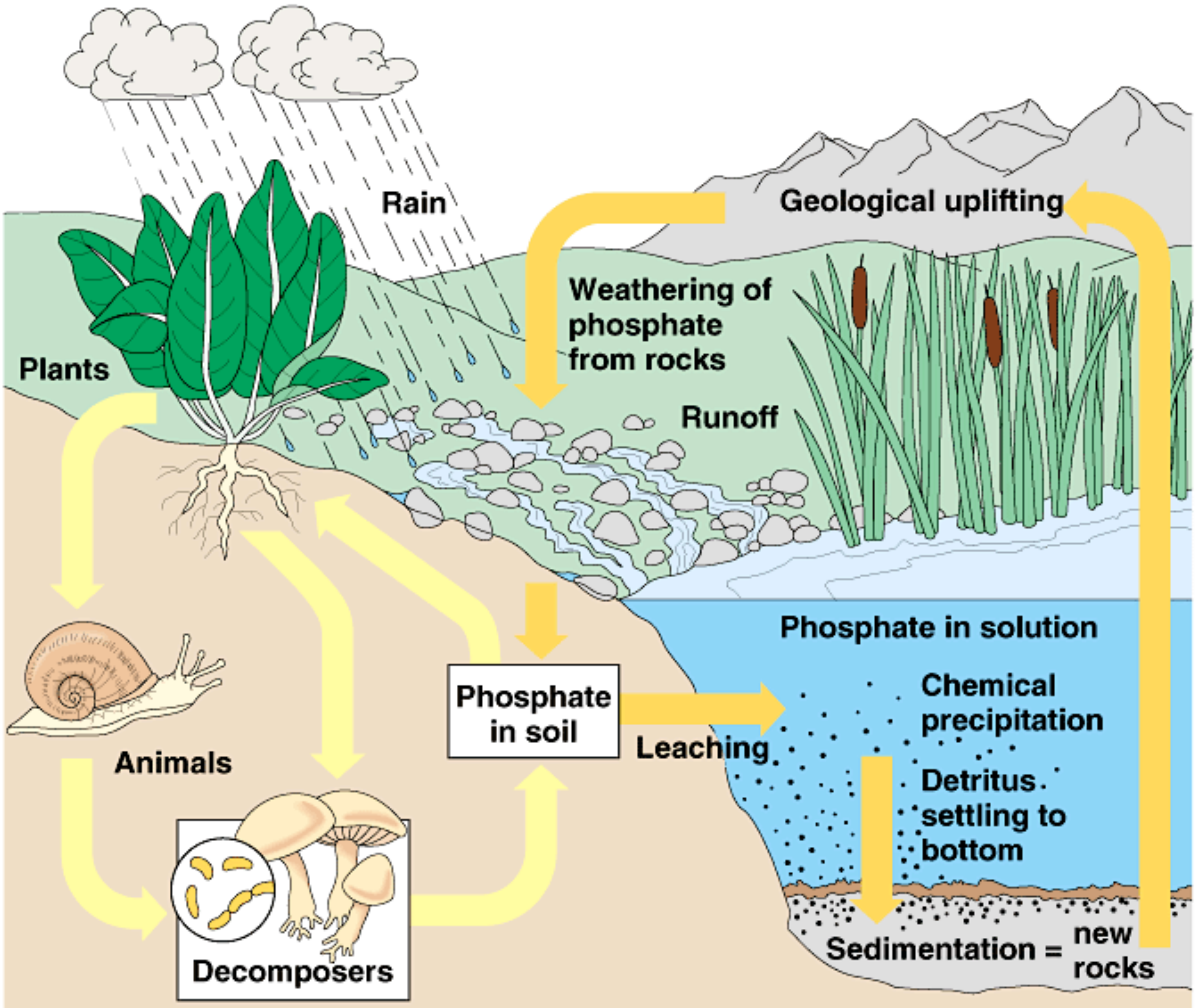
ERT-1.F.2

The major reservoirs of phosphorus in the phosphorus cycle are rock and sediments that contain phosphorus-bearing minerals.

ERT-1.F.3

There is no atmospheric component in the phosphorus cycle, and the limitations this imposes on the return of phosphorus from the ocean to land make phosphorus naturally scarce in aquatic and many terrestrial ecosystems. In undisturbed ecosystems, phosphorus is the limiting factor in biological systems.

PHOSPHORUS CYCLE



BIOLOGICAL IMPORTANCE

- Phosphorus is an important part of phospholipids (needed to make cell membranes), nucleic acids and ATP. In addition phosphorus is a mineral constituent of bones and teeth.

FORMS AVAILABLE TO LIFE

- Phosphates (PO_4^{3-}) absorbed by plants

RESERVOIRS

- Sedimentary rocks, soil, dissolved in the ocean and in biomass of organisms.

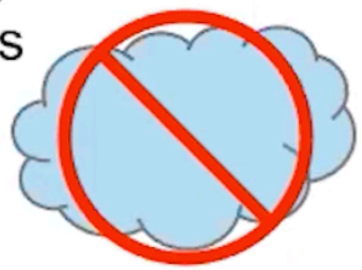
KEY PROCESSES

- Weathering of rocks, leaching form soil, eaten by consumers, excretion by organisms

1.6

The Importance of Phosphorus

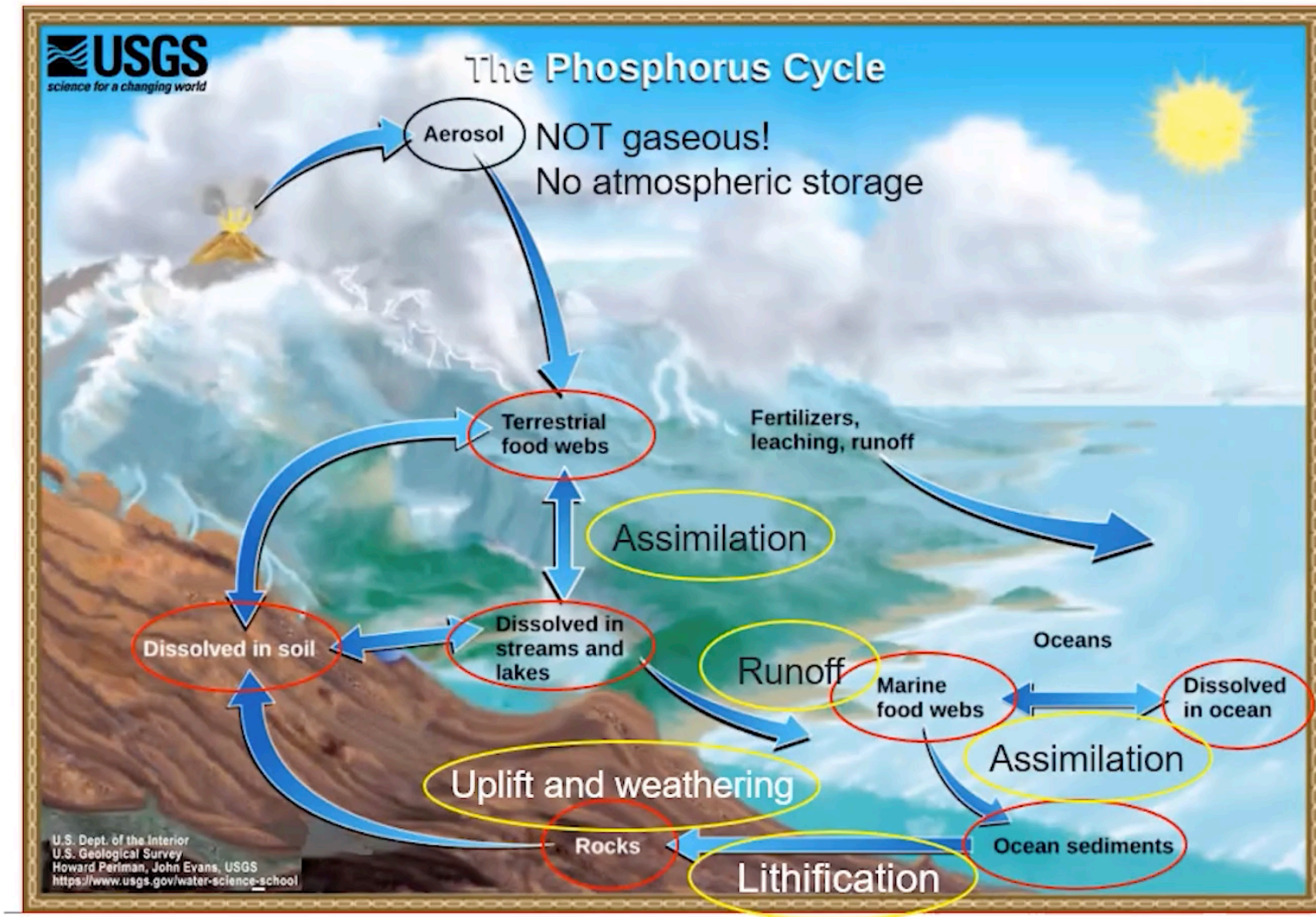
- The phosphorus cycle is a slooow cycle
  - Driven mainly by geologic processes
  - **NO ATMOSPHERIC PHASE**



- Because of the lack of atmospheric phosphorus and the length of time it takes to cycle, phosphorus is a **limiting factor** in ecosystems

- Producers need phosphorus to grow, and producers are the basis of an ecosystem's trophic structure. This makes phosphorus vitally important in ecosystems
  - Fertilizer also contains phosphorus because of its ability to aid the growth of producers!

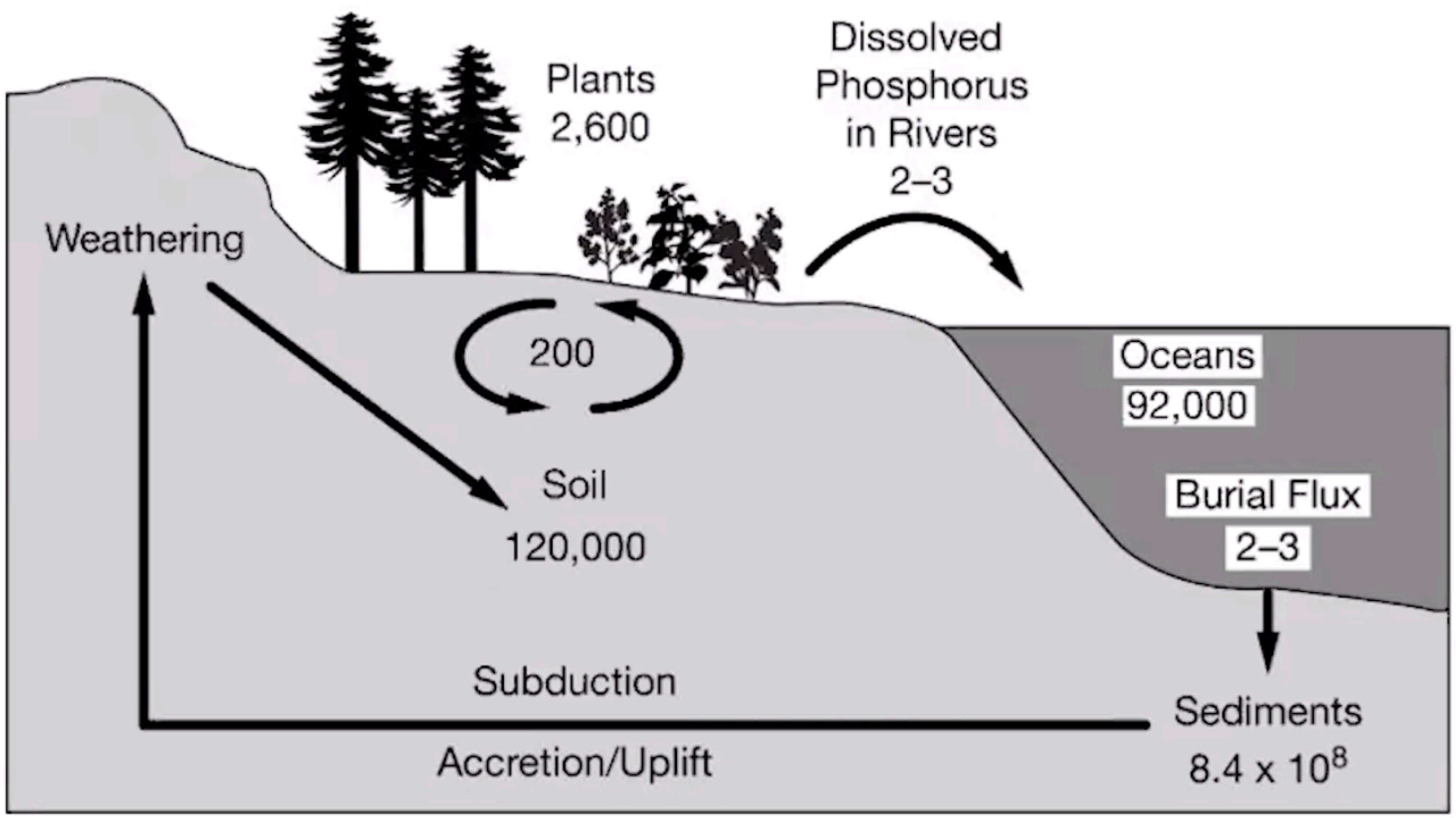
1.6



Key

- Reservoir
- Process

1.6



Source: released AP exam. Taken from: AP Classroom

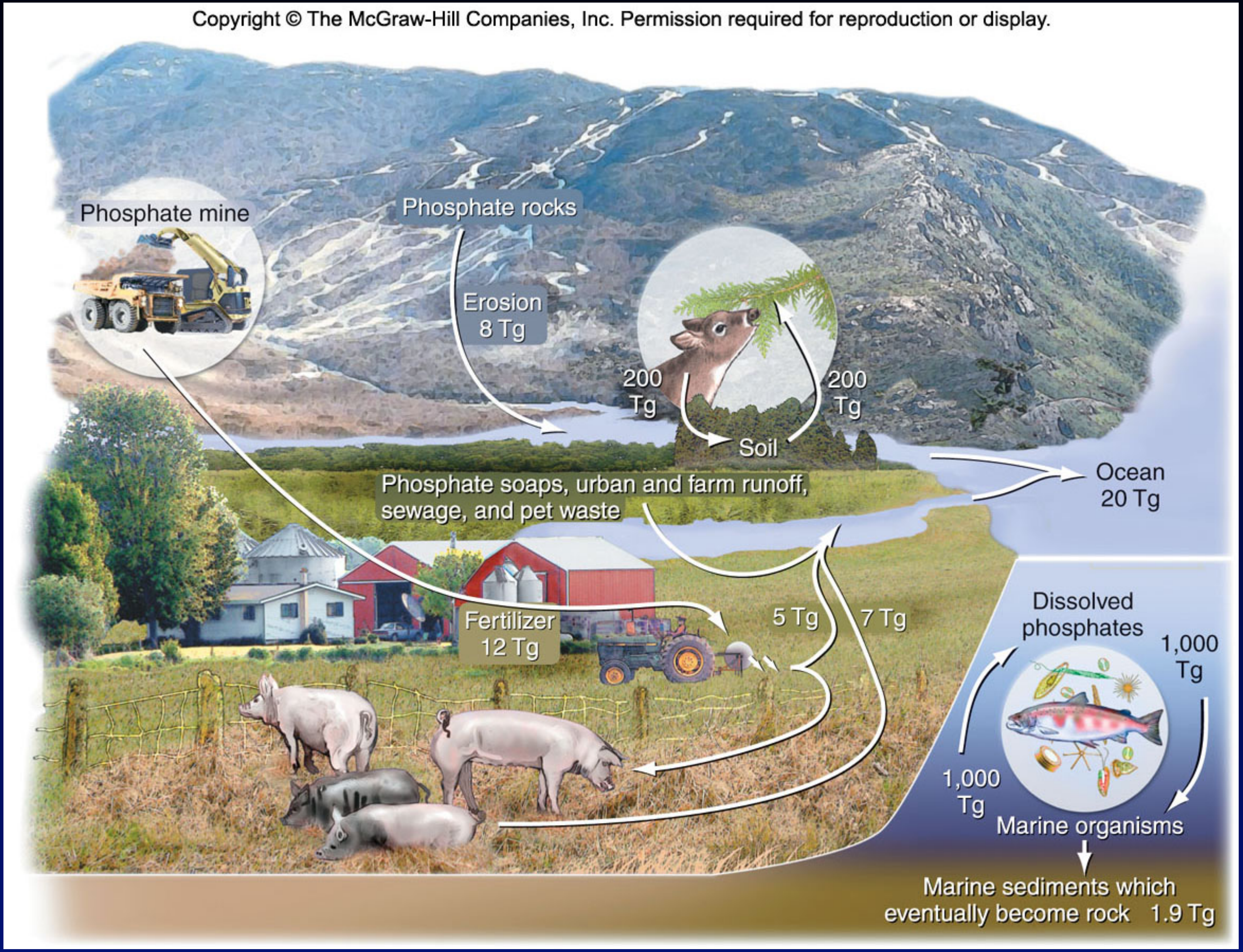
- Based on the diagram, **identify** Earth's major reservoir for phosphorous
- **Identify** the biological process that moves phosphorus from the soil to plants
- A farmer decides to fertilize his crops. A river runs adjacent to his farmland. **Explain** what might happen to the amount of dissolved phosphorus in the local river after crop fertilization.

Science Practice 2.B:
Explain relationships between different characteristics of environmental concepts, processes or models represented visually

Phosphorous Cycle

- Phosphorous is needed to make DNA, ATP (the energy currency of the cell) and other important biomolecules (Chap. 2).
- Phosphorous compounds are leached from rocks and minerals and usually transported in aqueous form.
  - Taken in and incorporated by producers
    - Passed on to consumers
      - Returned to environment by decomposition
- ***Cycle takes a long time as deep ocean sediments are significant sinks***

Phosphorus Cycle



Sulfur Cycle

Addendum

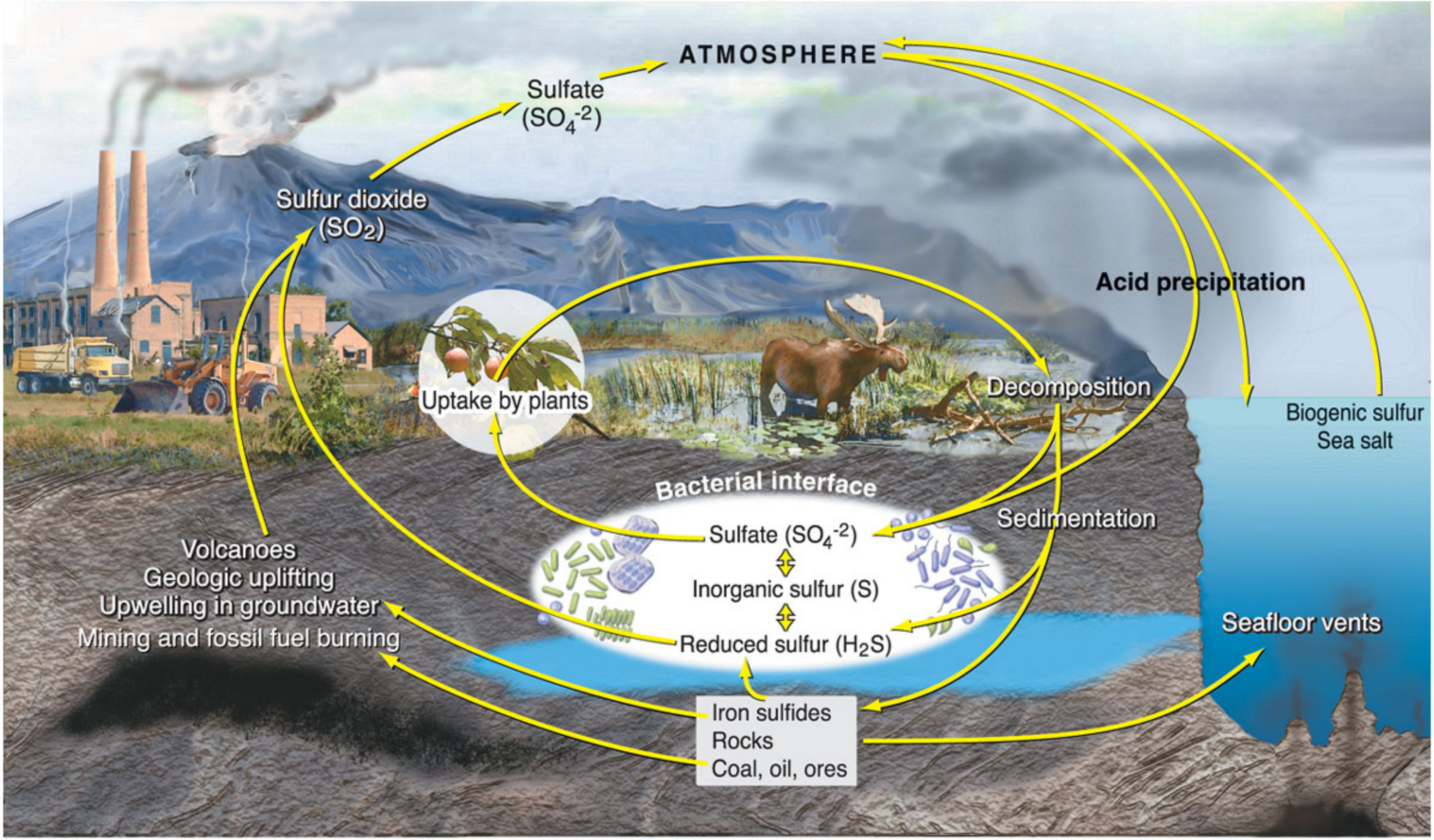
Sulfur Cycle

- Most sulfur is tied up in underground rocks and minerals. Inorganic sulfur is released into air by weathering and volcanic eruptions.

  - Cycle is complicated by large number of oxidation states the element can assume.

  - Human activities release large amounts of sulfur, primarily by burning fossil fuels.
    - Important determinant in rainfall acidity

Sulfur Cycle



TOPIC 1.7

The Hydrologic (Water) Cycle

Required Course Content

ENDURING UNDERSTANDING

ERT-1

Ecosystems are the result of biotic and abiotic interactions.

LEARNING OBJECTIVE

ERT-1.G

Explain the steps and reservoir interactions in the hydrologic cycle.

ESSENTIAL KNOWLEDGE

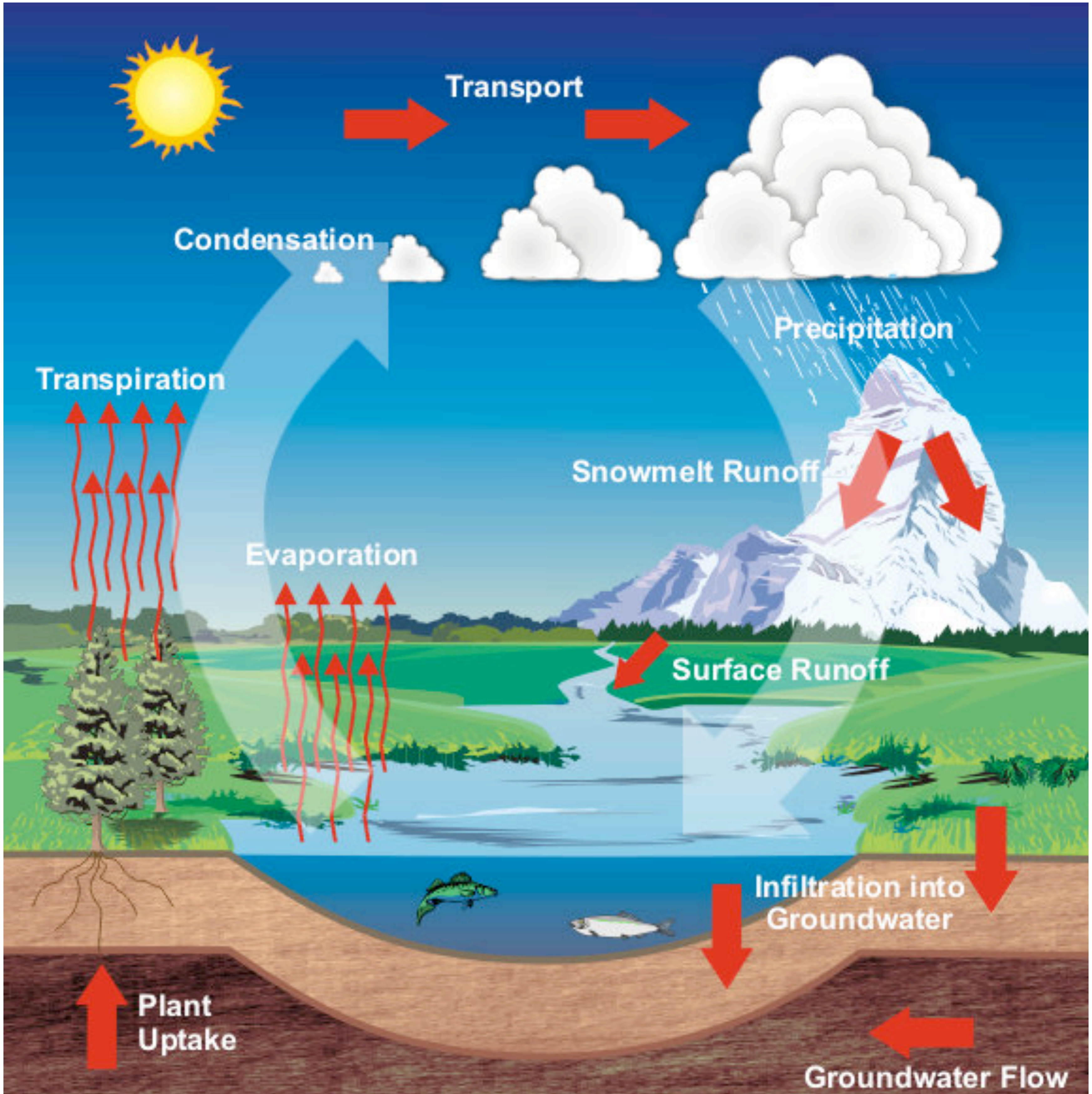
ERT-1.G.1

The hydrologic cycle, which is powered by the sun, is the movement of water in its various solid, liquid, and gaseous phases between sources and sinks.

ERT-1.G.2

The oceans are the primary reservoir of water at the Earth's surface, with ice caps and groundwater acting as much smaller reservoirs.

WATER CYCLE


Transport
Condensation
Precipitation
Transpiration
Snowmelt Runoff
Evaporation
Surface Runoff
Infiltration into
Groundwater
Plant
Uptake
Groundwater Flow

BIOLOGICAL IMPORTANCE

- Water is essential for all life, water also influences production & decomposition

FORMS AVAILABLE TO LIFE

- Mainly liquid water

RESERVOIRS

- Rough estimations: 97% in oceans, 2% in glaciers and ice caps, 1% in rivers and lakes

KEY PROCESSES

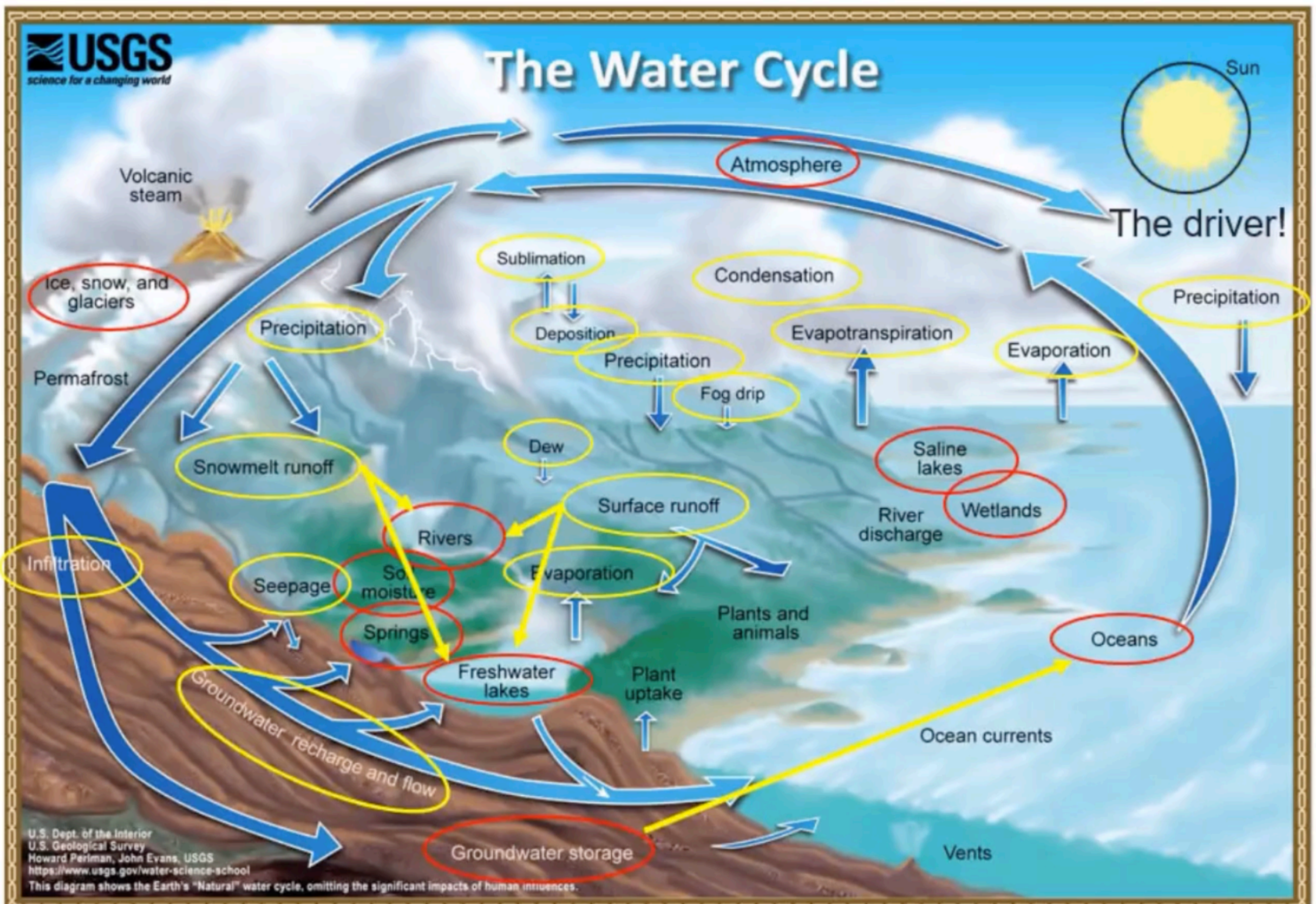
- Evaporation, Condensation and Precipitation

1.7

The Hydrologic Cycle – Big Picture

- The hydrologic cycle is *essential* to life on Earth
- The processes of the hydrologic cycle are driven by the **Sun** ☀
- **Oceans** are the primary reservoir of water on Earth (saltwater)
  - Ice caps and groundwater reserves are smaller, but still vital, reservoirs (freshwater)

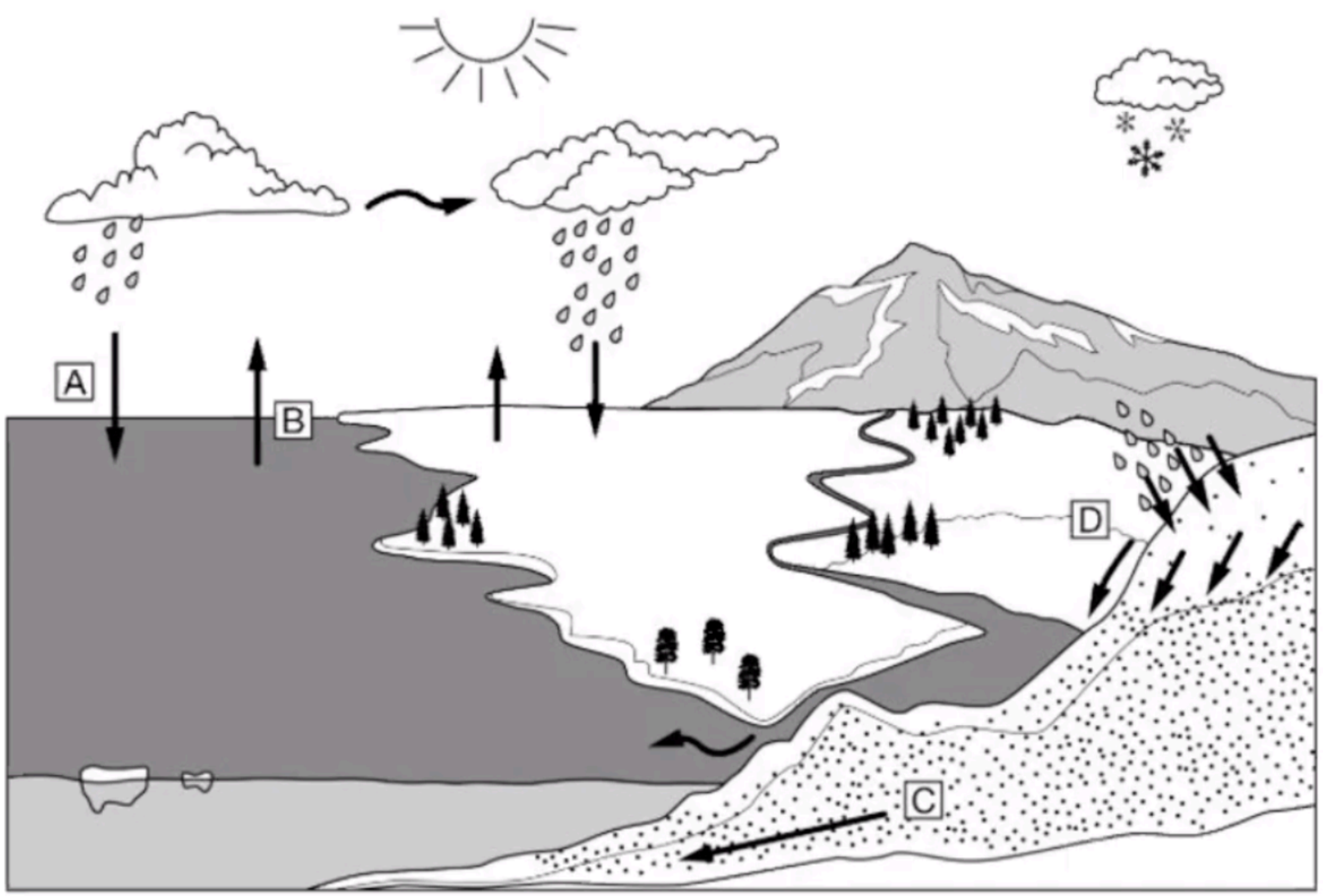
1.7



Key

- Reservoir
- Process

1.7

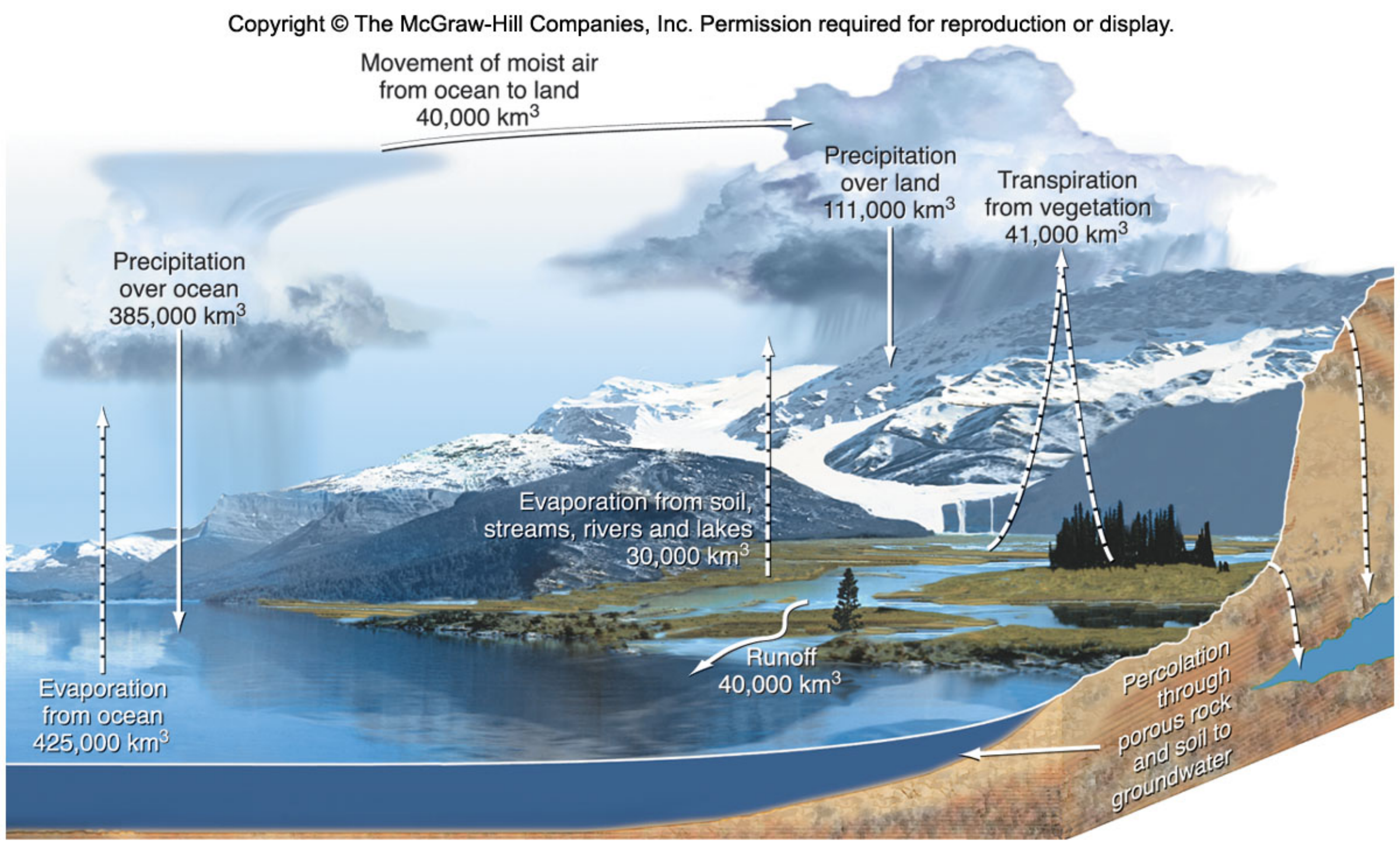


Source: released AP exam. Taken from: AP Classroom

- **Identify** the process point A
- **Explain** a likely impact to the process occurring at point B if the average annual mean temperature of this environment increases due to climate change
- A developer builds a residential community with 350 homes on the shores of the lake shown. **Describe** one likely change to the local hydrologic cycle as a result of this development.

Science Practice 2.B:
Explain relationships between different characteristics of environmental concepts, processes or models represented visually

Hydrologic Cycle



Conservation of Mass

- **Law of Conservation of Mass**: like energy, matter can not be created or destroyed.
  - Very little matter enters earth from space.
  - Thus the matter on *earth* is constant. Matter has been, is and will continue to be recycled over time.
  - Be Careful! Matter can be gained and lost from *ecosystems* themselves.

REMEMBER THIS???

- **Decomposers/Detrivores** consume **Detritus**, nonliving organic material (dead organisms and feces)
- Two most significant and important decomposers are Fungi and Bacteria
- They play a critical role in recycling matter...decomposers convert organic material into inorganic material that producers can then uptake and reuse. (recycled back into the ecosystem)
    - Consider This! If decomposition stopped detritus would build up and life would not exist

Decomposition & Nutrient Cycle Rates

- Decomposition is ***essential*** for nutrient cycling.
- Decomposition is ***highly variable***, mainly due to differences in rates of decomposition.
- Decomposition is once again ***under the influence of***:
    - *Temperature, Moisture and Nutrient Availability*
        - There is an optimum temperature for decomposition

What type of curve would you predict if graphed temperature and rates of decomposition?

Which variable belongs on the X axis? Y axis?

Identify the biomes below.

Which ecosystem has better (more fertile) soil?

- Decomposition in Tropical Rain Forests occurs rapidly
  - As a result nutrients spend little time in the soil
    - Ironically there soil is low nutrients, about 10% of ecosystems total

- Decomposition in Temperate Forests occurs less rapidly
  - As a result nutrients spend more time in the soil
    - The soil has a moderate amount of nutrients, about 50% of ecosystems total

Introduction
to
Energy Flow

Ecosystems

Review: Physical laws control energy flow and chemical cycling.

Review: Chemicals (matter) *cycles within* ecosystems.

Main Idea: Energy *flows through* ecosystems.

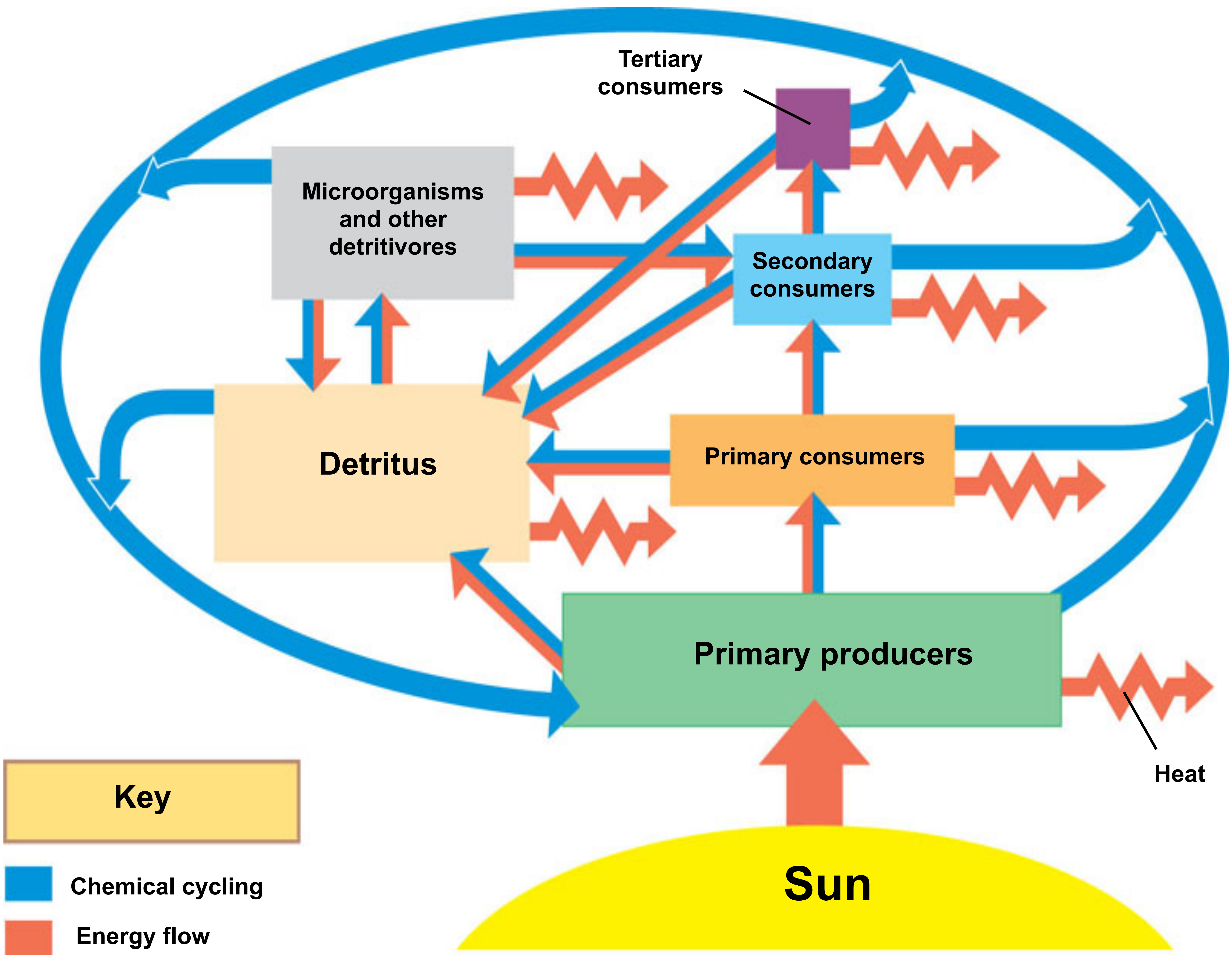
Conservation of Energy

- **The sun is the ultimate source of energy for most ecosystems and life itself on our planet.**
  - Energy enters ecosystems as solar radiation.
  - Autotrophs *transform* solar radiation into chemical energy.
  - Heterotrophs consume autotrophs and *transfer* this chemical energy through food chains.
- **First Law of Thermodynamics**: energy can not be created nor destroyed...only transferred and transformed.

- **Second Law of Thermodynamics**: energy exchanges (transfers and transformations) increase the entropy of the universe. In other words energy exchanges are inefficient some energy is always lost as heat
    - Remember energy is passing through food chains.
    - As chemical energy is passing through food chains it is ultimately *transformed* to heat and *transferred* back to space

Energy, Mass & Trophic Levels

- **Primary Producers** *consists of autotrophs and their trophic level supports all others*. Think of it this way...autotrophs link heterotrophs to the ultimate source of energy for most life...the sun!
    - Producers (autotrophs) are *photosynthetic organisms* that use solar energy to synthesize organic compounds (sugars) which they use to fuel cellular respiration and as building blocks for growth.


Tertiary consumers
Microorganisms and other detritivores
Secondary consumers
Detritus
Primary consumers
Primary producers
Heat
Key
Chemical cycling
Energy flow
Sun

TOPIC 1.8

Primary Productivity

Required Course Content

ENDURING UNDERSTANDING

ENG-1

Energy can be converted from one form to another.

LEARNING OBJECTIVE

ENG-1.A

Explain how solar energy is acquired and transferred by living organisms.

ESSENTIAL KNOWLEDGE

ENG-1.A.1

Primary productivity is the rate at which solar energy (sunlight) is converted into organic compounds via photosynthesis over a unit of time.

ENG-1.A.2

Gross primary productivity is the total rate of photosynthesis in a given area.

ENG-1.A.3

Net primary productivity is the rate of energy storage by photosynthesizers in a given area, after subtracting the energy lost to respiration.

ENG-1.A.4

Productivity is measured in units of energy per unit area per unit time (e.g., $kcal/m^2/yr$).

ENG-1.A.5

Most red light is absorbed in the upper 1m of water, and blue light only penetrates deeper than 100m in the clearest water. This affects photosynthesis in aquatic ecosystems, whose photosynthesizers have adapted mechanisms to address the lack of visible light.

Ecosystems

Main Idea: Energy and other limiting factors control primary production.

Main Idea: Primary production dictates the energy budget for the entire ecosystem.

ENERGY AND OTHER LIMITING FACTORS CONTROL PRIMARY PRODUCTION IN ECOSYSTEMS

- **Primary production** is the amount of light energy converted to chemical energy in a given period of time

- The amount of light energy converted to chemical energy by autotrophs effects the amount of heterotrophs it can support in higher trophic levels.

- **Energy transfer is a major theme in biology, energy transfer underlies all biological interactions.**

Photosynthesis

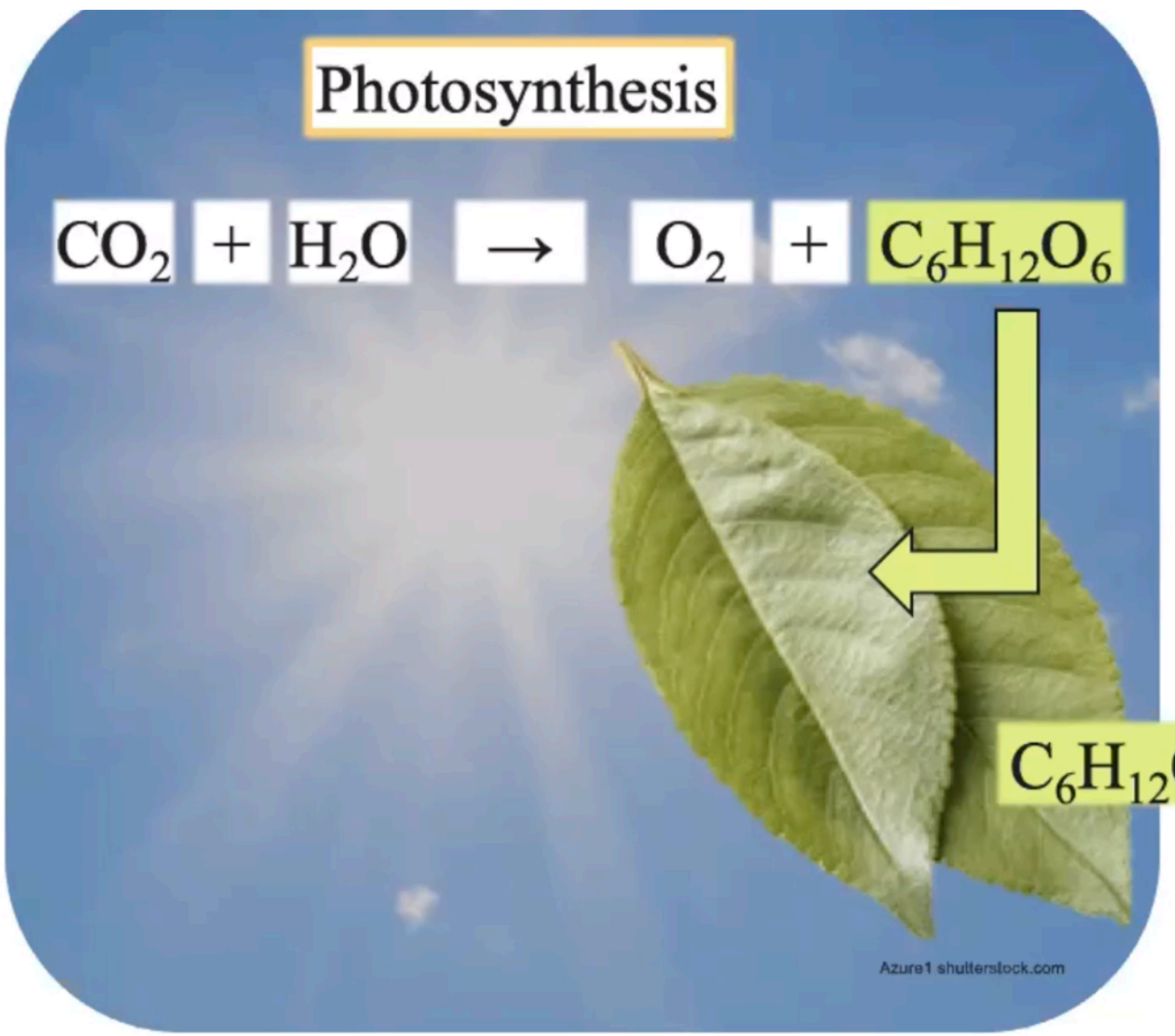
- Biological process by which energy from the sun (radiant energy) is transformed into chemical energy of sugar molecules

$$6\ CO_2 + 12\ H_2O + \text{radiant energy}$$

$$\downarrow$$

$$C_6H_{12}O_6 + 6\ H_2O + 6\ O_2$$

1.8



Cellular Respiration

Surplus: Heterotrophs
(*herbivores*)

$$C_6H_{12}O_6 + O_2 \rightarrow H_2O + CO_2$$

Cellular Respiration

Cellular Respiration

- The process where the chemical energy captured in photosynthesis is released within cells of plants and animals

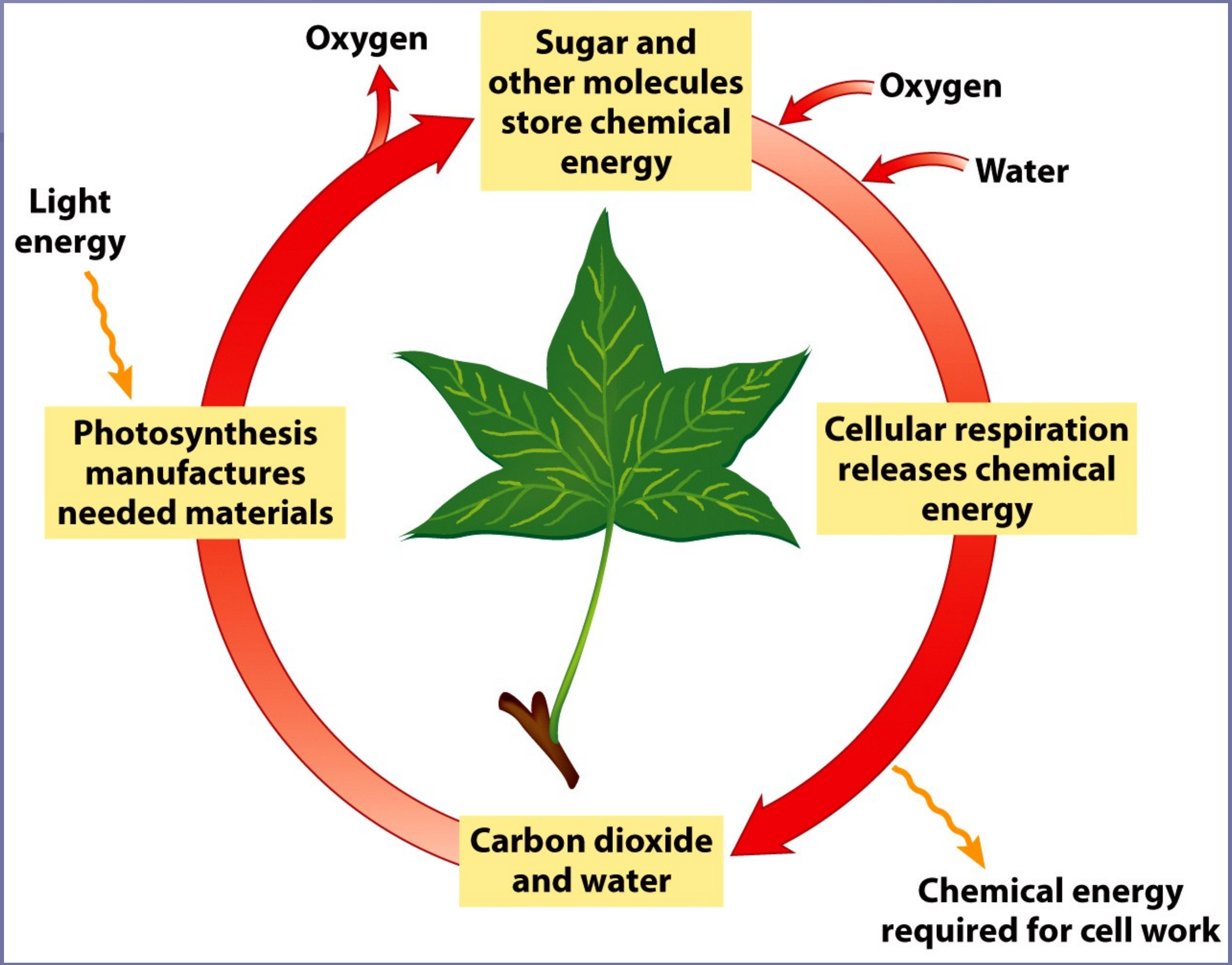
$$C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$$

$$\downarrow$$

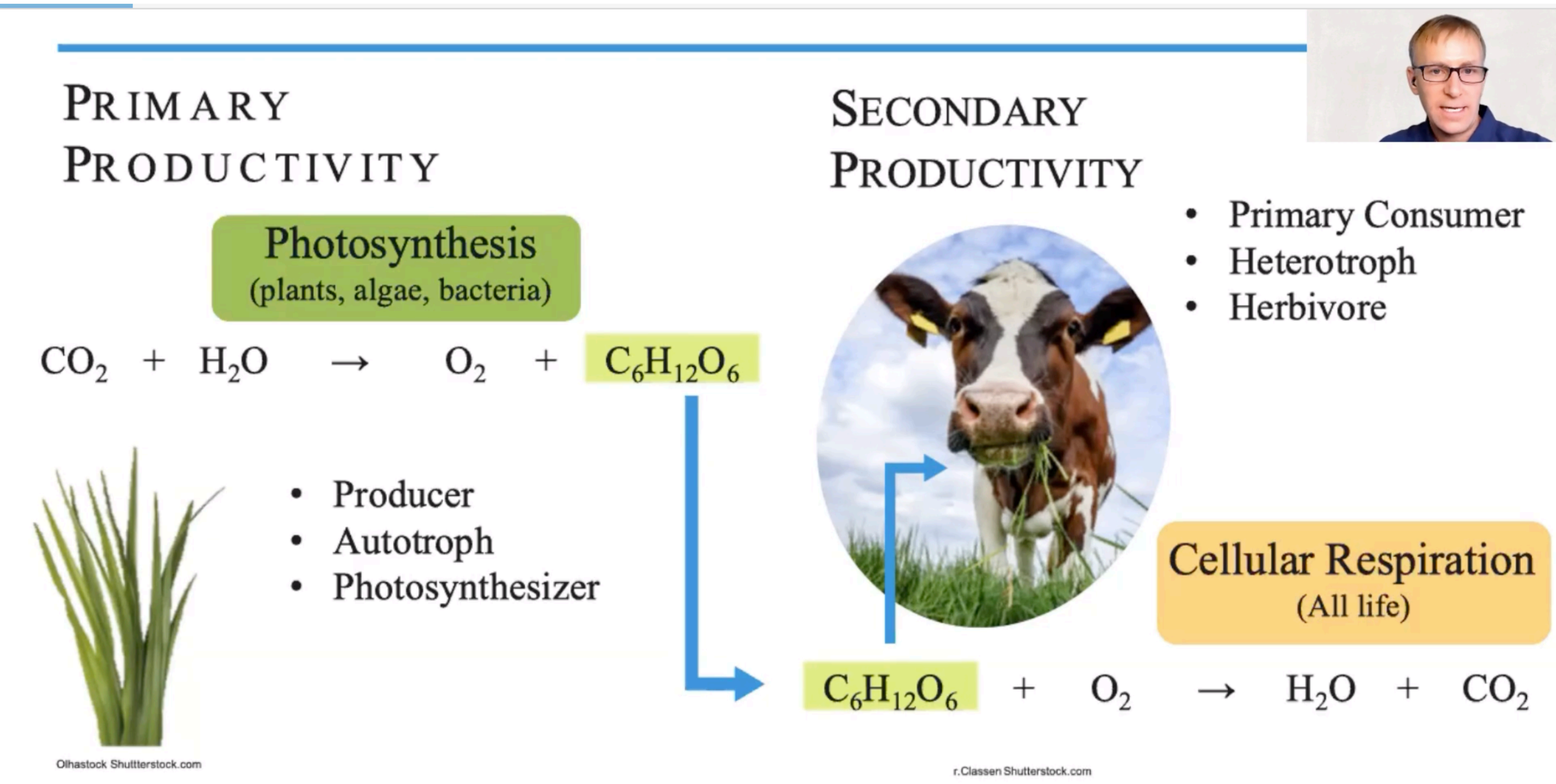
$$6\ CO_2 + 12\ H_2O + \text{energy}$$

- This energy is then used for biological work

Photosynthesis and Cellular Respiration



1.8


PRIMARY PRODUCTIVITY
Photosynthesis
(plants, algae, bacteria)
$CO_2 + H_2O \rightarrow O_2 + C_6H_{12}O_6$
• Producer
• Autotroph
• Photosynthesizer
Olhastock Shutterstock.com
SECONDARY PRODUCTIVITY
• Primary Consumer
• Heterotroph
• Herbivore
Cellular Respiration
(All life)
$C_6H_{12}O_6 + O_2 \rightarrow H_2O + CO_2$
r.Classen Shutterstock.com

1.8

PRIMARY PRODUCTIVITY

Photosynthesis from Producers - Cellular Respiration of Producers = ***Net*** Primary Productivity

Gross Primary Productivity - Cellular Respiration of Producers = ***Net*** Primary Productivity

GPP - R = NPP

Gross and Net Production

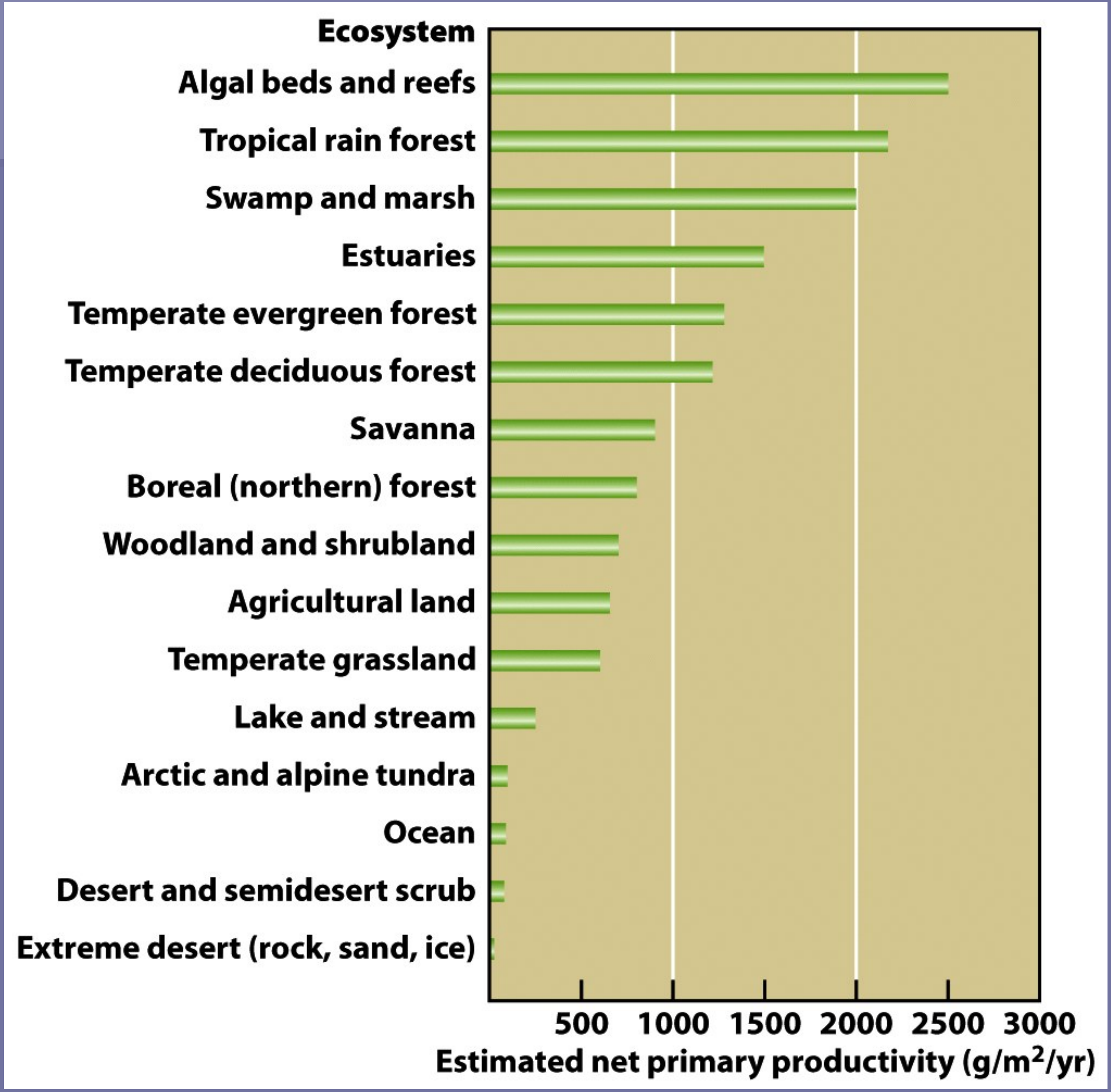
- **Gross Primary Production (GPP)** is the total amount of solar energy converted to chemical energy per unit time.
- **Net Primary Production (NPP)** is the difference between GPP and autotrophic respiration R_a.
  - $NPP = GPP - R_a$
    - Think of R_a as the energy that plants use to "run themselves" whatever energy is leftover can be used by the plant to add new biomass (grow)
      - This new biomass contains the chemical energy for heterotrophs

Ecosystem Energy Budgets

Global Energy Budgets

- WOW...In one day the earth receives enough solar energy to power every human beings' energy need for the next 20+ years at our current consumption rate. BUT...
  - A lot of solar radiation is absorbed, scattered or reflected by our atmosphere.
  - Most of the solar radiation that does reach the earth contacts things that can not photosynthesize and of the light that reaches autotrophs only certain wavelengths power photosynthesis
    - **All in all about 1% of visible light is converted to chemical energy.**

Variation in NPP by Ecosystem



- Different ecosystems vary considerably in their net primary production
  - And in their contribution to the total NPP on Earth

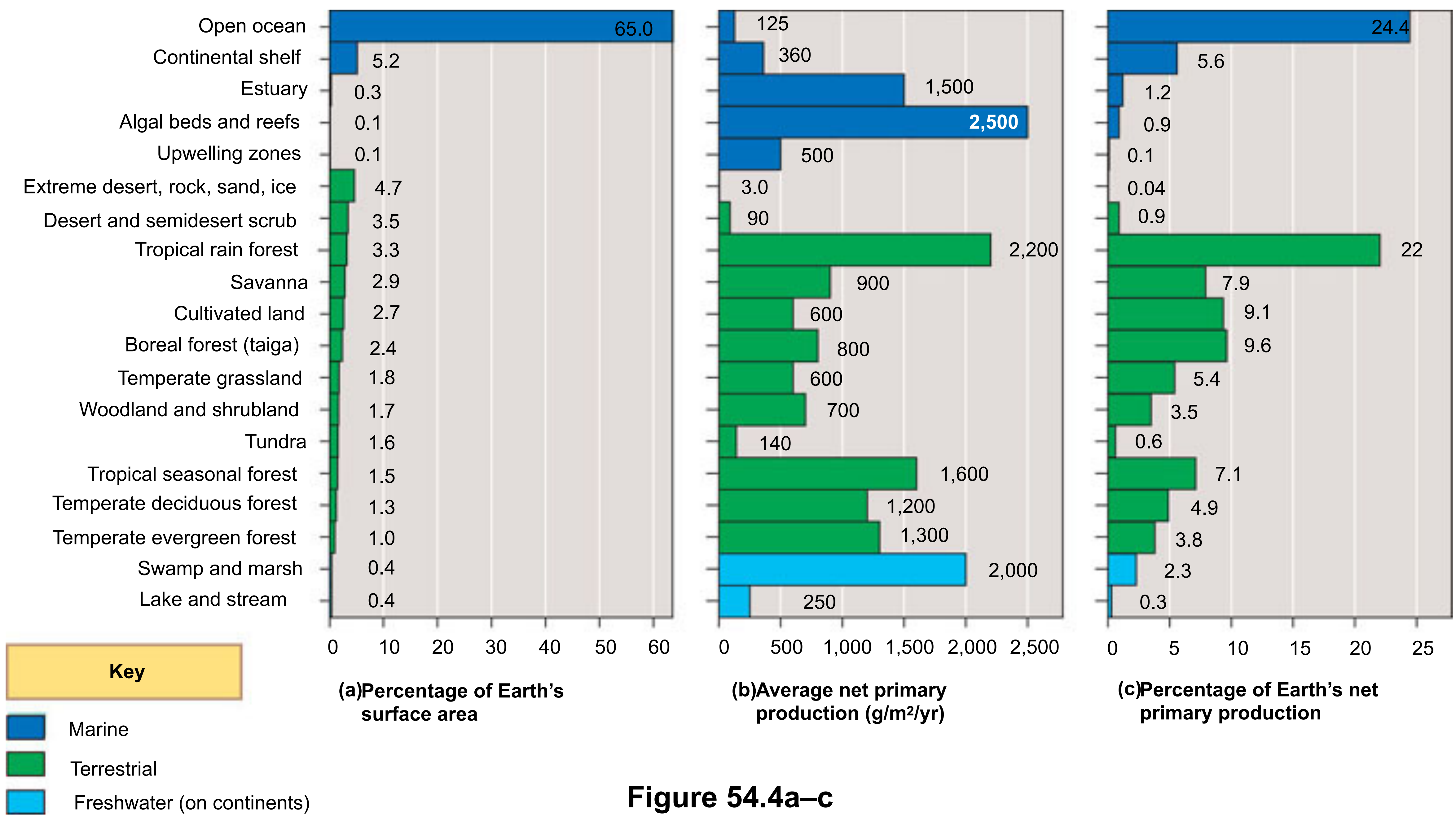


Figure 54.4a–c

Primary Production in Terrestrial Ecosystems

- **Water** and **Temperature** are the key limiting factors.
- In fact precipitation is a useful tool for predicting productivity because there is such a strong correlation between the two.

Climate and Terrestrial Biomes

- Climate has a great impact on the distribution of organisms, as seen on a climograph

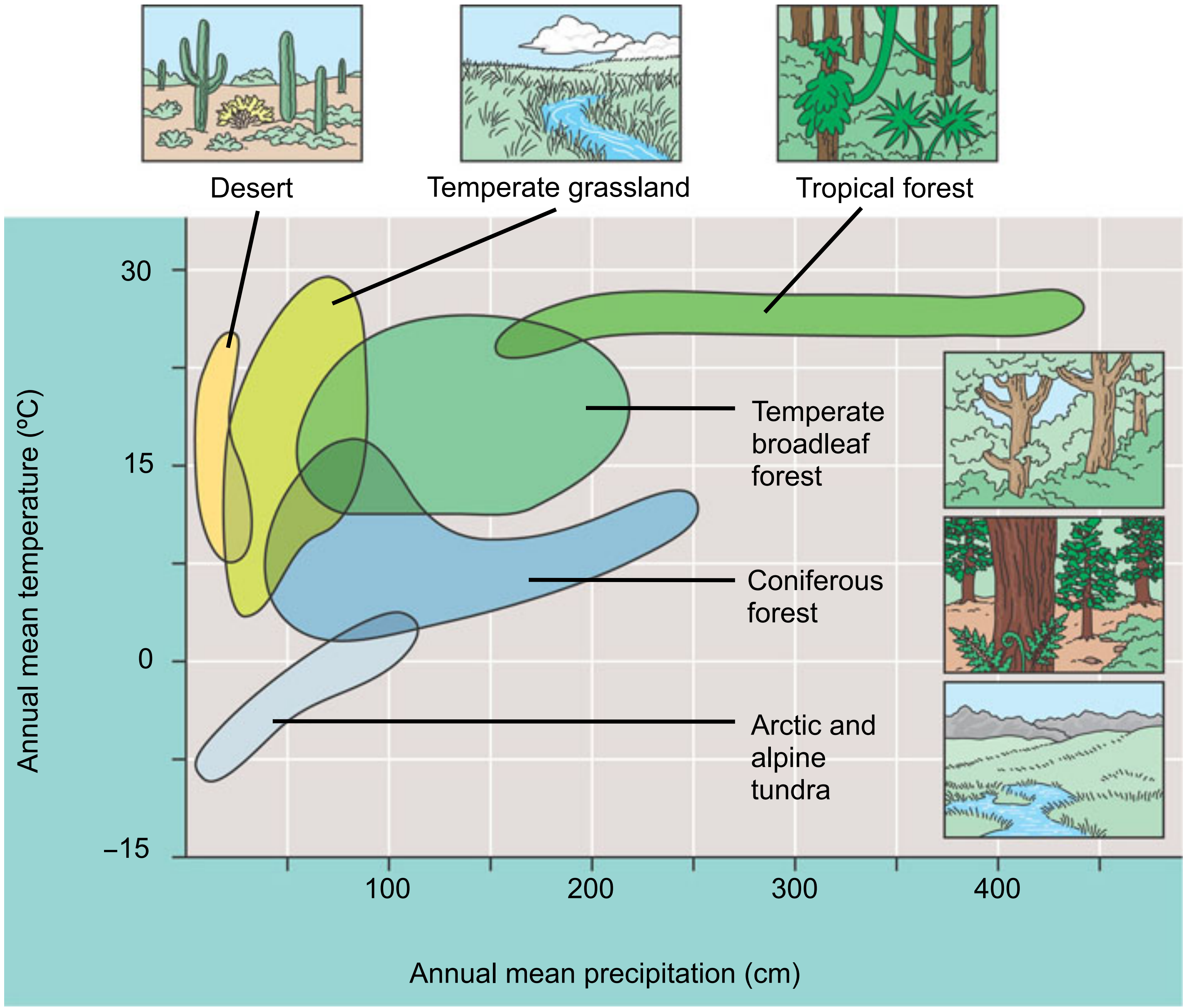
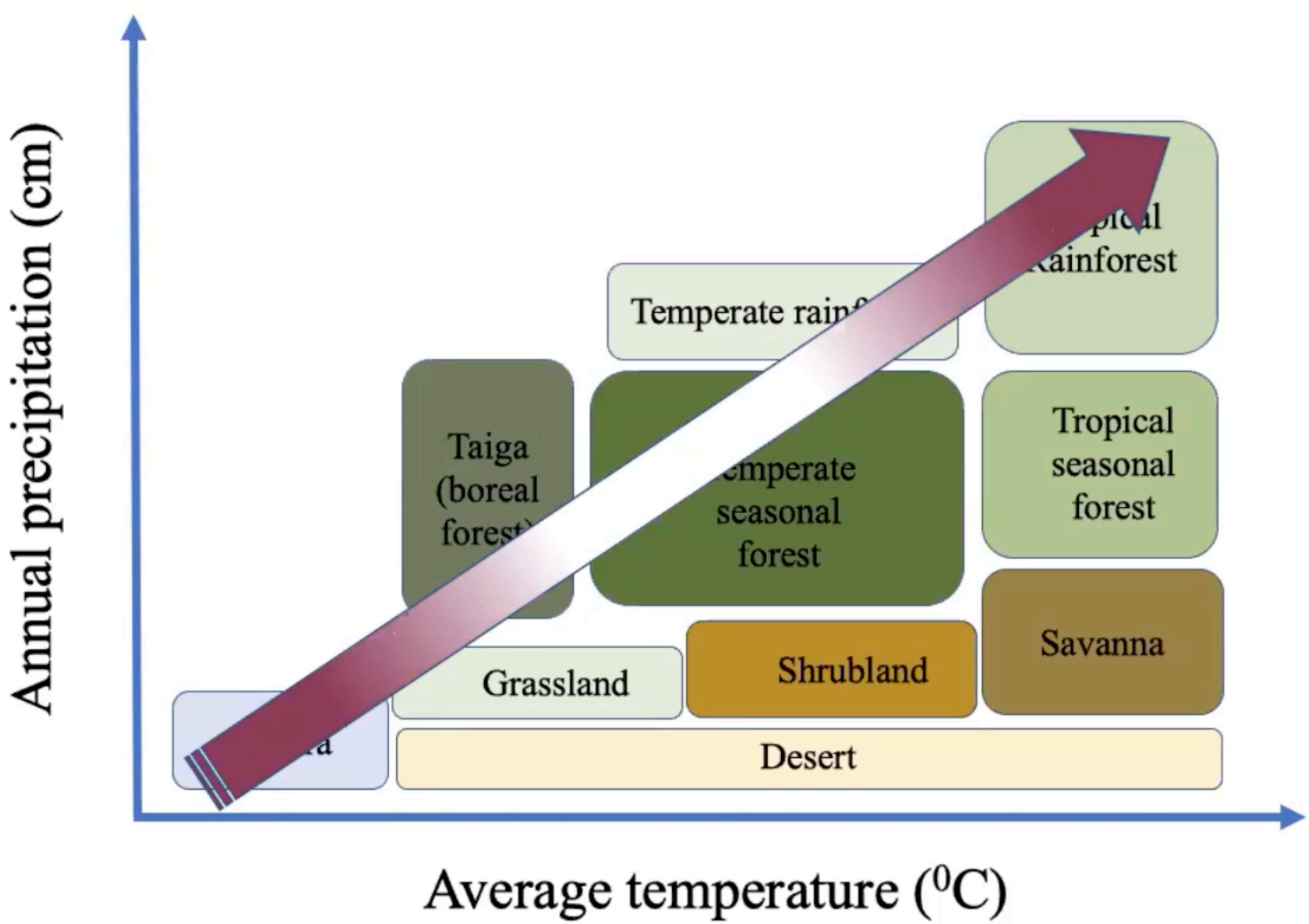
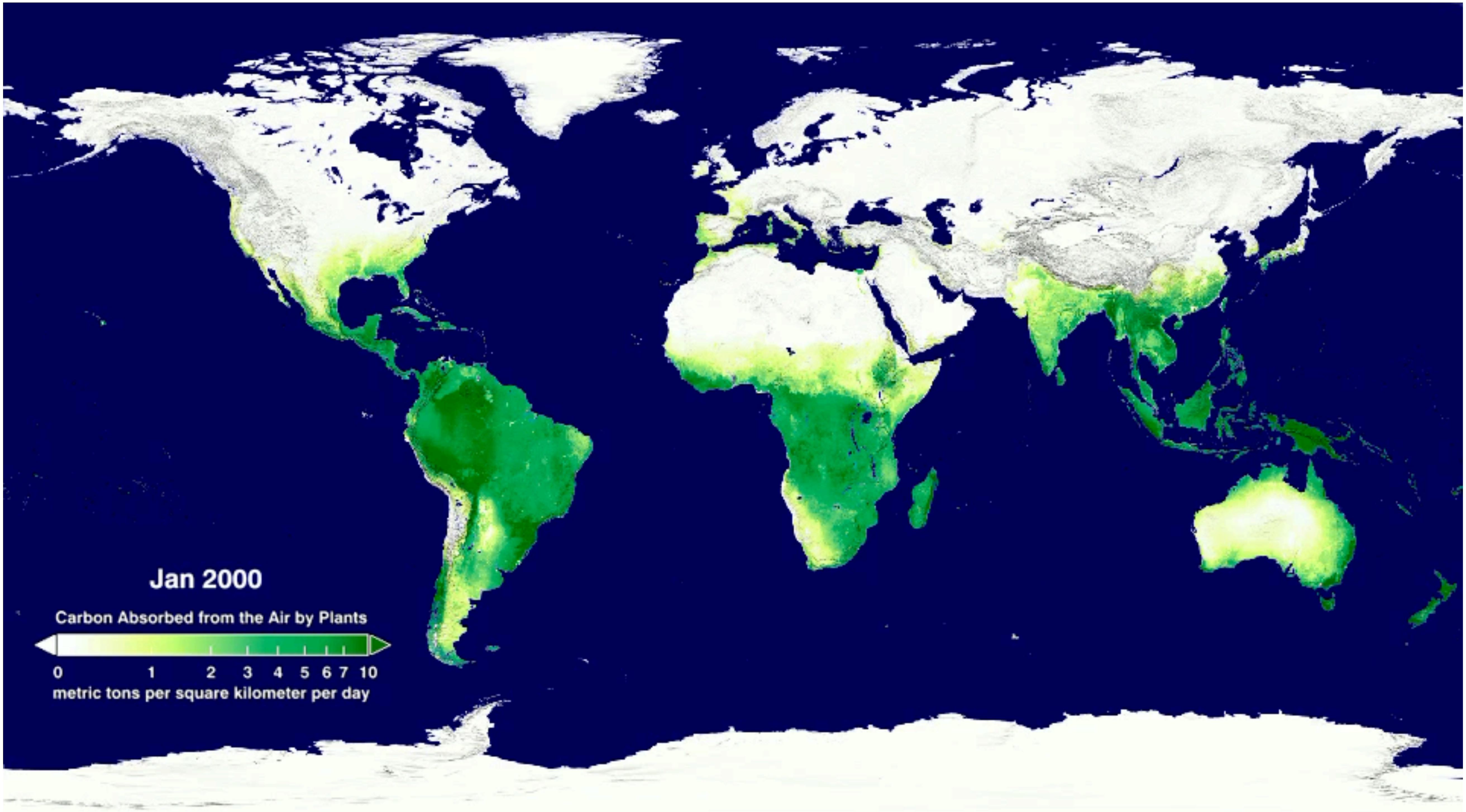


Figure 50.18

1.8

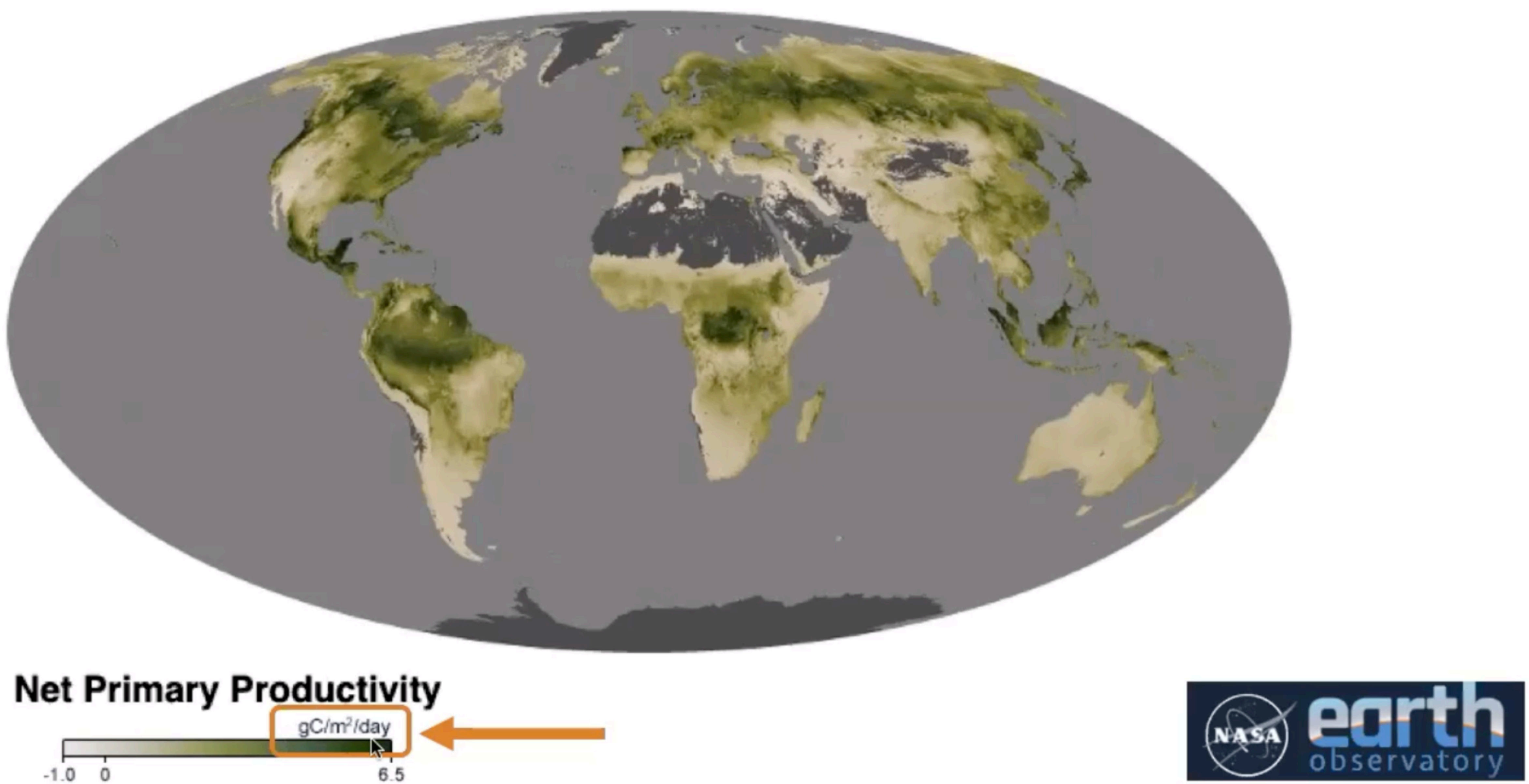

Annual precipitation (cm)
Temperate rain
Taiga (boreal forest
Tropical seasonal forest
seasonal forest
Savanna
Grassland
Shrubland
Desert
Average temperature (⁰C)

- **Gross Primary Production (GPP)** is the total amount of solar energy converted to chemical energy

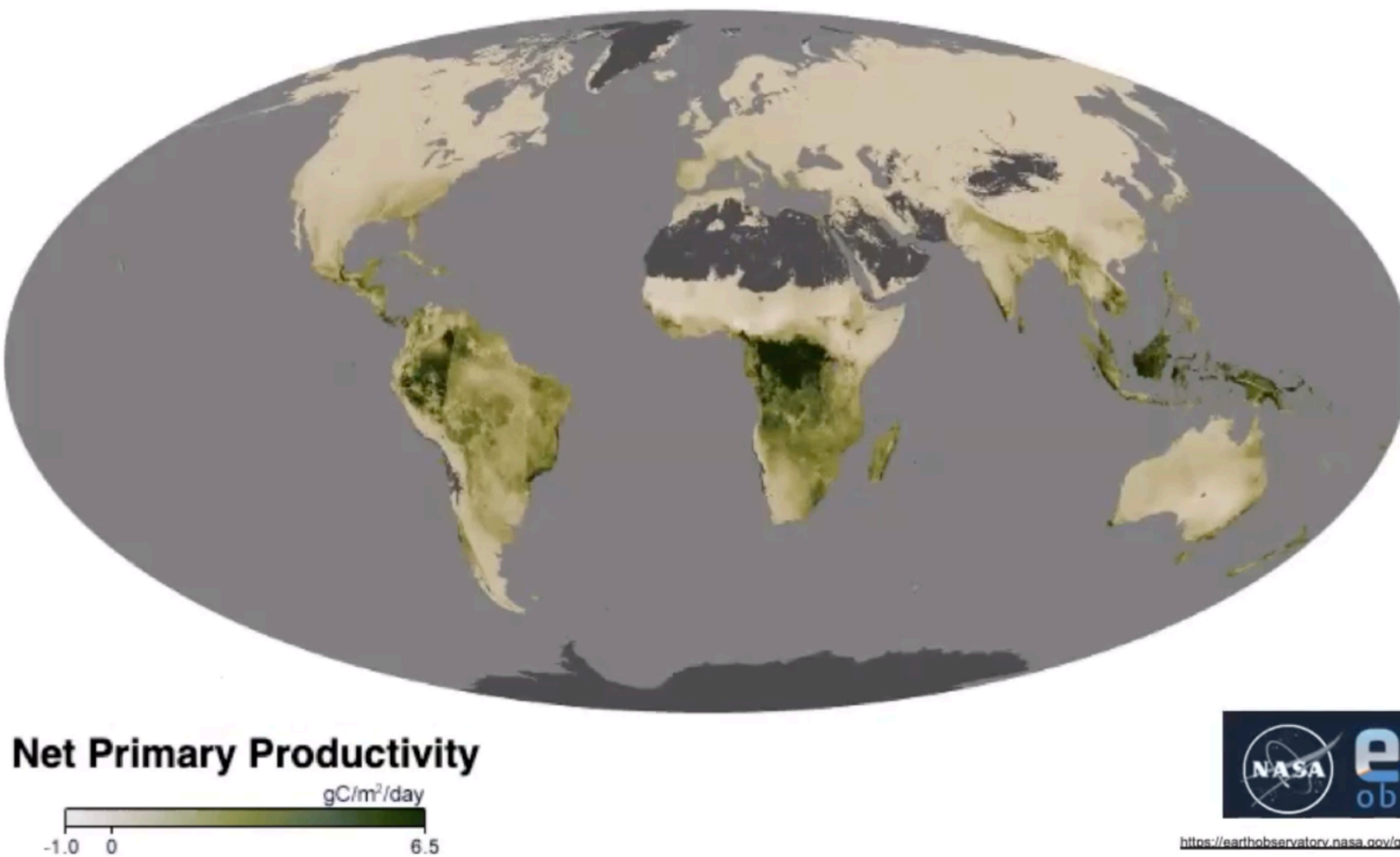


The gross primary productivity of the world's land areas for the period 2000-2009 as calculated from Terra's MODIS instrument. The original 8-day average GPP data has been smoothed to a 24-day average to make the animation less noisy.

1.8


Net Primary Productivity
gC/m²/day
-1.0
0
6.5
NASA earth observatory

1.8



https://earthobservatory.nasa.gov/global-maps/MOD17A2_M_PSN

Primary Production in Aquatic Ecosystems

Light Limitations

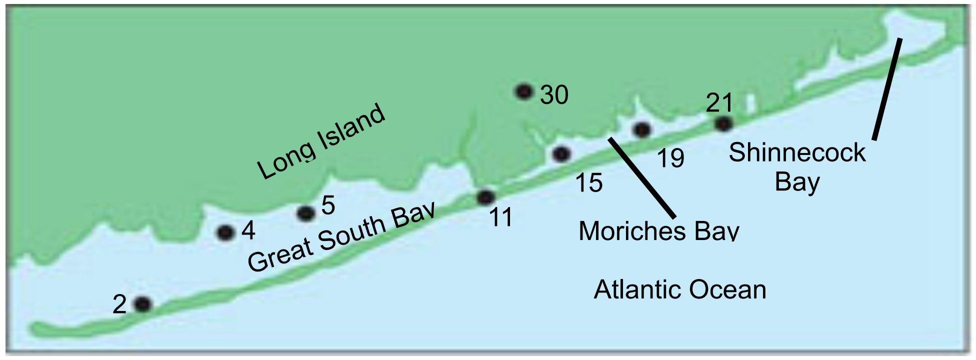
- Light is the obvious choice as limiting factor.
- After all more than half of the solar radiation is absorbed in the first 15 meters of water.
- *Light is very important however it does not appear to be the key limiting factor in aquatic ecosystems!*

Assuming that light was the key limiting factor scientists predicted that a gradient in production from the poles to the equator. Would the production gradient increase or decrease as moved away from the poles? Why? Does this gradient exist?

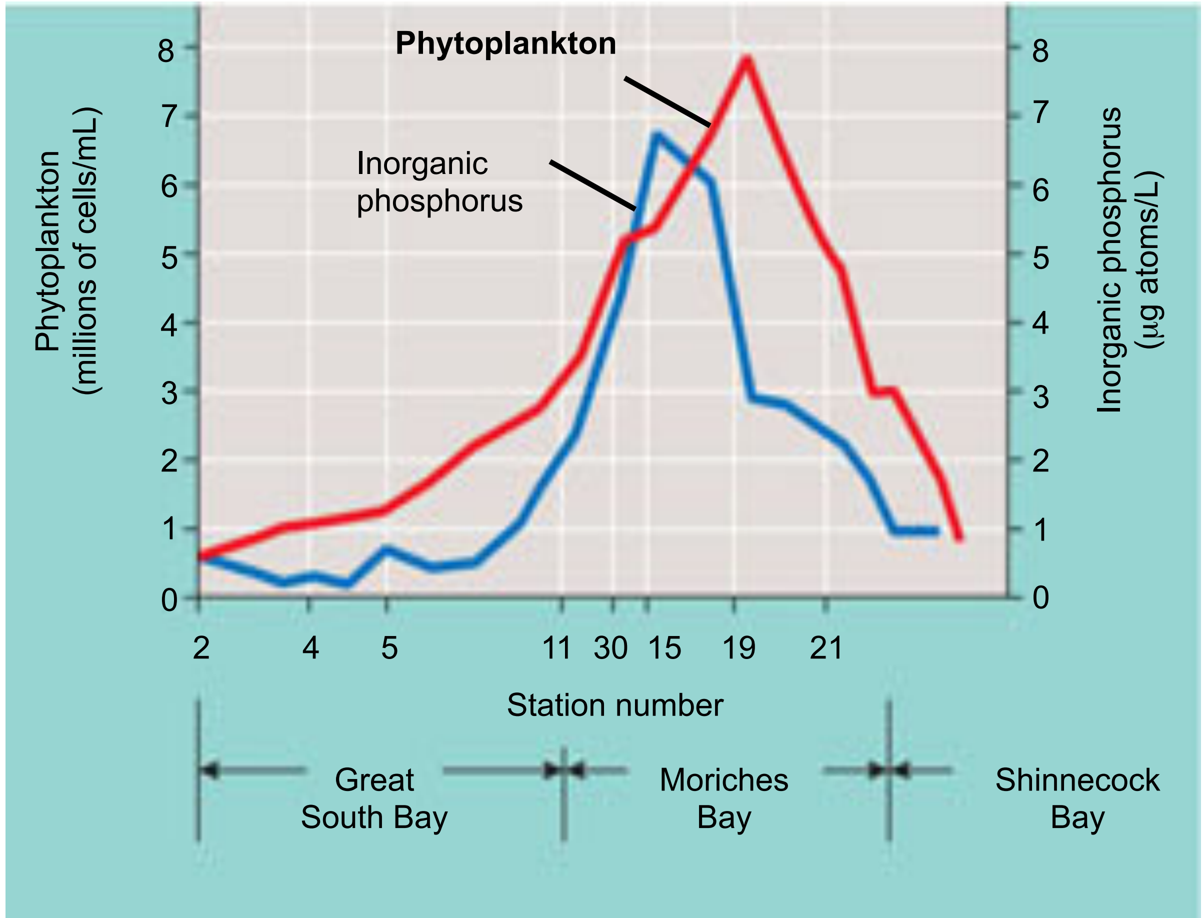
Nutrient Limitations

- *Nutrients appear to be the key limiting factor in aquatic ecosystem production!*
- The most common limited nutrients in aquatic ecosystems are the (macronutrients) nitrogen and phosphorous.
  - *Further support is found in upwellings (deep nutrient rich waters that circulate to the ocean surface), Areas of upwellings are diverse and abundant with life...they are often prime fishing locations.*

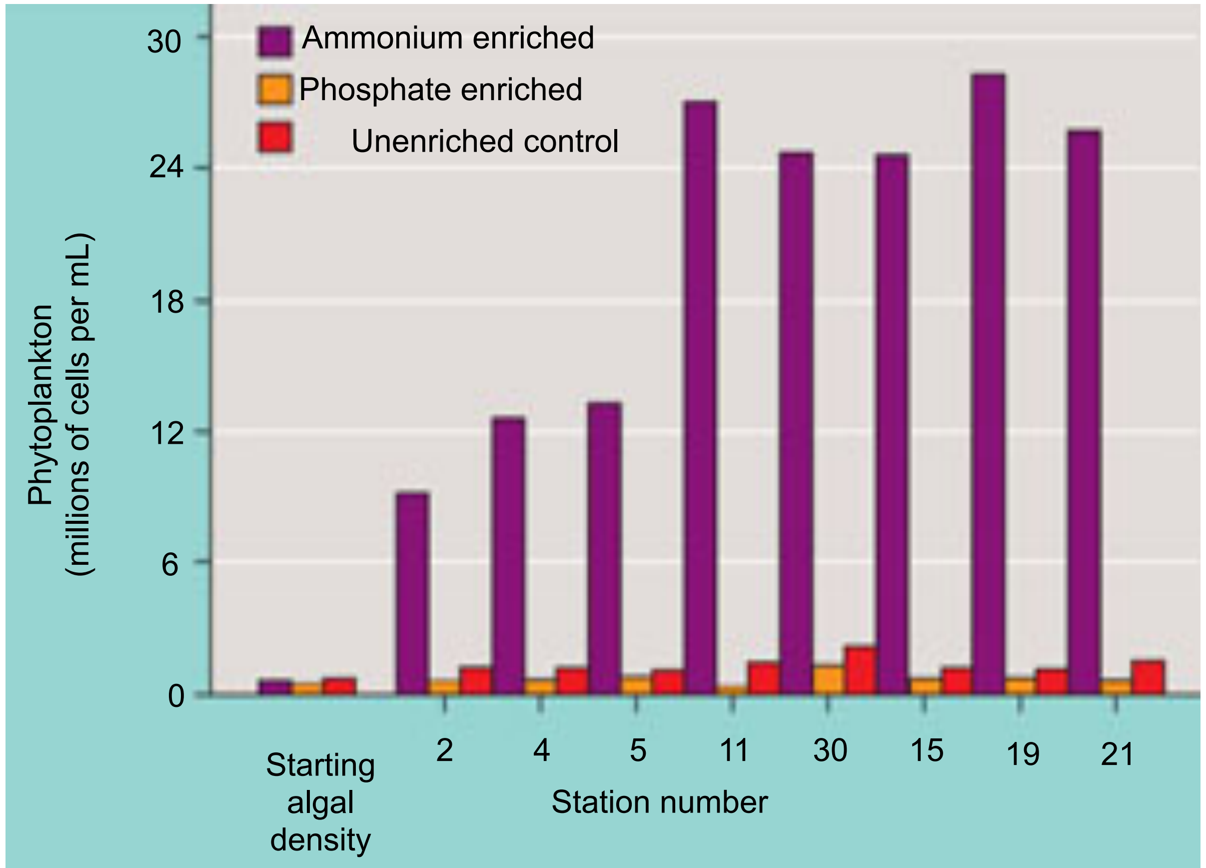
EXPERIMENT Pollution from duck farms concentrated near Moriches Bay adds both nitrogen and phosphorus to the coastal water off Long Island. Researchers cultured the phytoplankton Nannochloris atomus with water collected from several bays.



RESULTS Phytoplankton abundance parallels the abundance of phosphorus in the water (a). Nitrogen, however, is immediately taken up by algae, and no free nitrogen is measured in the coastal waters. The addition of ammonium (NH_4^+) caused heavy phytoplankton growth in bay water, but the addition of phosphate (PO_4^{3+}) did not induce



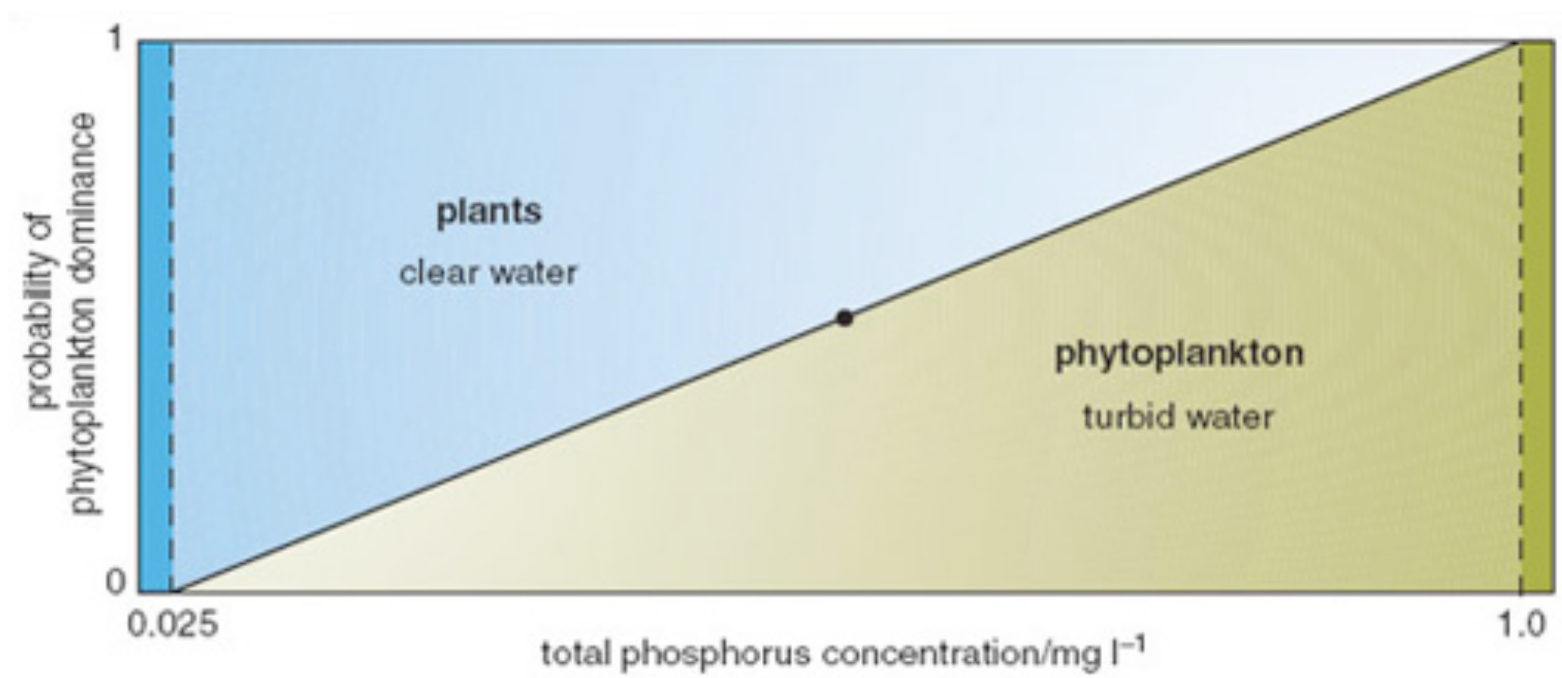
(a) Phytoplankton biomass and phosphorus concentration



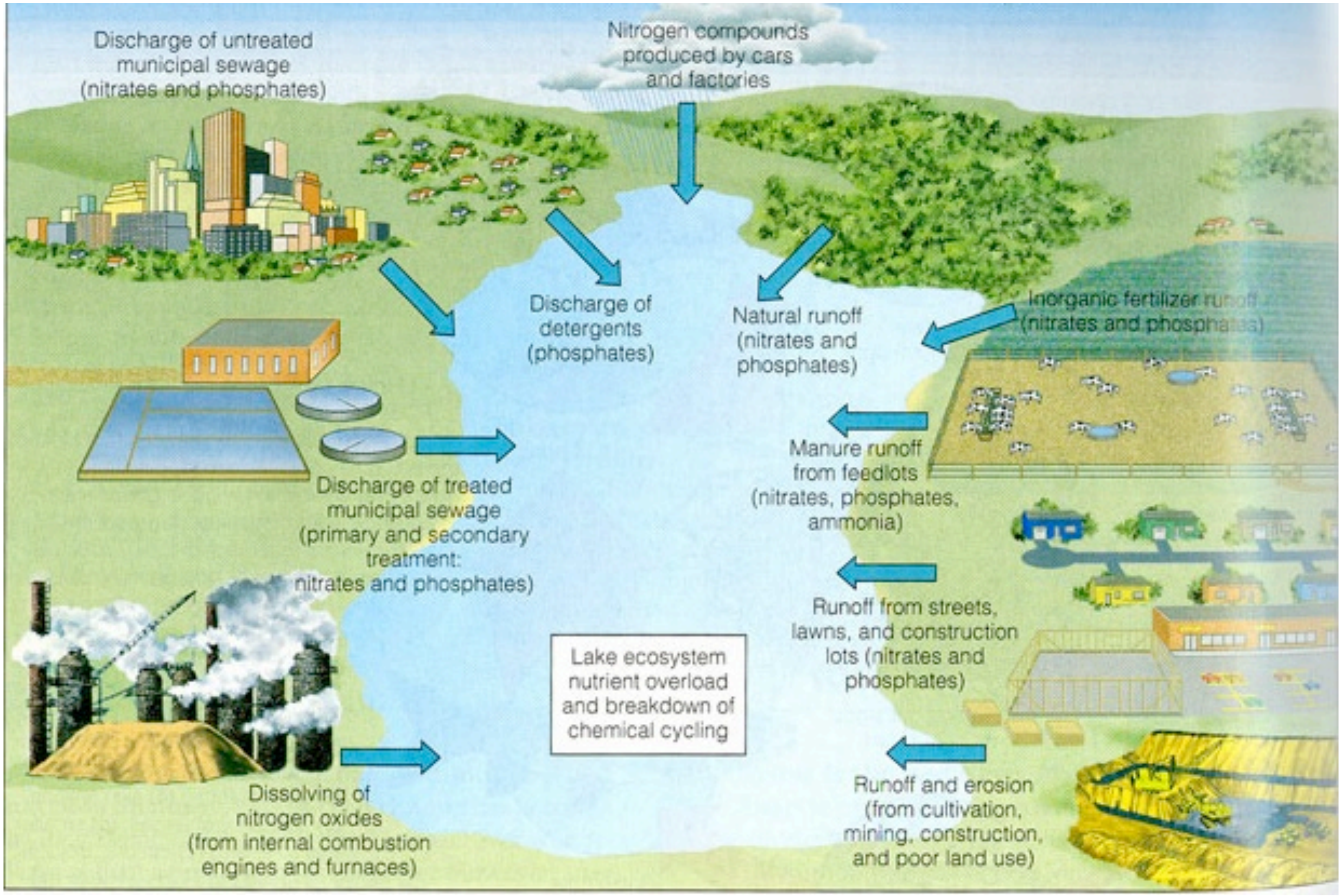
(b) Phytoplankton response to nutrient enrichment

CONCLUSION Since adding phosphorus, which was already in rich supply, had no effect on *Nannochloris* growth, whereas adding nitrogen increased algal density dramatically, researchers concluded that nitrogen was the nutrient limiting phytoplankton growth in this ecosystem.

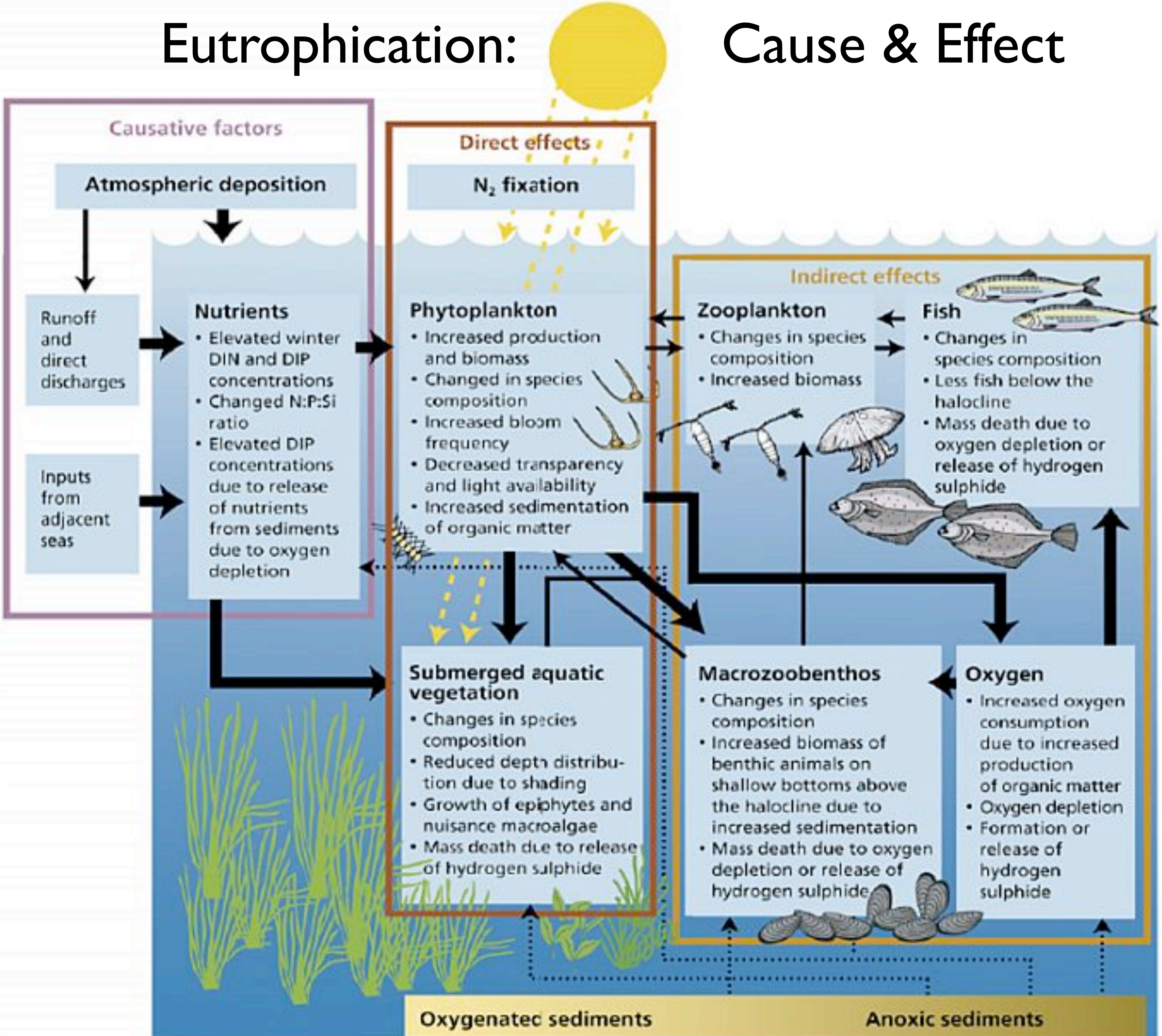
Increase in Phosphorous can cause Eutrophication



Cultural Eutrophication



Eutrophication: Cause & Effect



TOPIC 1.9

Trophic Levels

Required Course Content

ENDURING UNDERSTANDING

ENG-1

Energy can be converted from one form to another.

LEARNING OBJECTIVE

ENG-1.B

Explain how energy flows and matter cycles through trophic levels.

ESSENTIAL KNOWLEDGE

ENG-1.B.1

All ecosystems depend on a continuous inflow of high-quality energy in order to maintain their structure and function of transferring matter between the environment and organisms via biogeochemical cycles.

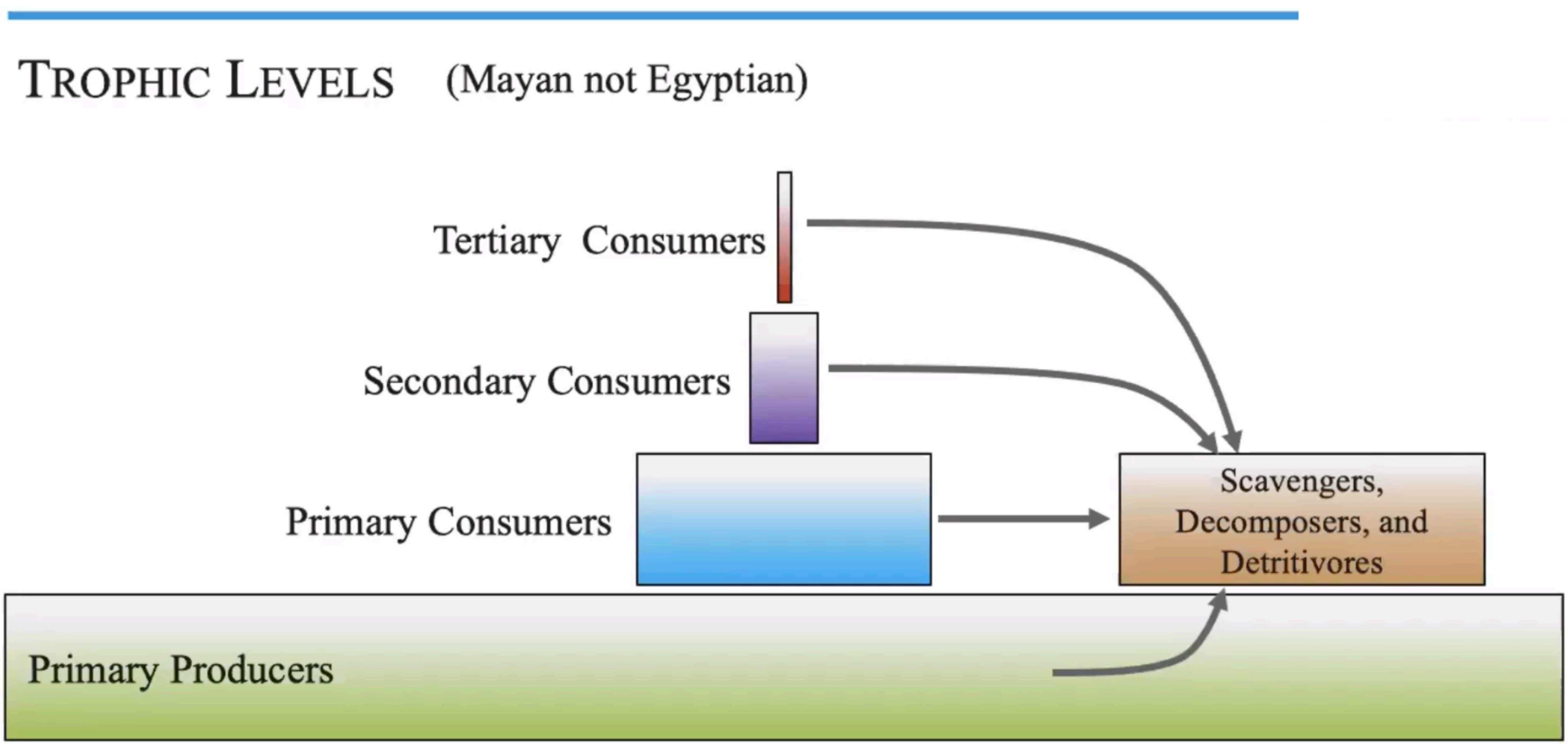
ENG-1.B.2

Biogeochemical cycles are essential for life and each cycle demonstrates the conservation of matter.

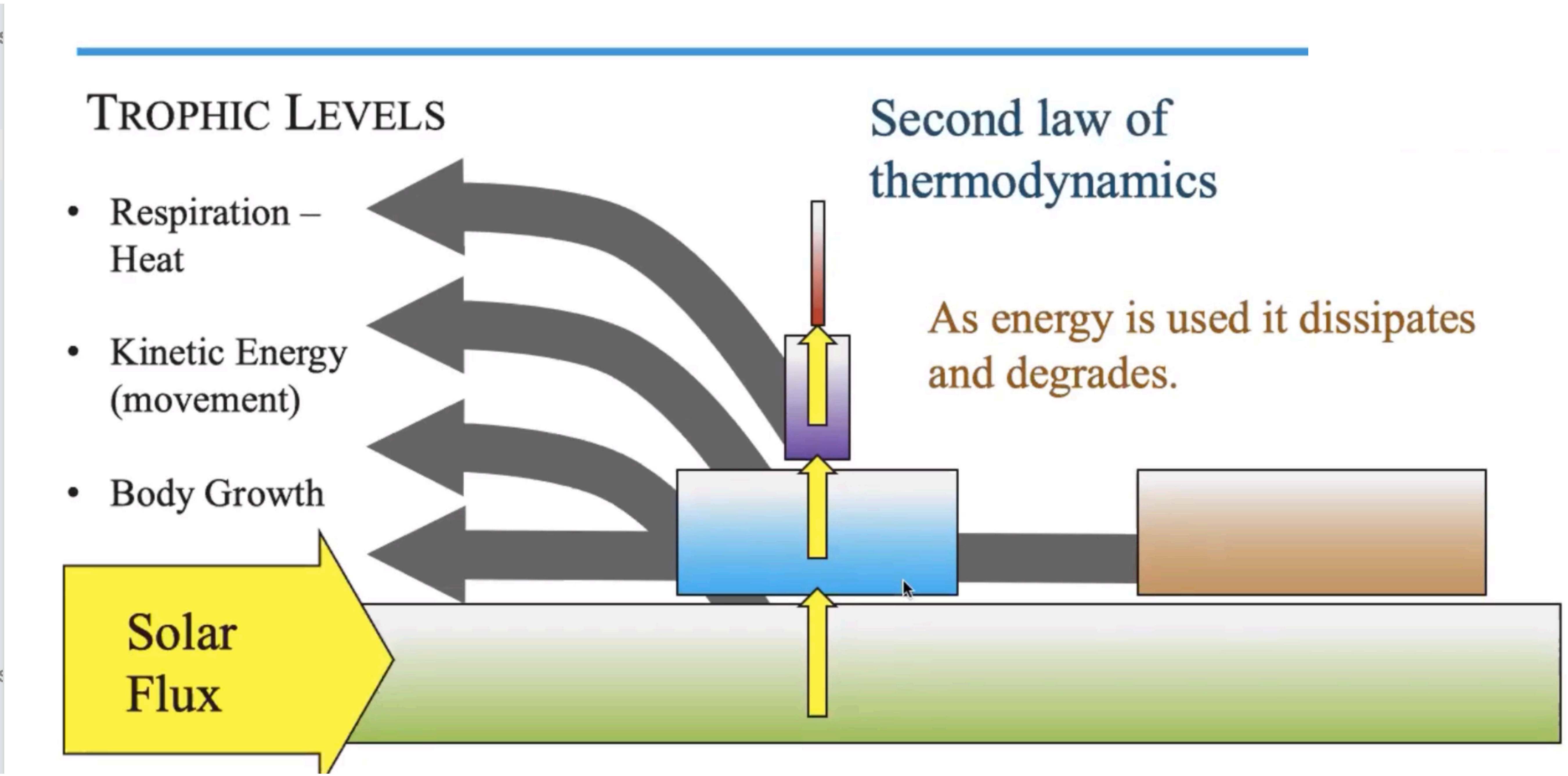
ENG-1.B.3

In terrestrial and near-surface marine communities, energy flows from the sun to producers in the lowest trophic levels and then upward to higher trophic levels.

1.9

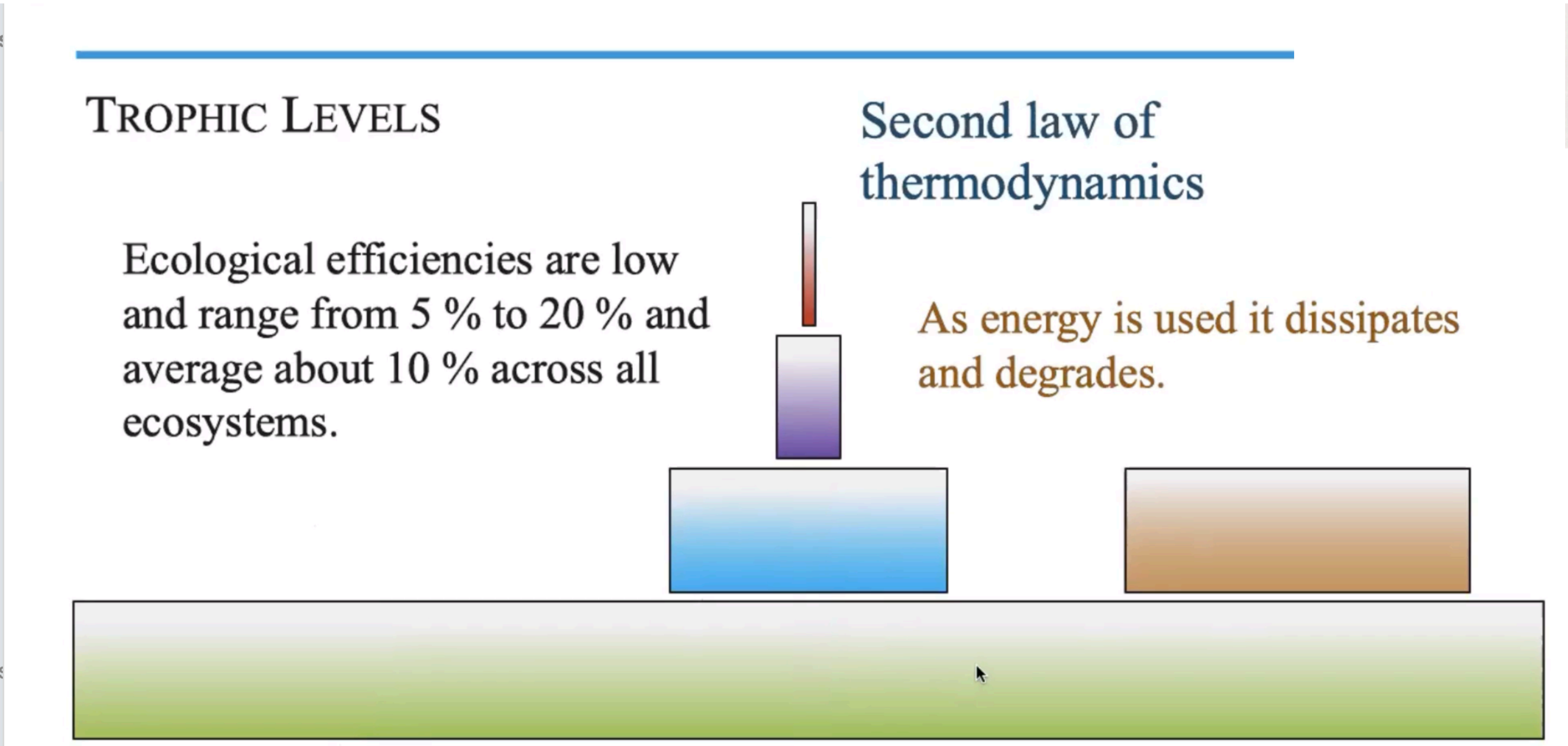

TROPHIC LEVELS (Mayan not Egyptian)
Tertiary Consumers
Secondary Consumers
Primary Consumers
Scavengers, Decomposers, and Detritivores
Primary Producers

1.9



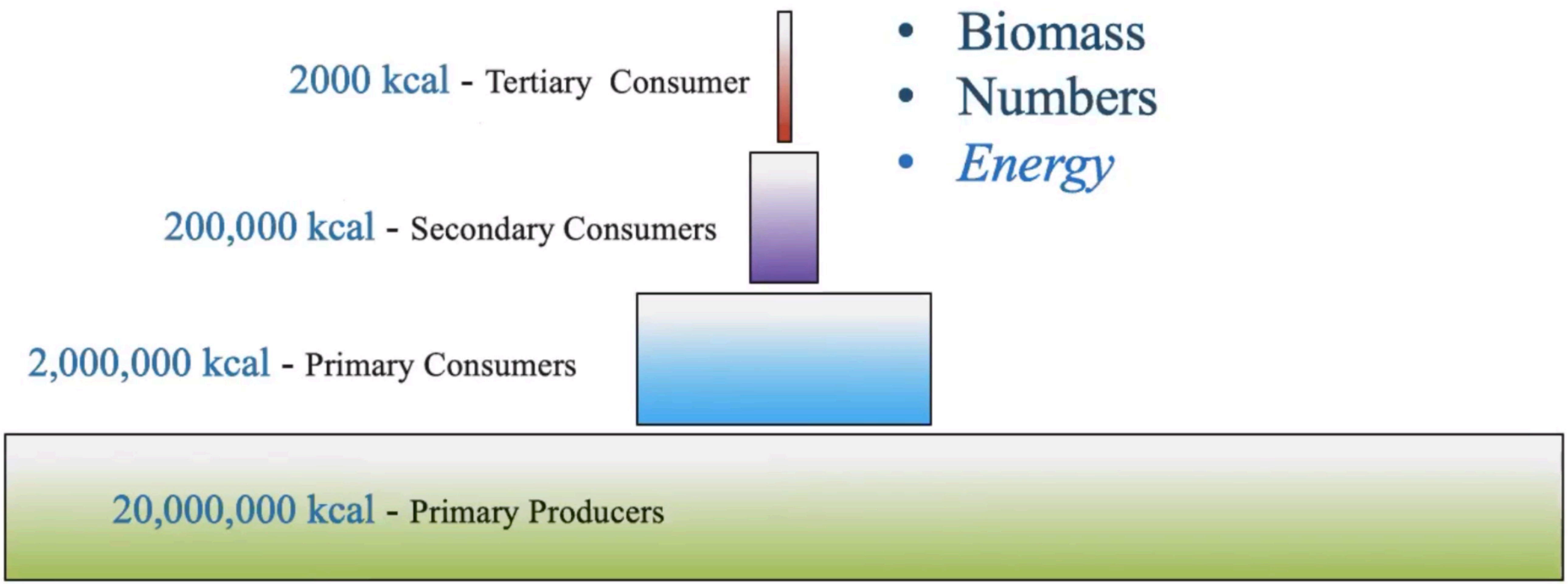
TROPHIC LEVELS
Second law of thermodynamics
Respiration – Heat
Kinetic Energy (movement)
Body Growth
As energy is used it dissipates and degrades.
Solar Flux

1.9


TROPHIC LEVELS
Second law of thermodynamics
Ecological efficiencies are low and range from 5 % to 20 % and average about 10 % across all ecosystems.
As energy is used it dissipates and degrades.

1.9

Trophic Levels



Pyramid of:

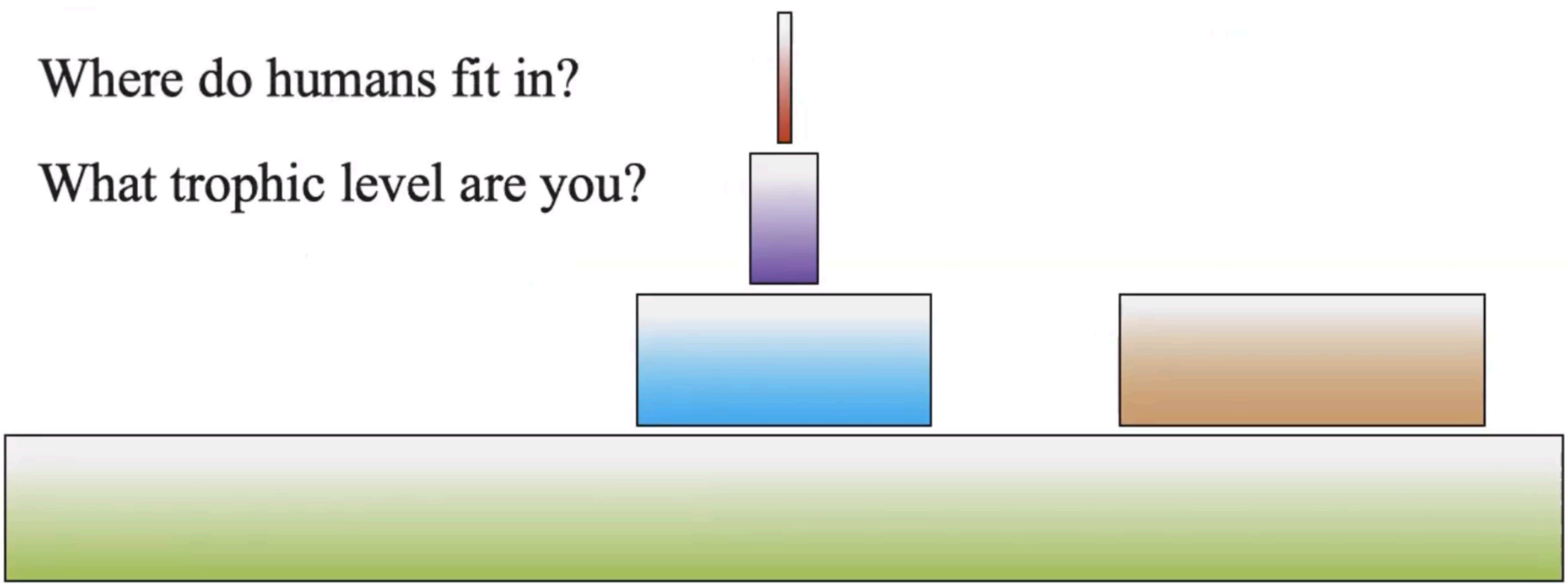
- Biomass
- Numbers
- *Energy*

1.9

TROPHIC LEVELS

Where do humans fit in?

What trophic level are you?



TOPIC 1.10

Energy Flow and the 10% Rule

Required Course Content

ENDURING UNDERSTANDING

ENG-1

Energy can be converted from one form to another.

LEARNING OBJECTIVE

ENG-1.C

Determine how the energy decreases as it flows through ecosystems.

ESSENTIAL KNOWLEDGE

ENG-1.C.1

The 10% rule approximates that in the transfer of energy from one trophic level to the next, only about 10% of the energy is passed on.

ENG-1.C.2

The loss of energy that occurs when energy moves from lower to higher trophic levels can be explained through the laws of thermodynamics.

Ecosystems

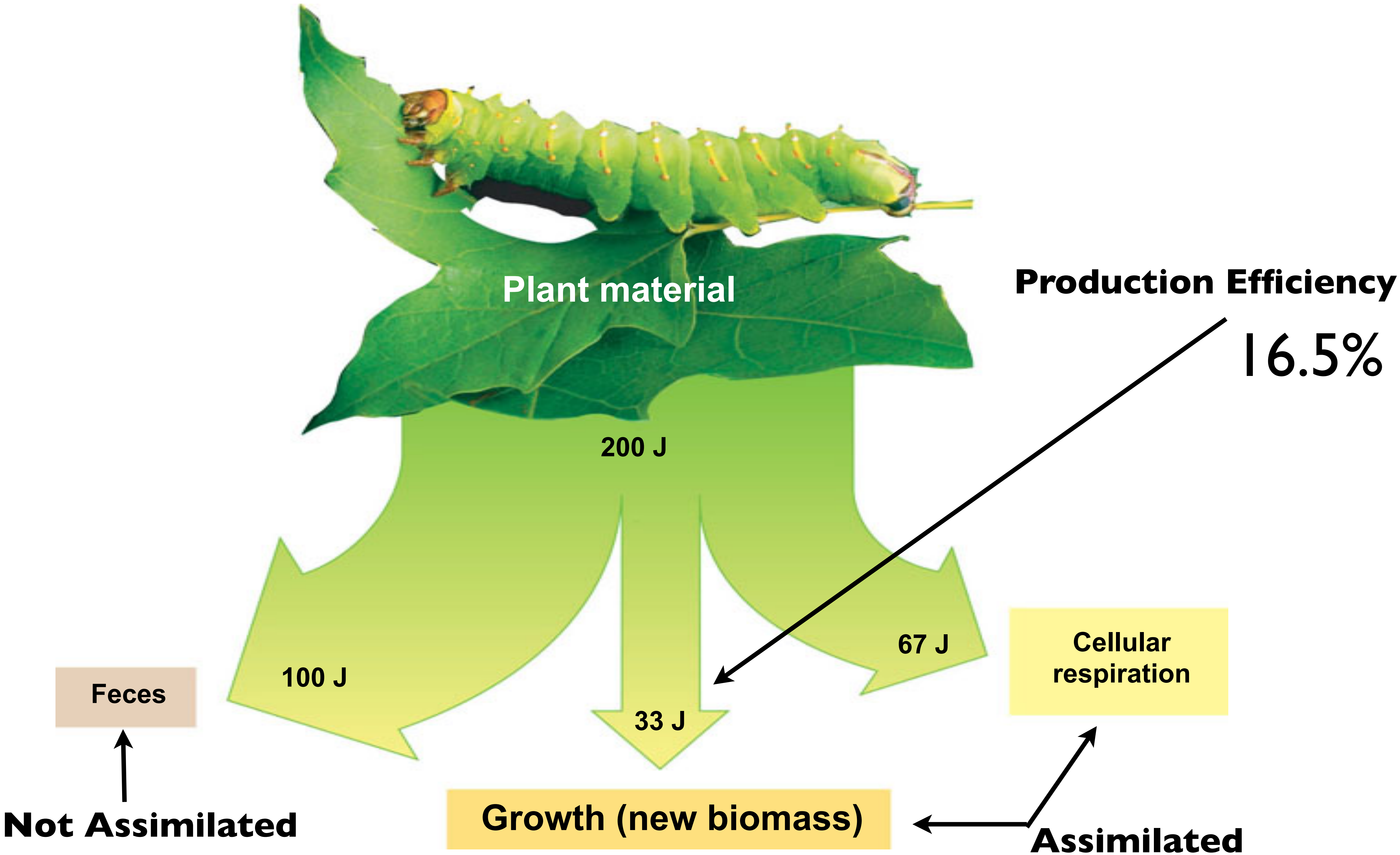
Main Idea: Energy transfer is not efficient, most energy is lost.

ENERGY TRANSFER BETWEEN TROPHIC LEVELS IS TYPICALLY AROUND 10% (WITH 90% LOST)

- **Secondary production**: the amount of chemical energy in consumers food that is actually converted to their own *new biomass* during some time period.

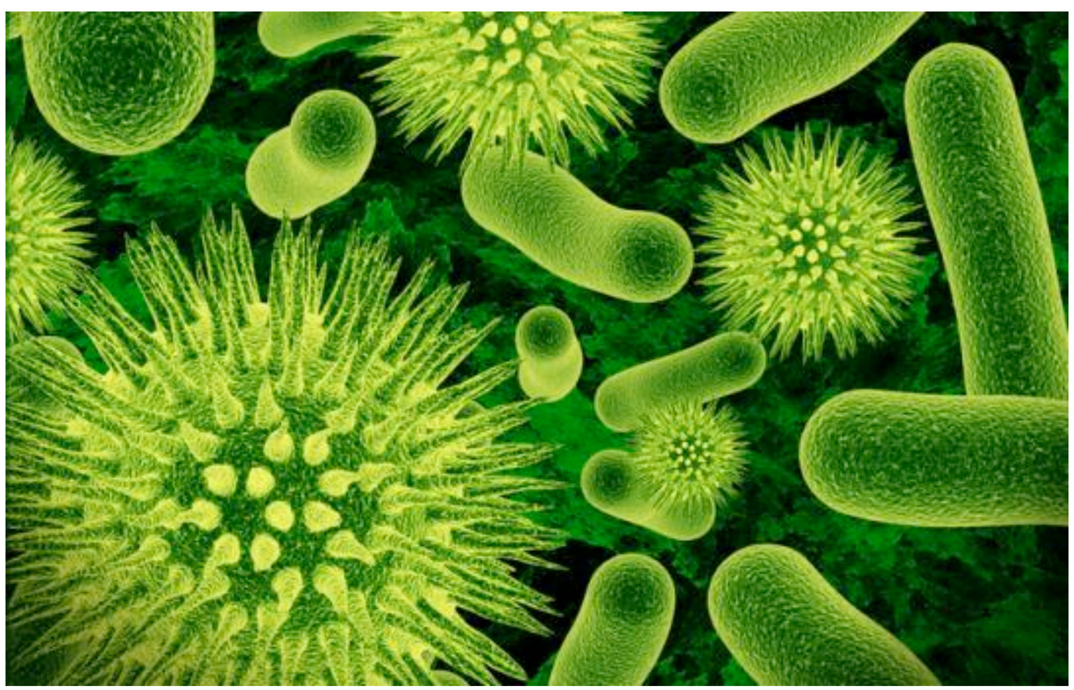
Production Efficiency

- **Think about it...** only the chemical energy stored by herbivores is in their biomass (either in their own biomass or the biomass of their offspring)
  This is only energy available to secondary consumers!
- We can measure production efficiency.


Production Efficiency
16.5%
Plant material
200 J
100 J
67 J
33 J
Feces
Cellular respiration
Growth (new biomass)
Not Assimilated
Assimilated

Match the pictures with their production efficiencies.


1-3%
1-3%
10%
40%
90%

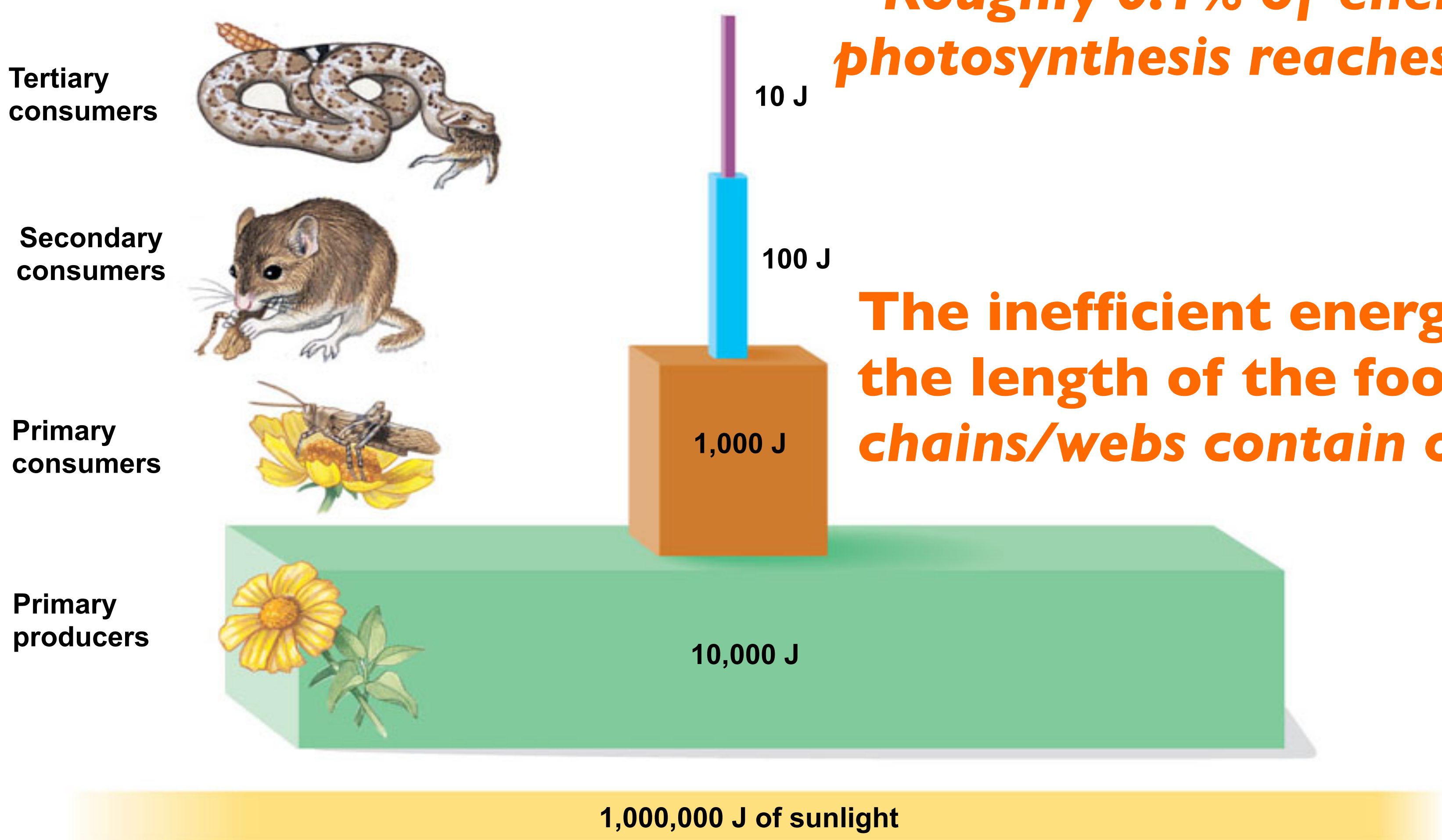



Explain your choices.

Birds & Mammals(1-3%), alot of energy maintaining body heat
Fish (10%)
Microorganisms (40%) due efficient surface area to volume ratio

Trophic Efficiency & Ecological Pyramids

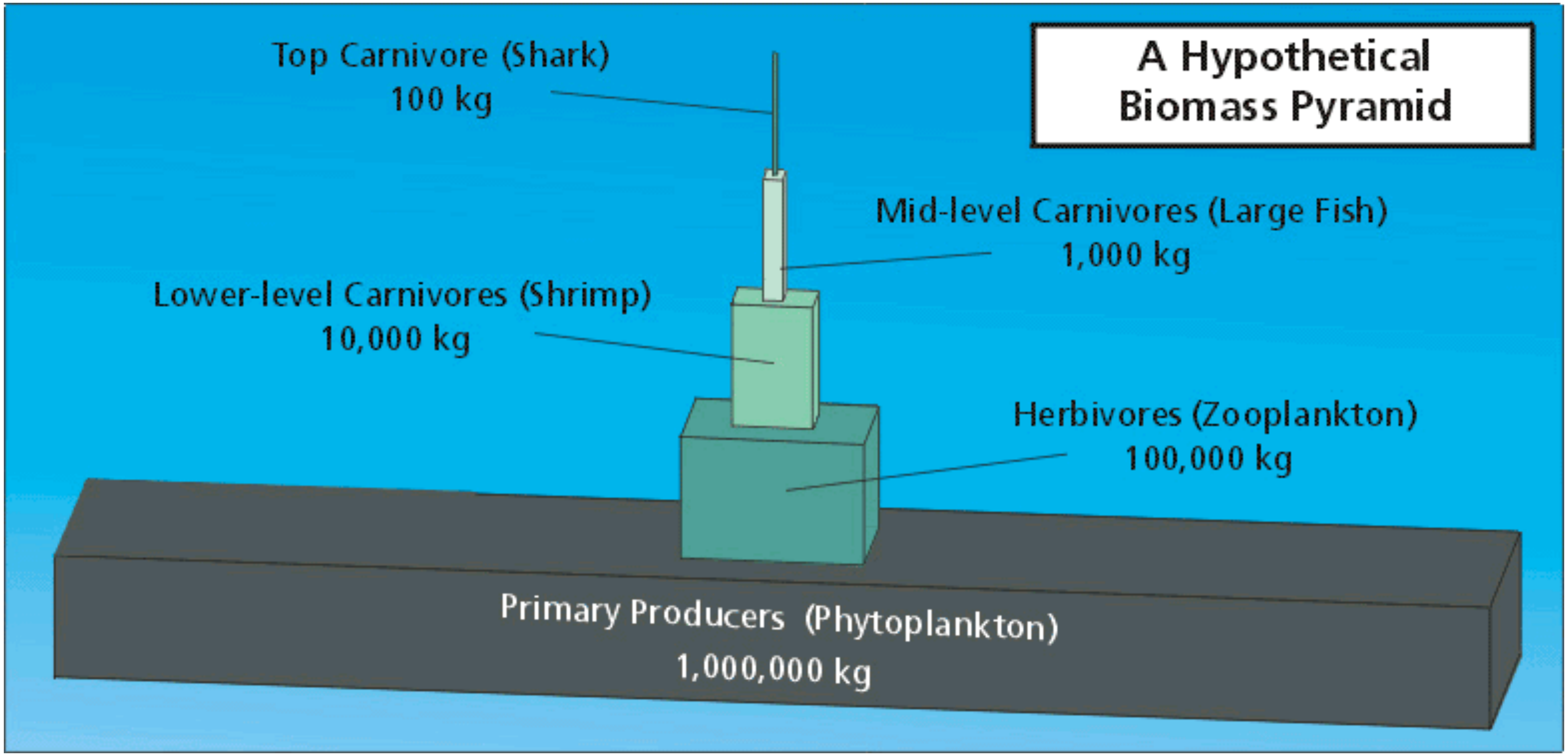
- **Trophic Efficiency**, the percent of production transferred one trophic level to the next. (Ranges between 5-20%)
  - Trophic efficiency must be less than production efficiency.



** Roughly 0.1% of energy fixed by photosynthesis reaches top consumers*

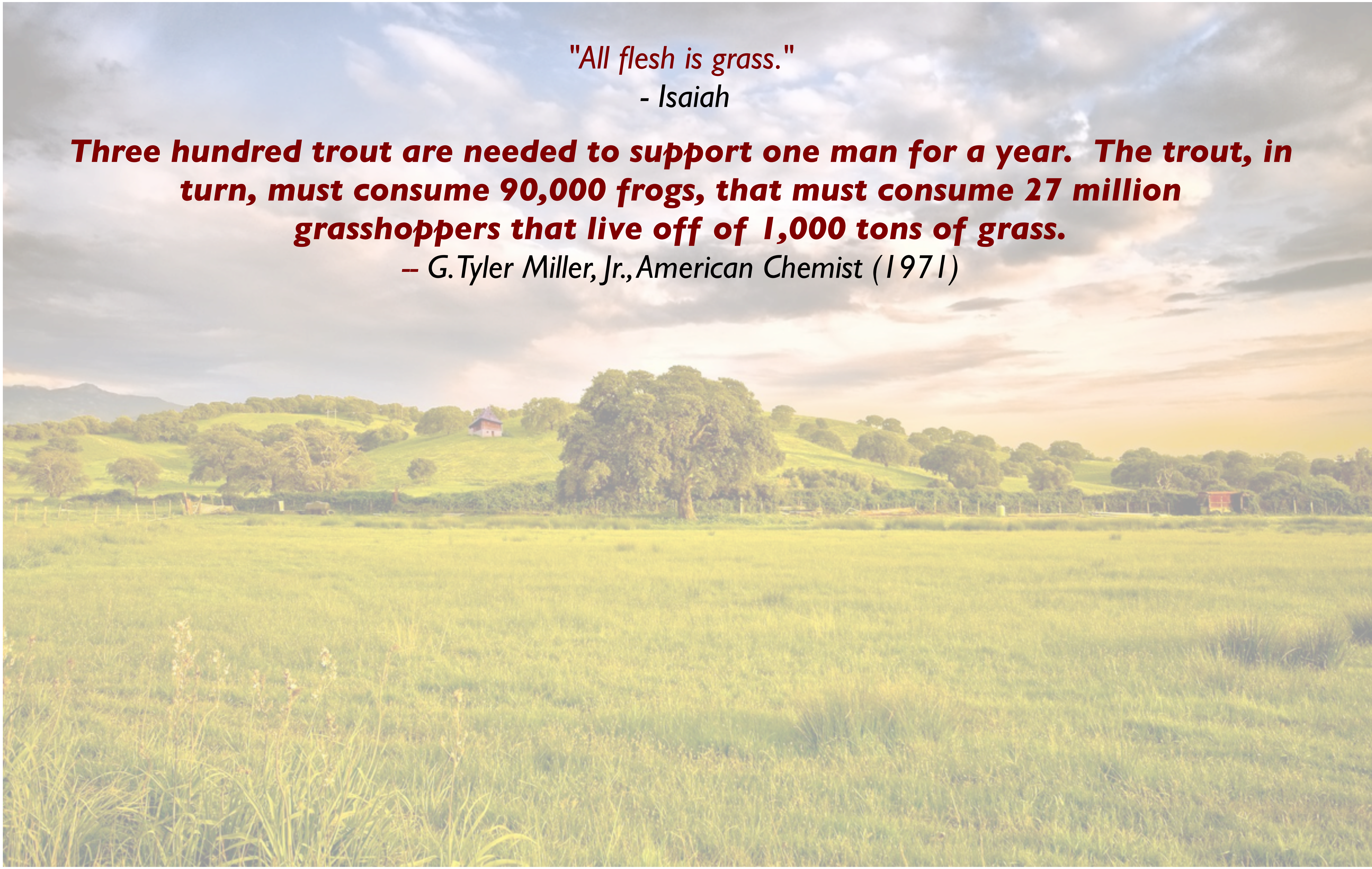
The inefficient energy transfer is multiplied over the length of the food chain. *Thus most food chains/webs contain only 4 or 5 trophic levels.*

Which trophic level is most vulnerable to extinction? Why?



Each tier represents the standing crop (the total dry mass of all organisms) in a trophic level.

Can you make an argument that humans might be better off if they were vegetarians?



"All flesh is grass."

- Isaiah

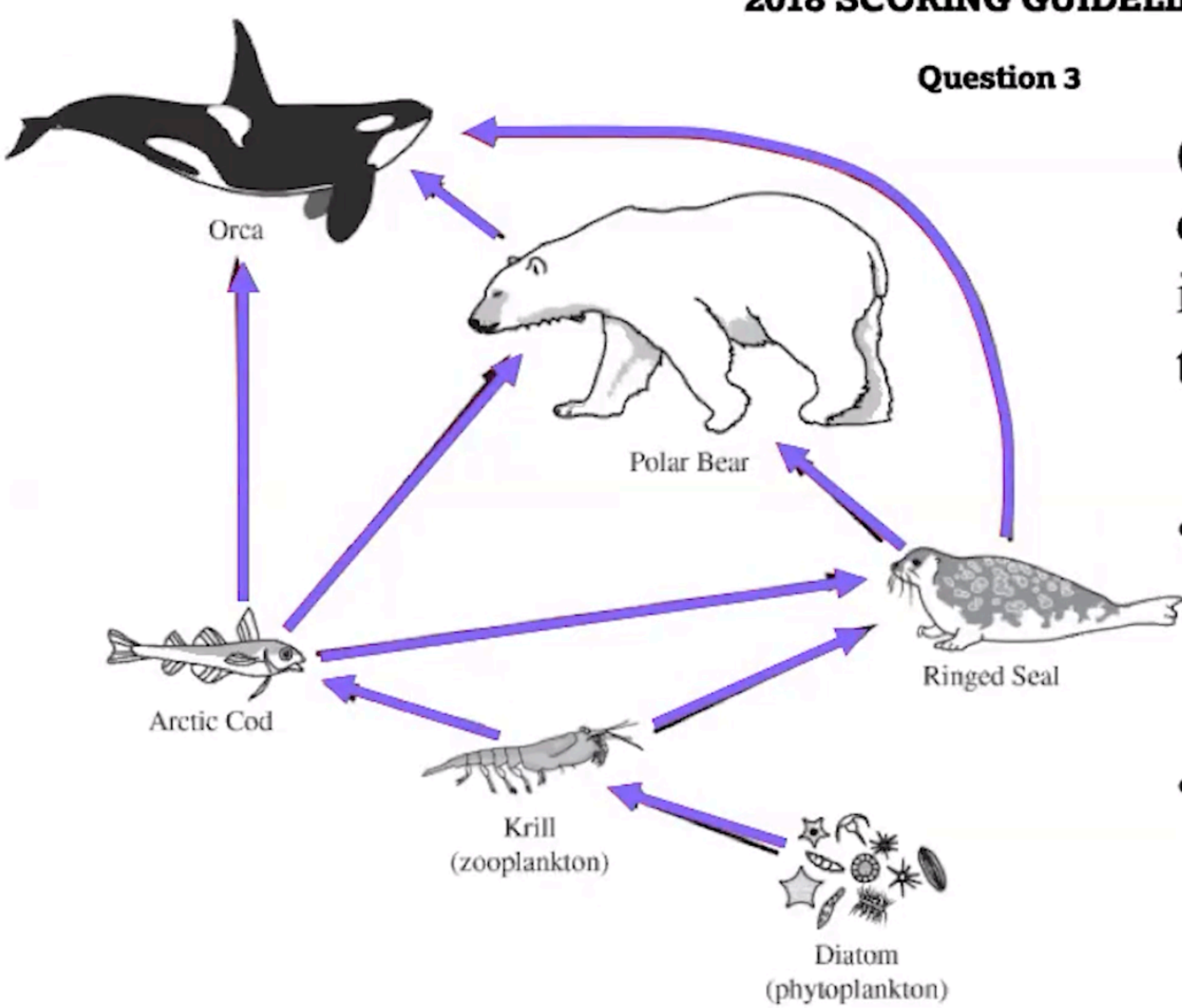
Three hundred trout are needed to support one man for a year. The trout, in turn, must consume 90,000 frogs, that must consume 27 million grasshoppers that live off of 1,000 tons of grass.

-- G. Tyler Miller, Jr., American Chemist (1971)

1.10

AP® ENVIRONMENTAL SCIENCE
2018 SCORING GUIDELINES

Question 3



(b) Other than showing which organisms are consumed by other organisms, **describe** what is indicated by the direction of the arrows in the diagram.

- Shows the flow of **energy** among trophic levels

OR

- Shows the flow of **matter** through trophic levels

TOPIC 1.11

Food Chains and Food Webs

Required Course Content

ENDURING UNDERSTANDING

ENG-1

Energy can be converted from one form to another.

LEARNING OBJECTIVE

ENG-1.D

Describe food chains and food webs, and their constituent members by trophic level.

ESSENTIAL KNOWLEDGE

ENG-1.D.1

A food web is a model of an interlocking pattern of food chains that depicts the flow of energy and nutrients in two or more food chains.

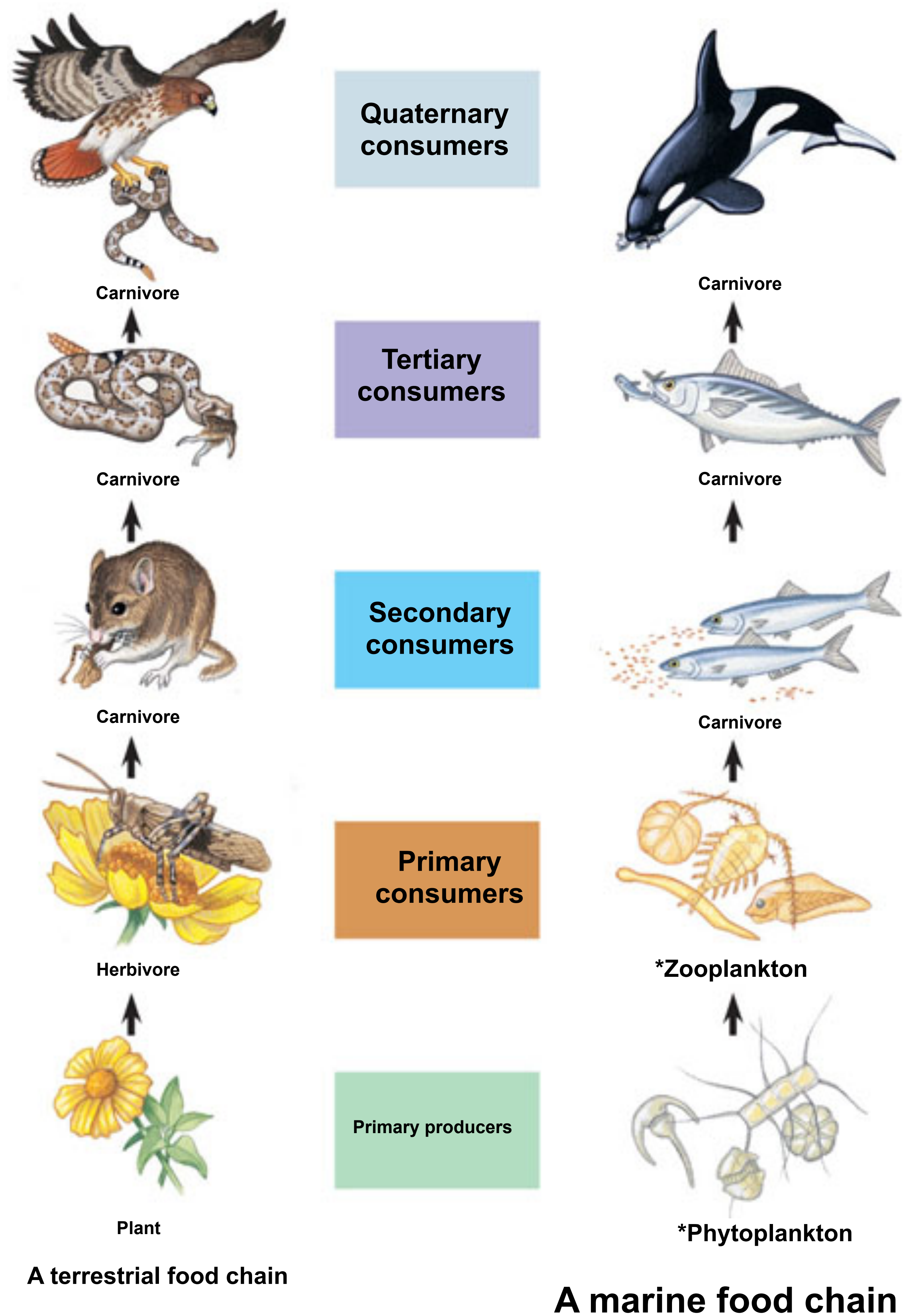
ENG-1.D.2

Positive and negative feedback loops can each play a role in food webs. When one species is removed from or added to a specific food web, the rest of the food web can be affected.

Trophic Structure

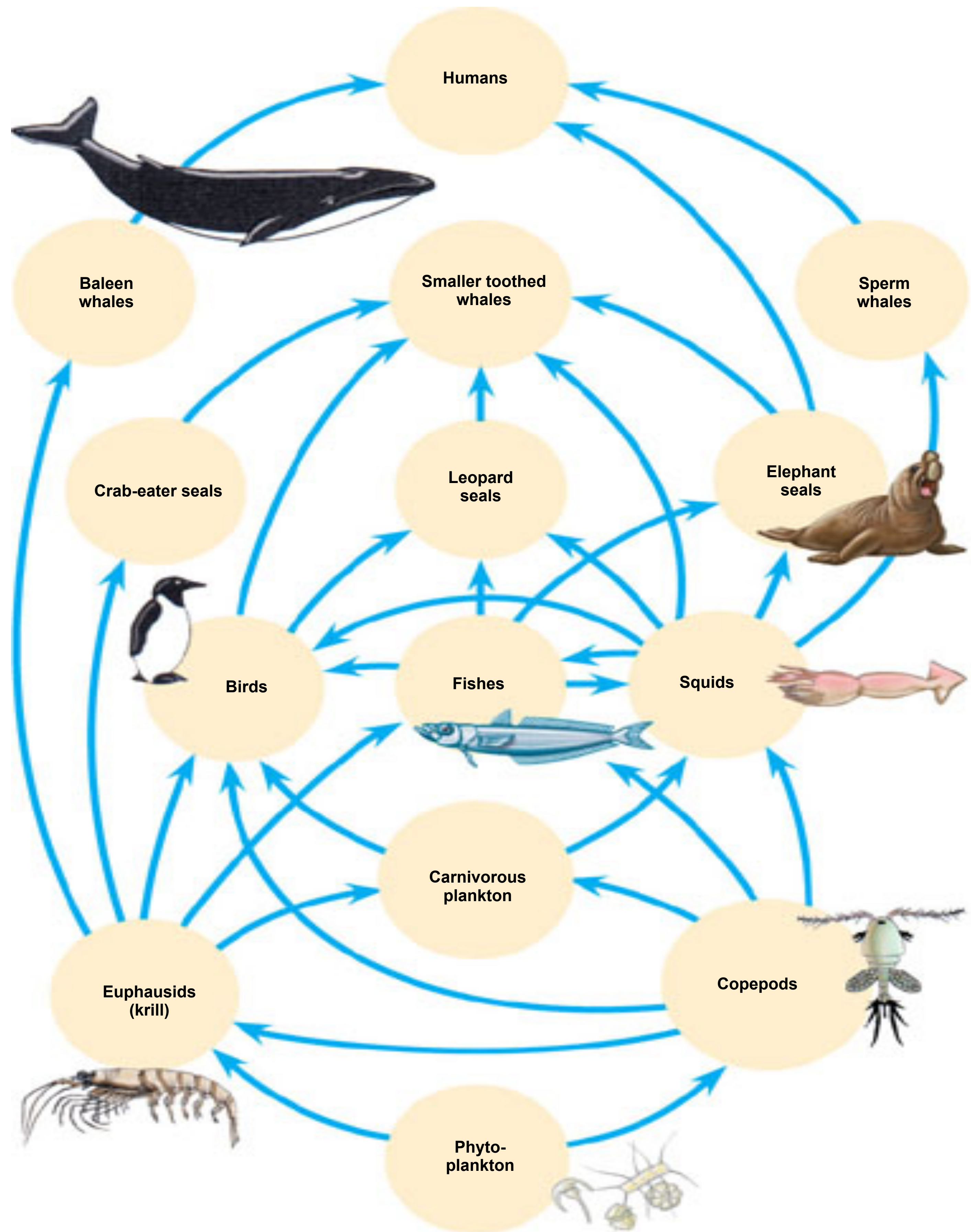
- **Trophic Structure**...feeding relationships within the community.
- The movement of food energy from autotrophs through and up to the largest consumers...**food chains**.

Food Chains



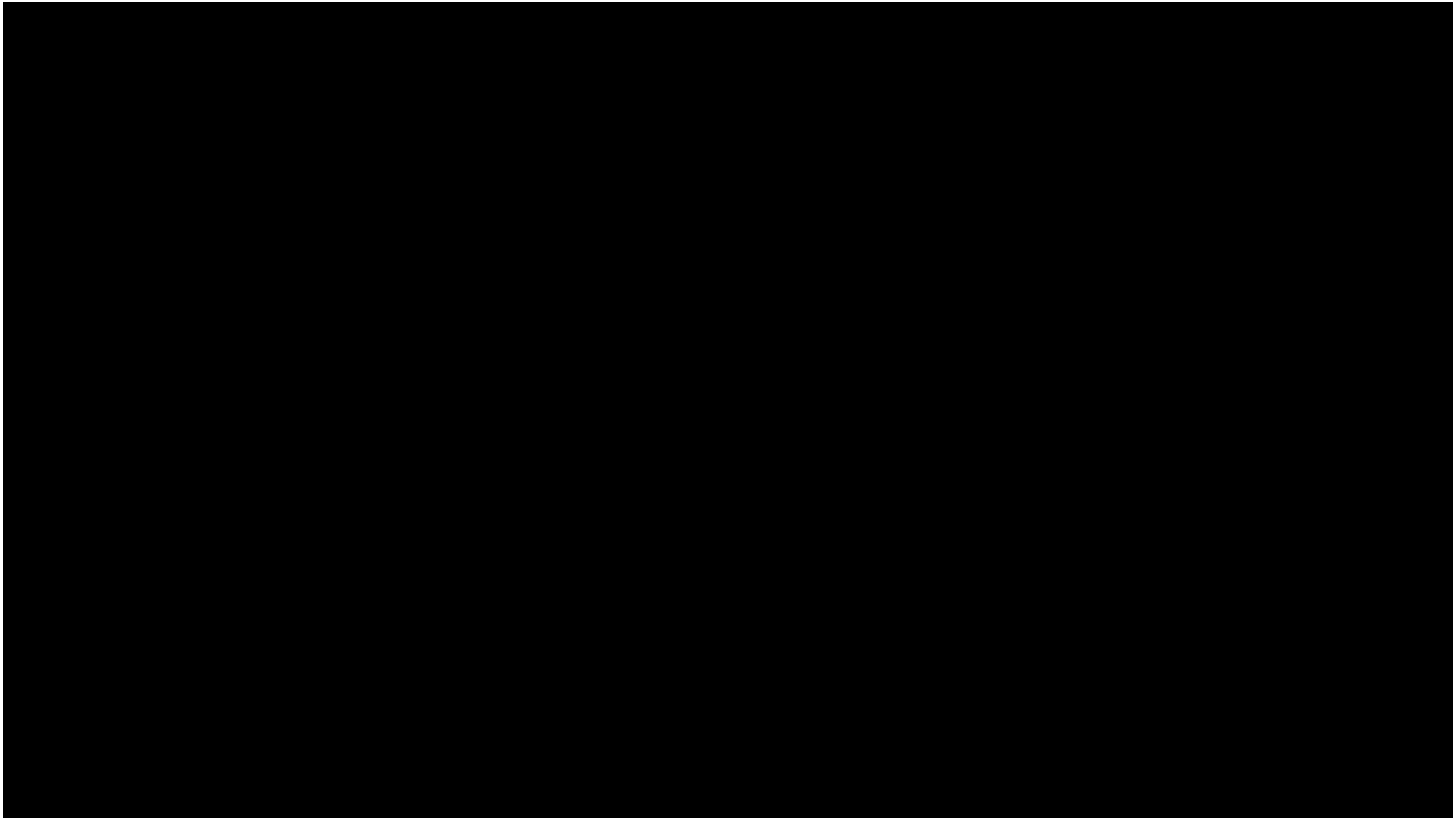
Food Webs

- Interconnected and linked food chains make up **food webs**.
- The arrow points in the direction of foods movement. In other words A → B indicates that B is eating A. Many students reverse this so be careful



Could you interpret these feeding relationships IF...
1.the pics were removed?
2. the pics and names were removed?
3.What if I removed all pics, names and turned in upside down?

Phytoplankton



1. Food Chain Lengths

- Food chains are limited in their lengths.
    - The *Energetic Hypothesis* states that the energy transfer one one trophic level to another is inefficient (about 10-20%) and after 3 - 5 transfers there is not enough energy to support another level.

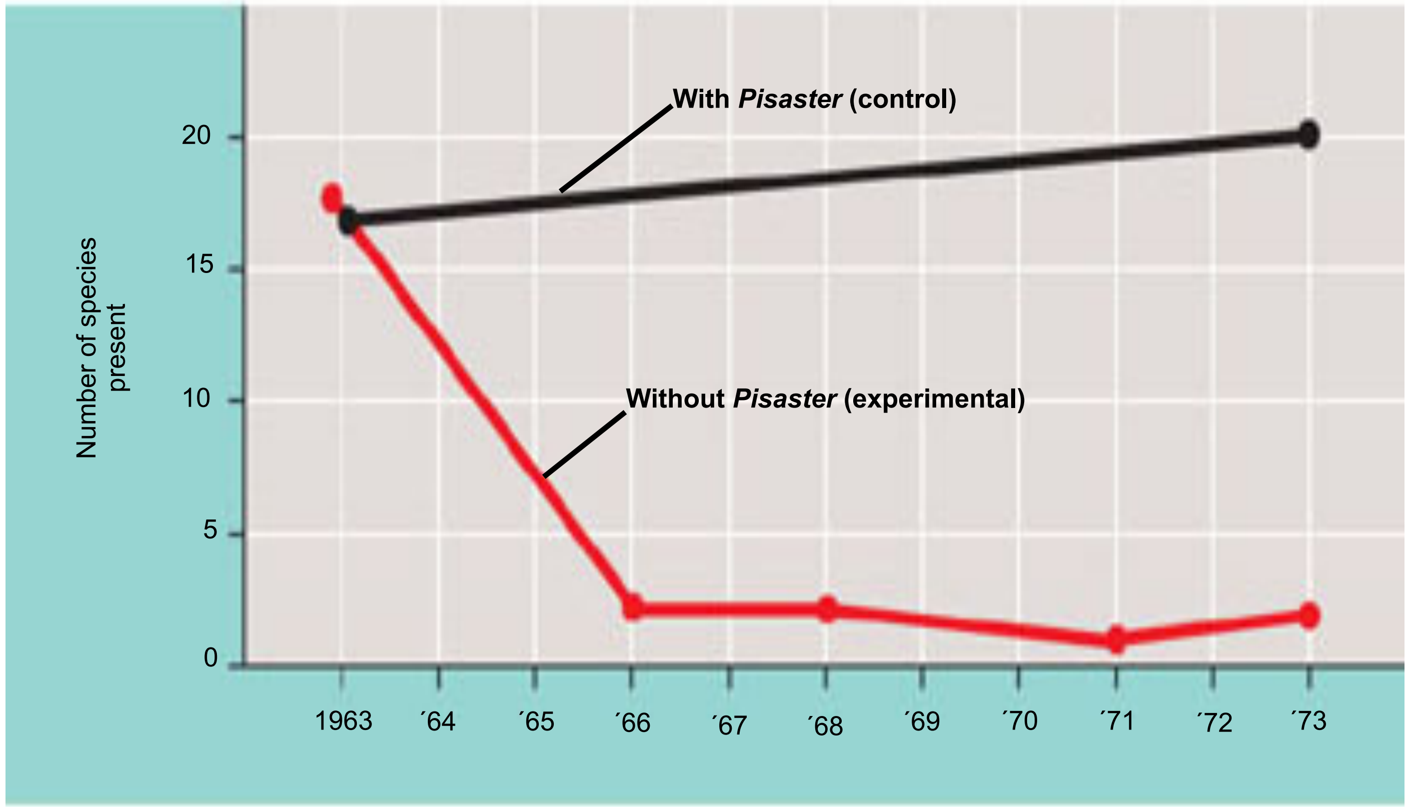
Dominant Species

- Certain species have a proportionally larger impact in the community due to their abundance or a key role that they play in community interactions
  - 1. **Dominant Species**; are the most abundant or have the highest biomass.

Keystone Species

- 2. **Keystone Species**; are the most abundant but they exert strong control on community dynamics due their unique role or niche.

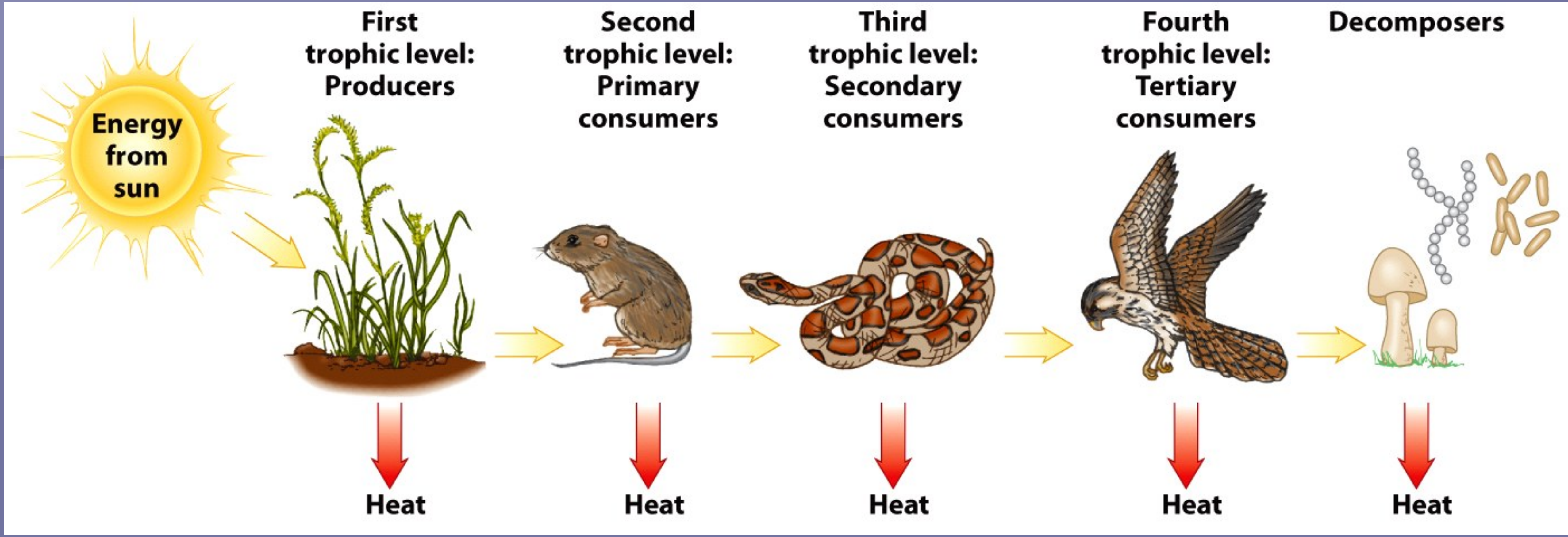
(a) The sea star *Pisaster ochraceous* feeds preferentially on mussels but will consume other invertebrates.



(b) When *Pisaster* was removed from an intertidal zone, mussels eventually took over the rock face and eliminated most other invertebrates and algae. In a control area from which *Pisaster* was not removed, there was little change in species diversity.

What is a "keystone"?

Energy Flow

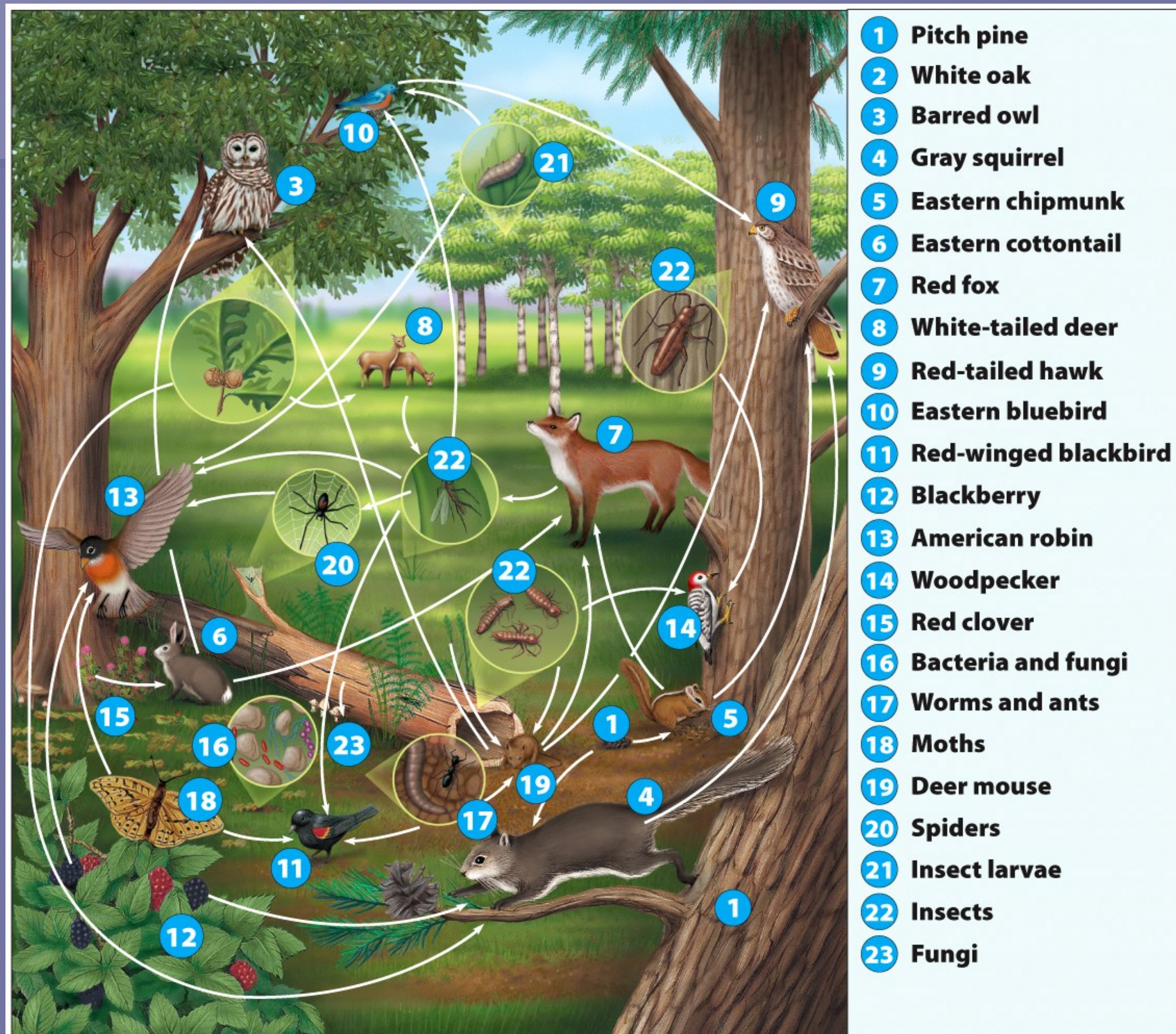


- Passage of energy through an ecosystem
  - Producers
  - Primary consumers
  - Secondary consumers
  - Decomposers

Food Chains - The Path of Energy Flow

- Energy from food passes from one organisms to another based on their Trophic Level
  - An organisms position in a food chain determined by its feeding relationships
- First Trophic Level: Producers
- Second Trophic Level: Primary Consumers
- Third Tophic Level: Secondary Consumers
- Decomposers are present at all trophic levels

Food Web


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

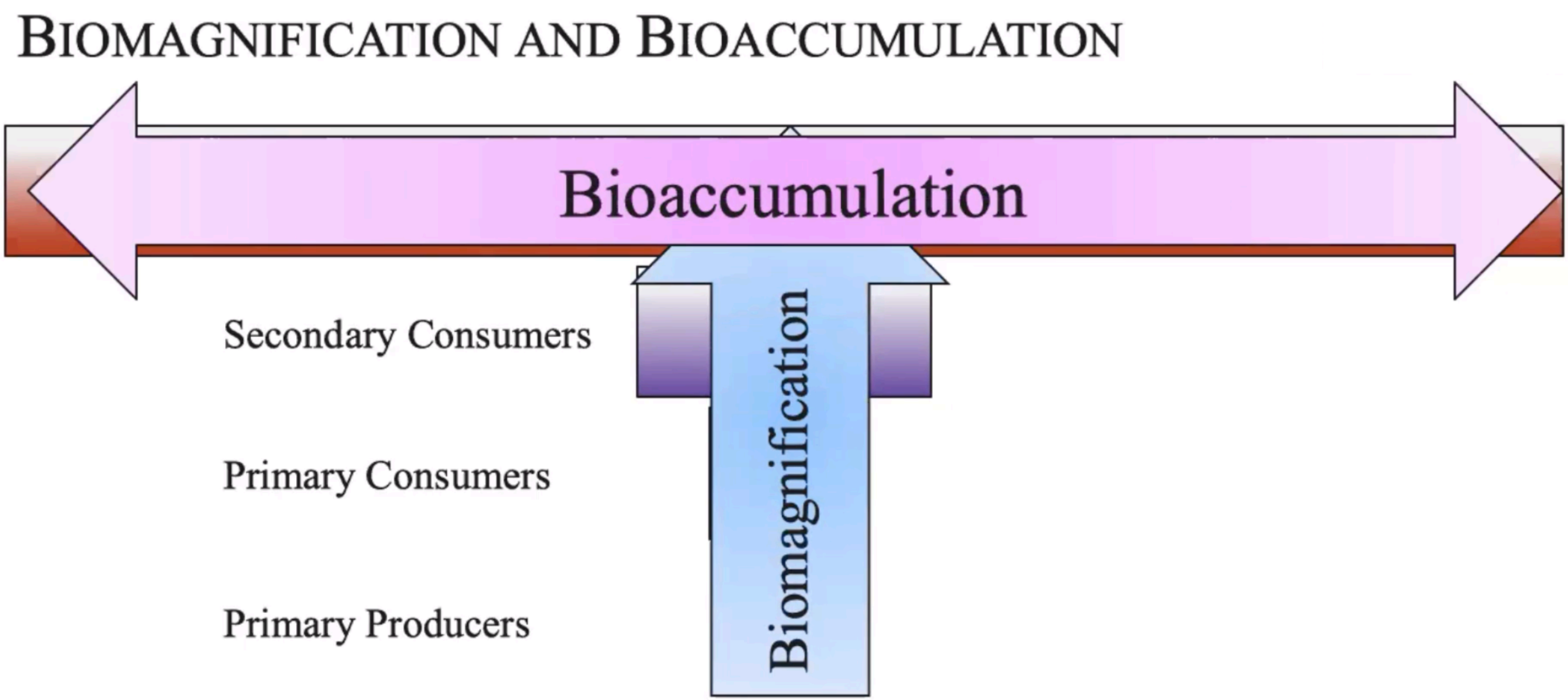
1.11

Trophic Cascade

Human impact on a food web, some are ecological in nature and some are economical.

Mercury, Lead, DDT, Invasive Species, Overfishing

1.11


BIOMAGNIFICATION AND BIOACCUMULATION
Bioaccumulation
Secondary Consumers
Primary Consumers
Primary Producers
Biomagnification