BIOMES AND BIODIVERSITY

Biomes and Biodiversity Lecture

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Biomes & Biodiversity Objectives

1. Define a biome and identify its abiotic and biotic components.
2. Differentiate the physical and biological factors affecting the evolution of life within a biome.
3. Recognize the biodiversity that is present within biomes and define the resilience of biomes.
4. Identify current threats to Earth's biomes, biodiversity, and ecosystem services.

Objective 1: Define a biome and identify its abiotic and biotic components.

Abiotic Factors

- Non-living chemical and physical components in the environment, which are essential for life
- Inorganic compounds that are not organic (i.e., they lack carbon-hydrogen bonds)
- Impact an organism's ability to survive, grow, reproduce, and determine the types and numbers of organisms that can exist within a biome

Examples of abiotic factors:

Air (oxygen, carbon dioxide, nitrogen), Water, Sunlight, Soil Minerals, Humidity

Biotic Factors

- Living components of an ecosystem
- Made up of organic compounds, meaning that they are composed of carbon-hydrogen molecules
- Can have both direct and indirect effects on a biome, can impact an organism's interactions with other organisms, predation, place within a food chain, waste cycle, disease, etc.

Examples of biotic factors:

1. Living organisms: virus, bacteria, fungi, plants, animals, insects, parasites
2. Organic molecules: DNA, RNA, proteins, lipids, carbohydrates

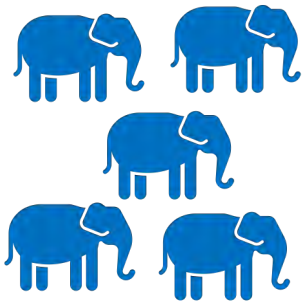
Hierarchy of Life on Earth

biotic

Organism

A living individual organism

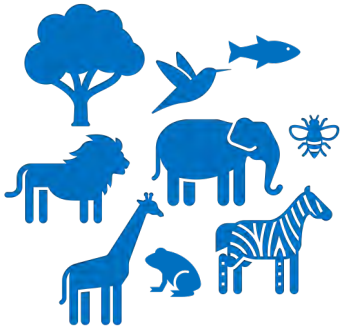
biotic



Population

Many individuals of the same species that can breed and produce offspring

biotic



Community

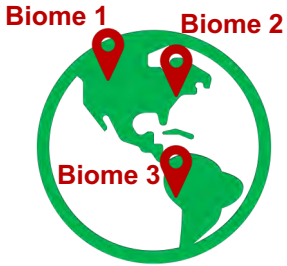
Many individuals from different species interacting with one another

abiotic + biotic

Ecosystem

A community and all its abiotic components

abiotic + biotic

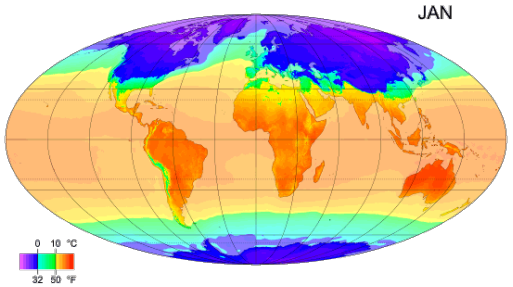


Biome

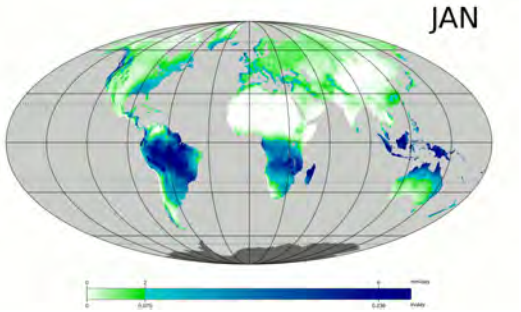
Ecosystems that occupy a large geographic area.

What is a biome?

A major community that has been established by global climate (i.e., long-term temperature and precipitation patterns) and is defined by the organisms and vegetation that are adapted to live in this large geographical area.



Earth's Monthly Mean Surface Air Temperature (1961-90)



Earth's Monthly Mean Surface Air Precipitation (1961-90)

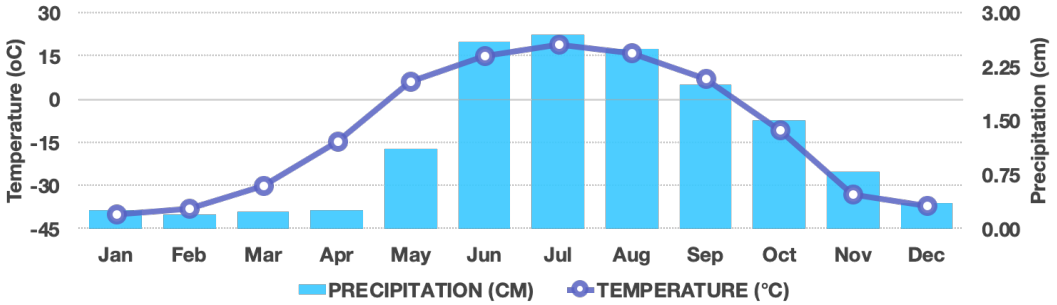
What is climate?

Climate is long-term average weather patterns that occurs at a location over decades, centuries and eons. The two main factors that control climate are temperature and precipitation.

Major Factors that Control Climate

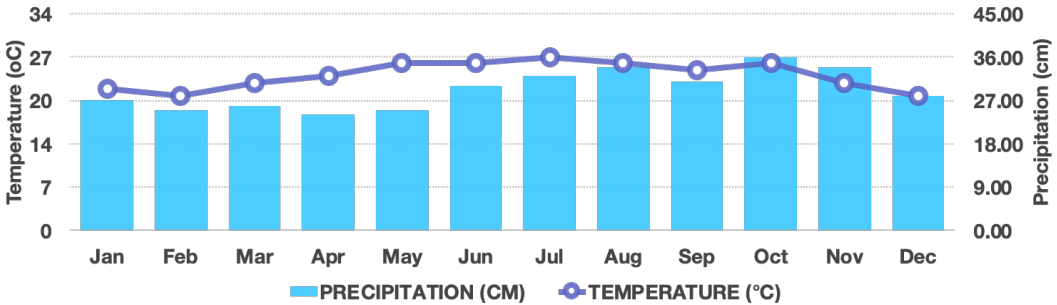
- **Temperature** – location can be hot, warm or cold
- **Precipitation** – location can be wet or dry
- **Tilt of Earth on its axis** – causes seasons (spring, summer, fall, winter)
- **Sun** – produces heat and energy for our planet
- **Latitude** – distance from equator (hot), poles are cold
- **Elevation** – orographic precipitation, higher altitudes are cold
- **Mountain ranges and shape of the land** – rain shadow effect
- **Ocean currents** – distance from ocean, warm or cold currents
- **Winds** – direction of prevailing winds can bring rain, cold, heat
- **Vegetation** – trees of tropical rainforest release moisture producing clouds and rain
- **Human activity** – deforestation, burning fossil fuels, urbanization

Climograph – single graph that displays data for two variables (1) monthly average temperature and (2) monthly average precipitation for a single location on Earth. Climograph is a simple way to graphically describe a location's climate.



Climograph for Biome 1

cold & dry



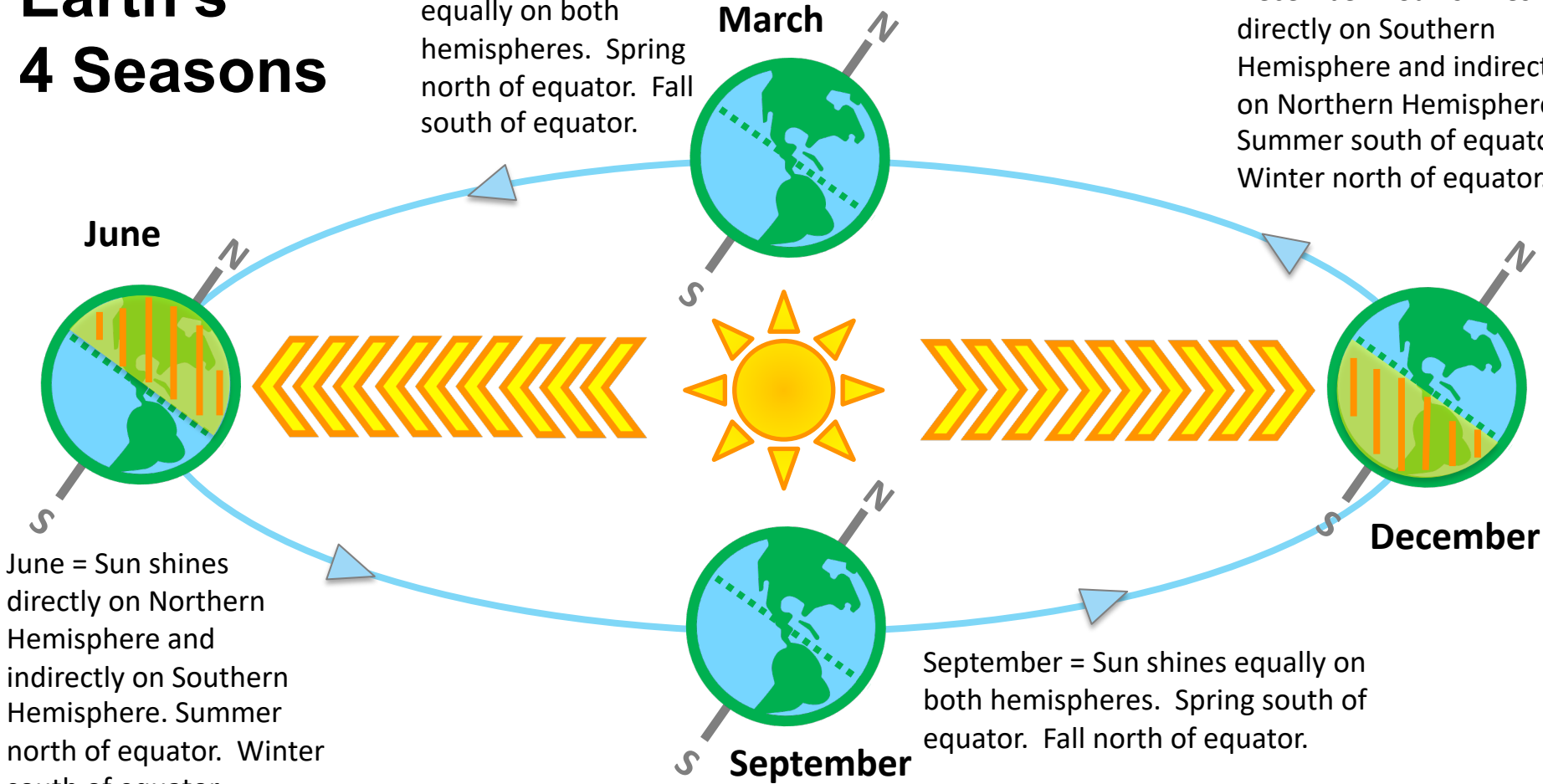
Climograph for Biome 2

hot and wet

Earth's 4 Seasons

March = Sun shines equally on both hemispheres. Spring north of equator. Fall south of equator.

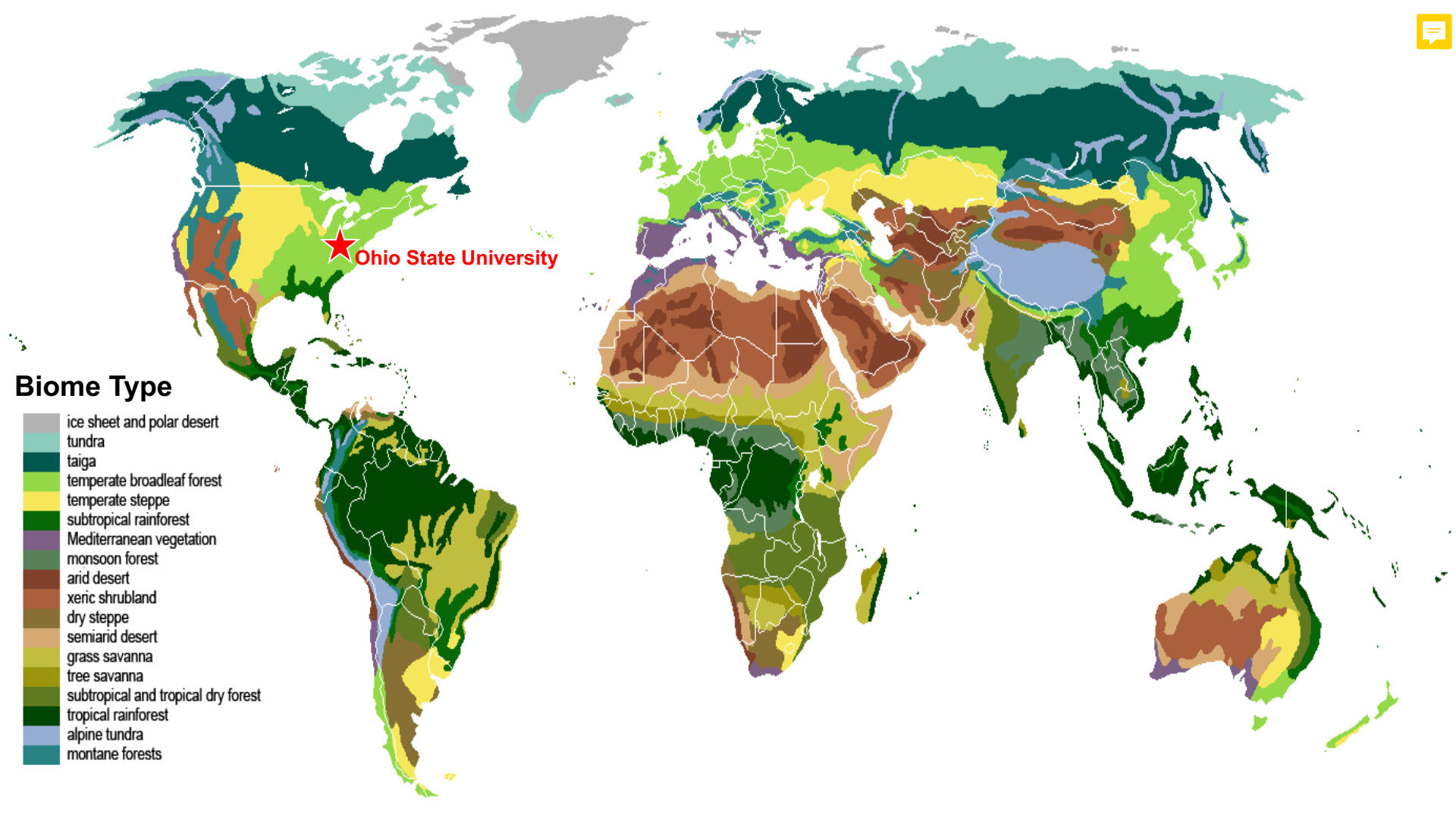
December = Sun shines directly on Southern Hemisphere and indirectly on Northern Hemisphere. Summer south of equator. Winter north of equator.



June = Sun shines directly on Northern Hemisphere and indirectly on Southern Hemisphere. Summer north of equator. Winter south of equator.

September = Sun shines equally on both hemispheres. Spring south of equator. Fall north of equator.

https://spaceplace.nasa.gov/seasons/en/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Biome Type
ice sheet and polar desert
tundra
taiga
temperate broadleaf forest
temperate steppe
subtropical rainforest
Mediterranean vegetation
monsoon forest
arid desert
xeric shrubland
dry steppe
semiarid desert
grass savanna
tree savanna
subtropical and tropical dry forest
tropical rainforest
alpine tundra
montane forests

Earth’s Biomes

The exact number of biomes on the planet depends on how the biomes are classified. Not all scientists classify these regions in the same way.

Some scientists use broad classifications and count as few as 5 or 6 biomes on Earth. Others use very precise classification and count hundreds of specific biomes.

Biomes are also difficult to delineate because there are no defined boundaries between them. There are often areas between them that may share similar characteristics called transition zones or **ecotones**. Climate change also shifts biomes over time, making it more challenging to map out all of Earth’s biomes accurately.

Earth has THREE broad categories of biomes that are based on **climate** (i.e., temperature and precipitation) and determined by predominant **vegetation**.

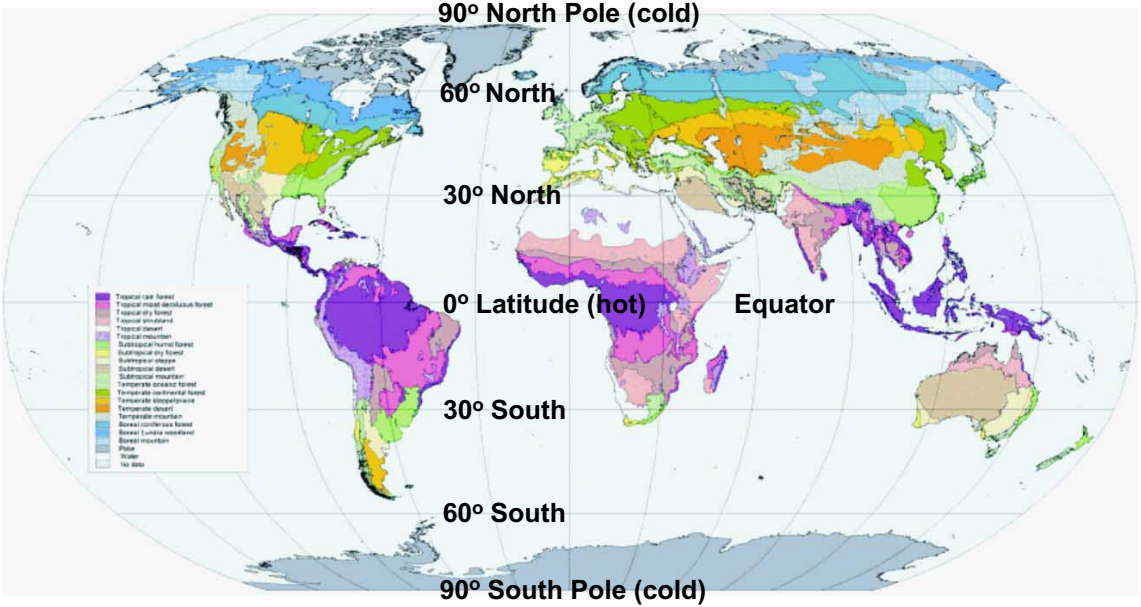
Marine Biomes

Freshwater Biomes

Terrestrial Biomes

Climate

The climate of Earth's major biomes is defined by temperature and precipitation.



Temperature varies with latitude and altitude. As latitude and altitude increase, temperatures decrease.

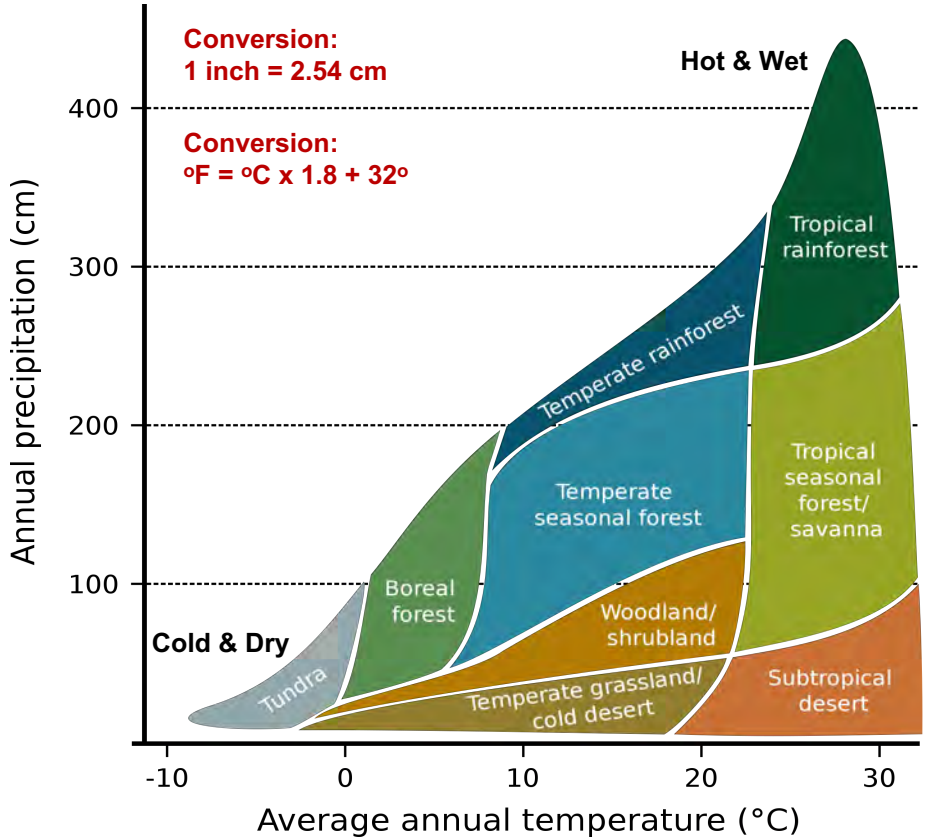
Image by Dcasey98, Wikimedia Commons

Whittaker's biome-types

Whittaker defined climates based on the affects of both temperature and precipitation on terrestrial vegetation. These factors (temperature and precipitation) will determine the major type of vegetation that occurs within a biome.

For example, tropical rainforest is hot and wet; tundra is cold and dry.

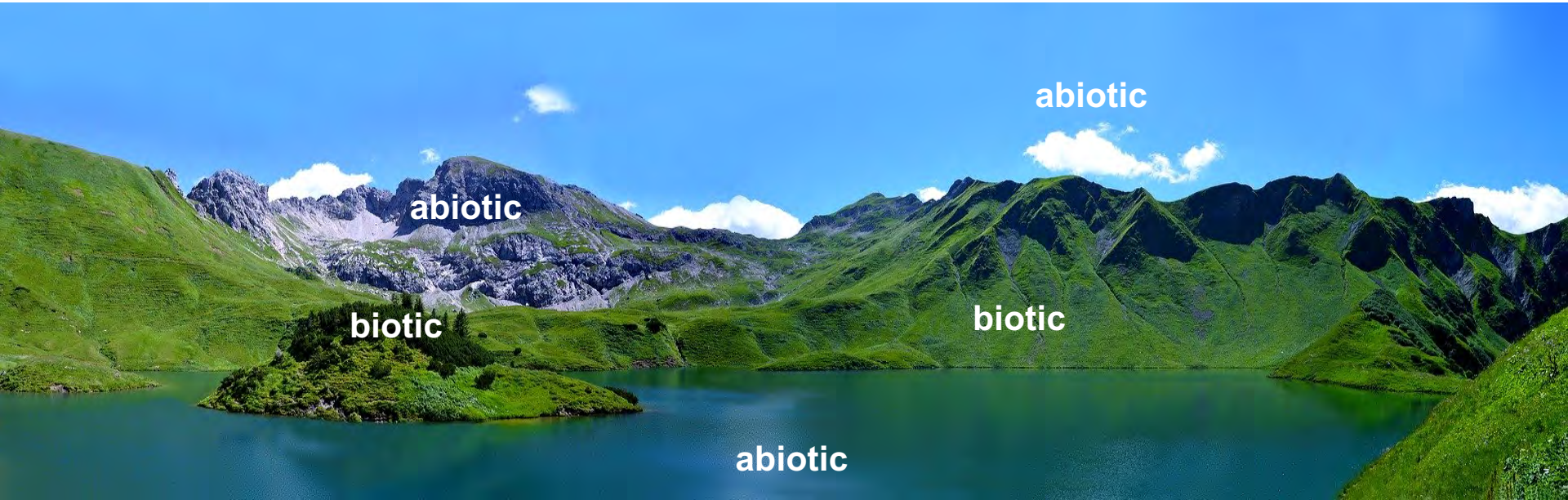
Image by Navarras, Wikimedia Commons



Vegetation – assembly of dominate plant species

- Terrestrial biomes vary by type of vegetation, and vegetation is a function of climate (i.e., temperature and precipitation), latitude, elevation, animal species (e.g., types of herbivores) and other abiotic factors (e.g., avalanche, coastal location, fire, flooding).
- Each biome requires us to consider the types of interactions between and among plant and animal species, as well as, the nutrient requirements for all organisms living within the biome.
- Species interactions vary depending on climate (i.e., temperature and precipitation) and the ability of organisms to maintain homeostasis within narrow tolerance limits, which they have evolved to live within (e.g., oak trees have evolved to live in temperatures of about -10^{o}C to 35^{o}C.

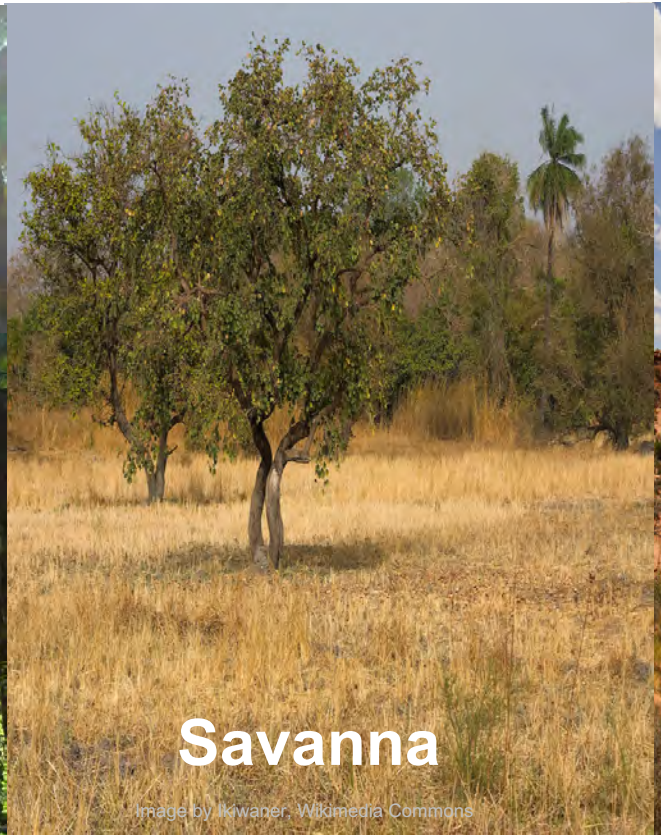
Biomes can be further distinguished by individual ecosystems based on interactions between **biotic and abiotic components**.



Terrestrial Biomes

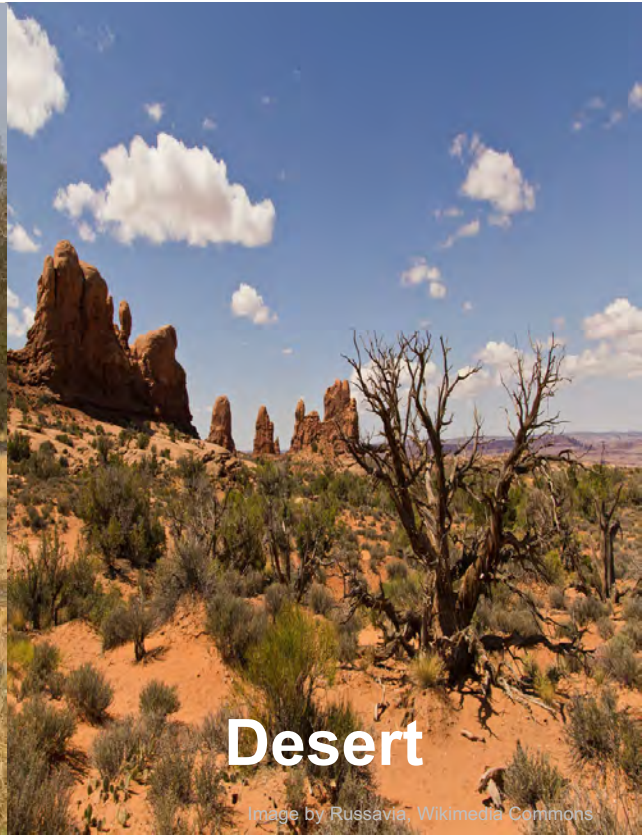
Tropical rainforest

Image byFramame, Wikimedia Commons



Savanna

Image by Ikwaner, Wikimedia Commons



Desert

Image by Russavia, Wikimedia Commons

Terrestrial Biomes

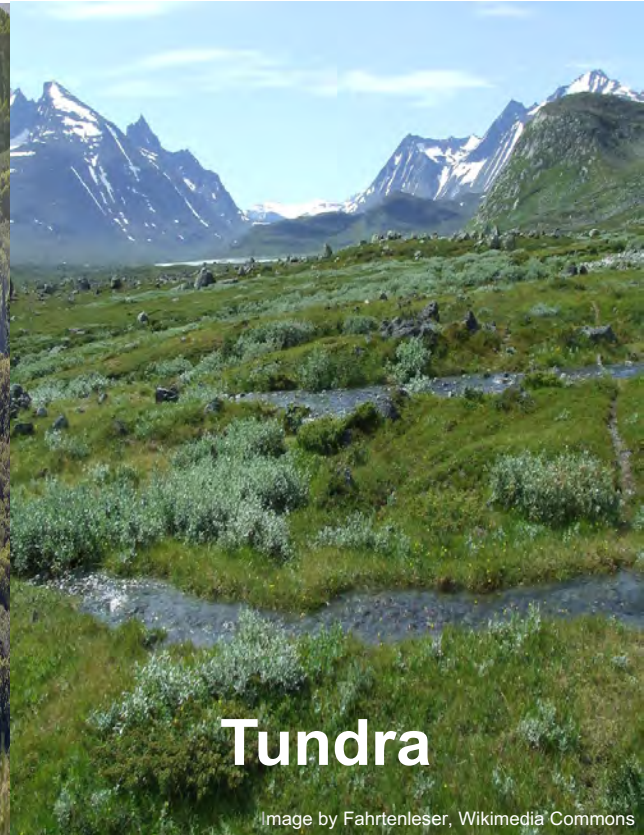


Image by Fahrtenleser, Wikimedia Commons

Freshwater Biomes

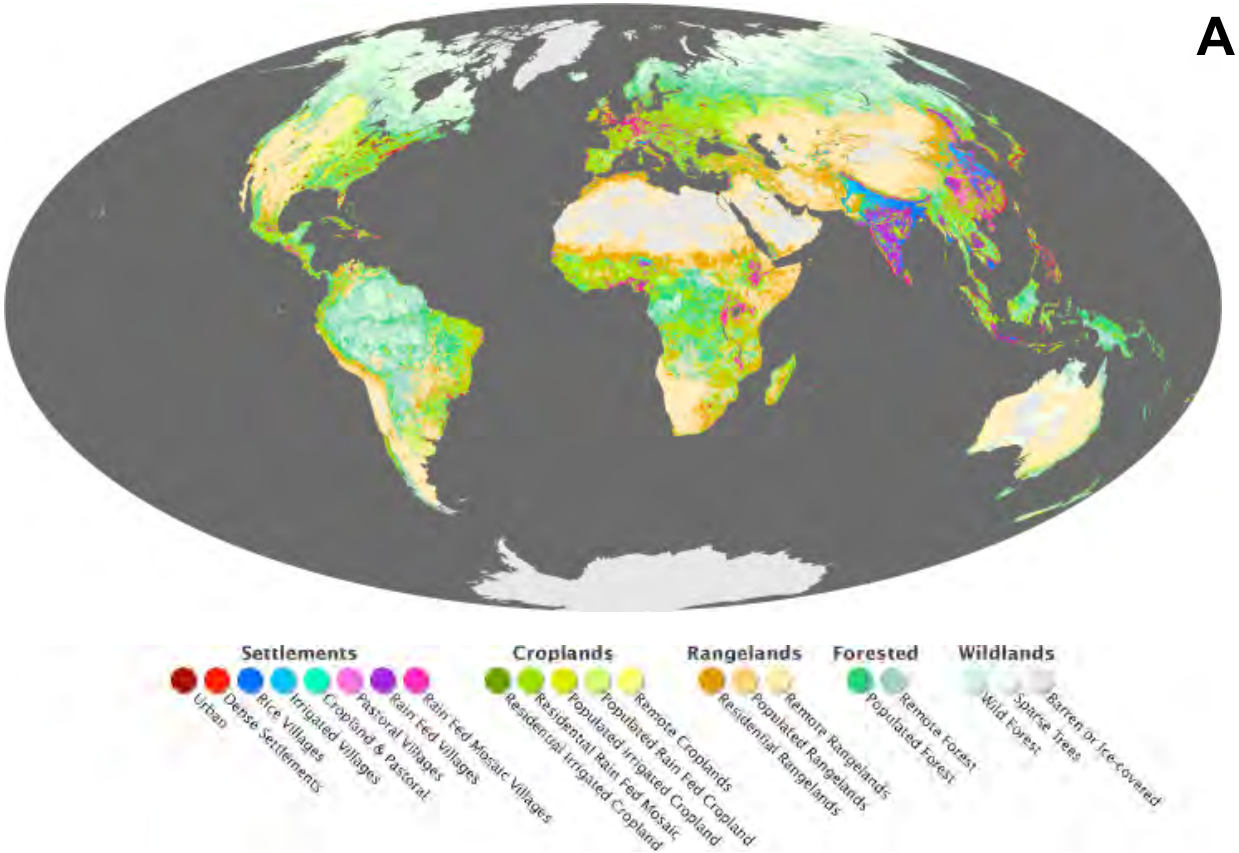
- Ponds
- Lakes
- Streams
- Rivers
- Springs
- Wetlands

Marine Biomes

Image by Ville Koistinen, Wikimedia Commons

- Oceans
- Coral reefs
- Estuaries
- Mangroves

Image Ellis and Ramankutty via NASA

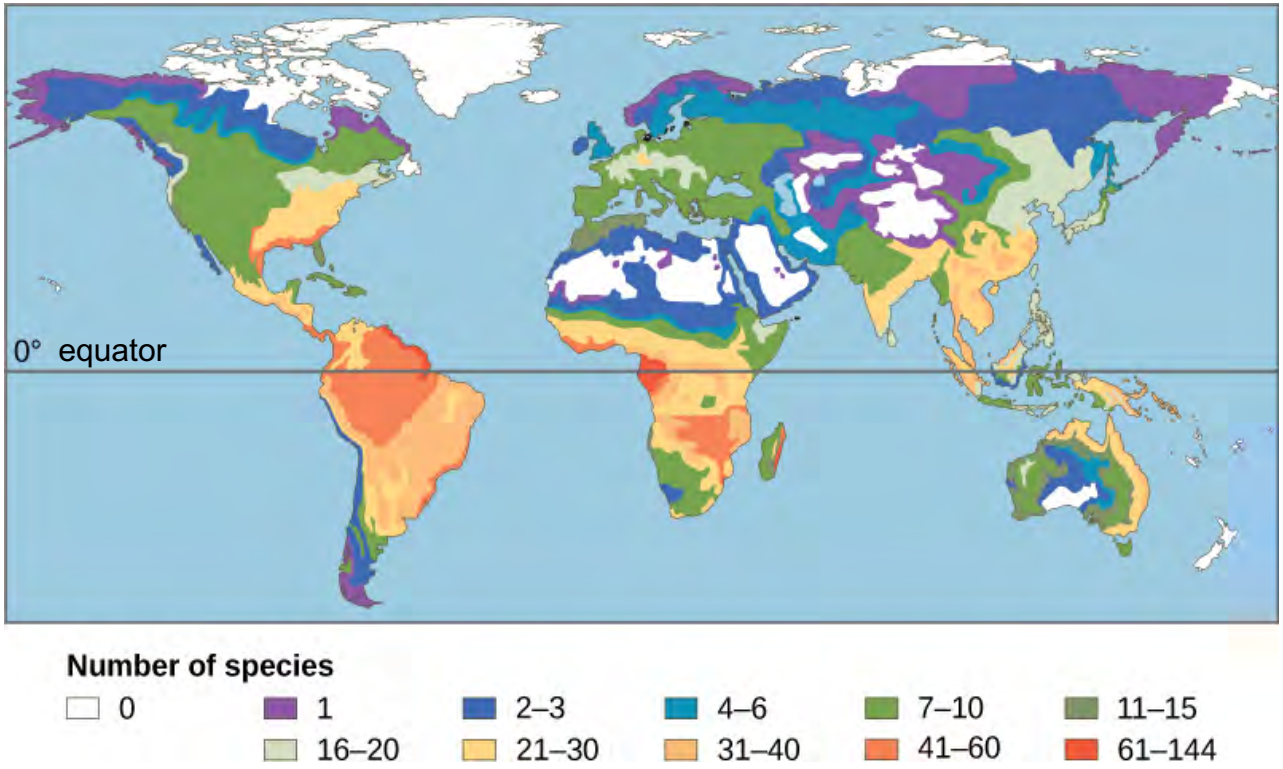


Anthropogenic Biomes?

While there are many natural biomes around the globe, there are also large areas of land that have been altered by human activity. Humans need places to live, raise livestock, grow crops, etc. Some scientists argue that this creates anthropogenic biomes or anthromes.

Objective 2: Differentiate the physical and biological factors affecting the evolution of life.

Image by CFCF, Wikimedia Commons



This map shows the number of amphibian species across the globe.

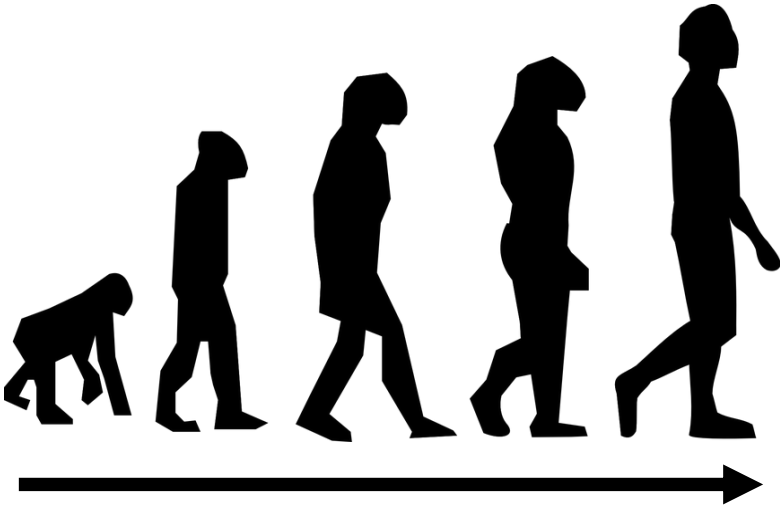
Different species of plants and animals have adapted to live within each of Earth's biomes.

Each biome contains a unique number and type of species that can survive the conditions and thrive in the biome.

Evolution = natural process by which organisms diversify over time because of changes in their heritable characteristics.

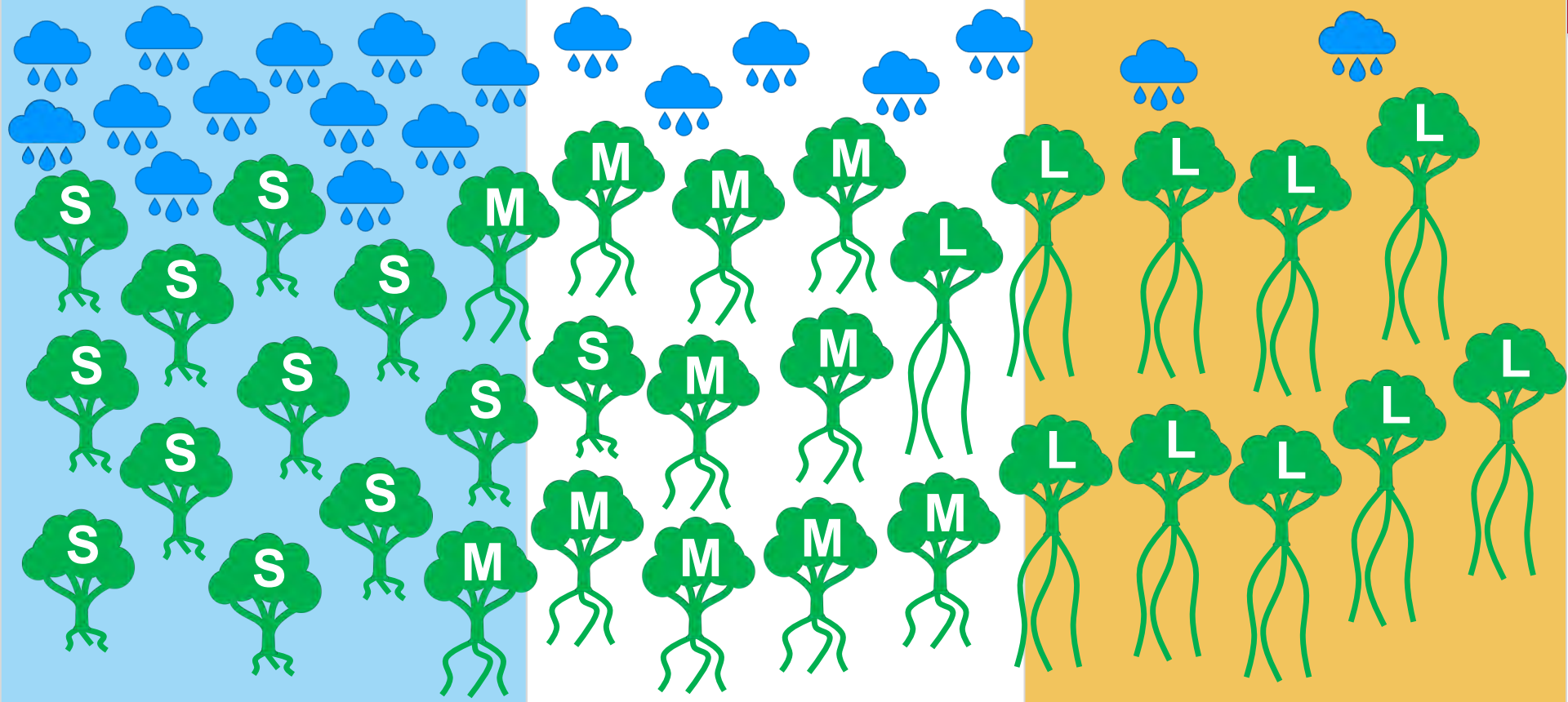
Better-adapted individuals will survive and pass on their genes and traits to their offspring. This changes how common certain variants of genes are found in the population, some will increase, others decrease. This process leads to the evolution of a species.

Evolution is often a slow process



5-million years of evolution between *Australopithecus* and modern-day *Homo sapiens*

Example of Evolution by Natural Selection based on Precipitation



Wet climate favors trees with short roots (S)

Intermediate precipitation favors trees with medium roots (M)

Dry climate favors trees with long roots (L)

Evolution by natural selection is a slow process that takes thousands to millions of years. Likewise, climates change naturally over long periods of time (e.g., thousands to millions of years). Organisms evolve to adapt to new climates.

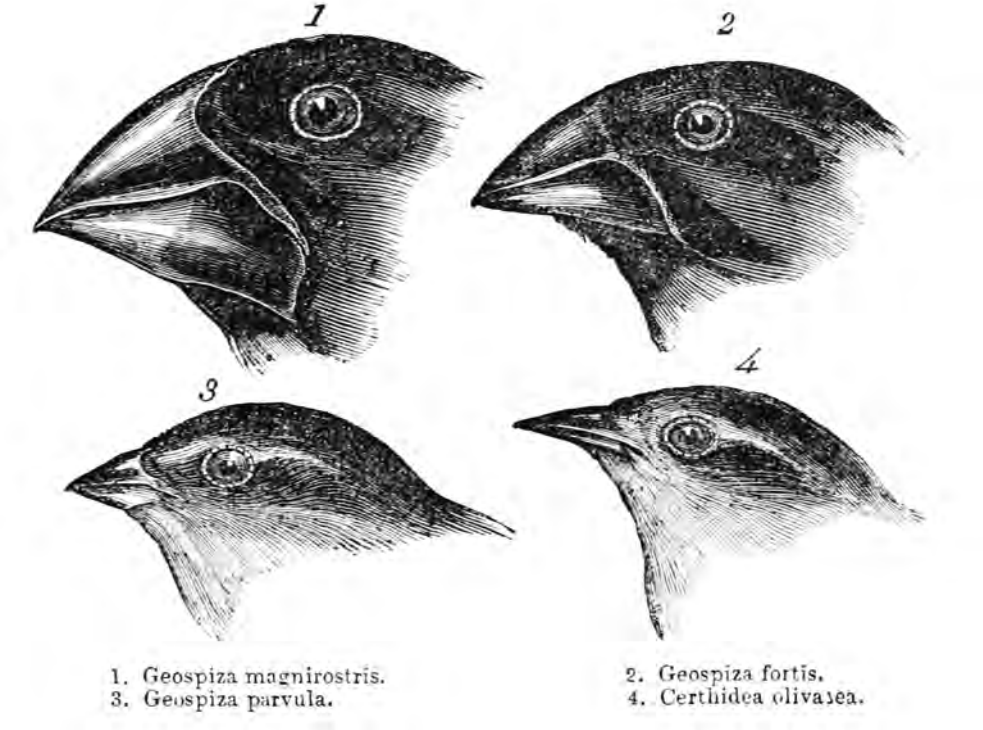
Extinction of a species occurs when climate changes faster than an organism can adapt. Human activity can cause fast and dramatic changes in climate that takes place in just a few decades. Organisms can't evolve and adapt to these climatic changes in such a short period of time, which can lead to their extinction.

For example, polar bears face the real threat of extinction because rapid global warming is causing the dramatic loss of Arctic sea ice where they live.

Female polar bear (*Ursus maritimus*) on sea ice, Barter Island, Alaska (USA). Photo by Alan Wilson, http://www.naturespicsonline.com, January 1, 2007.

Forces of Evolution

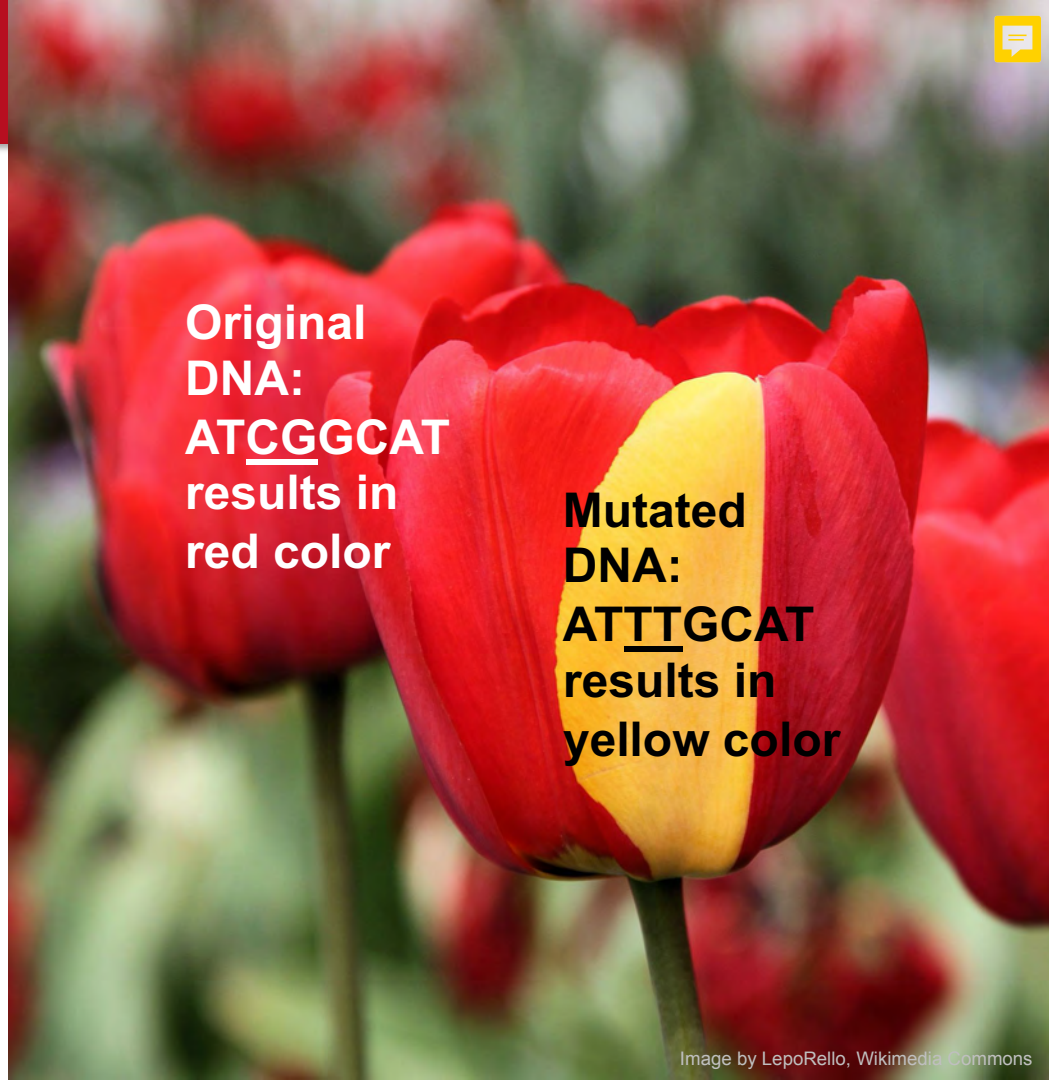
- Mutation
- Gene Flow
- Genetic Drift
- Natural Selection



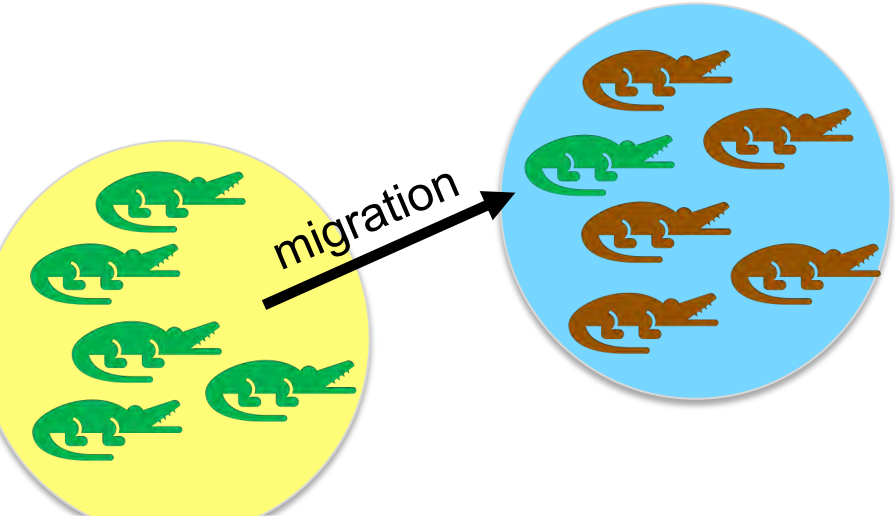
Charles Darwin's finches from Galapagos (1835)

Mutation = occurs when the DNA sequence of a gene is changed, altered or damaged. This sequence change can result in different phenotypes (i.e., observable characteristic). For example, red-colored flower changes to yellow.

Mutations can be beneficial, neutral, or harmful to an organism.



Gene Flow = the movement of genetic variation between populations of organisms



Genetic Drift = the change in the frequency of a gene for a population over time due to random mating. This results in the loss of some gene variability.

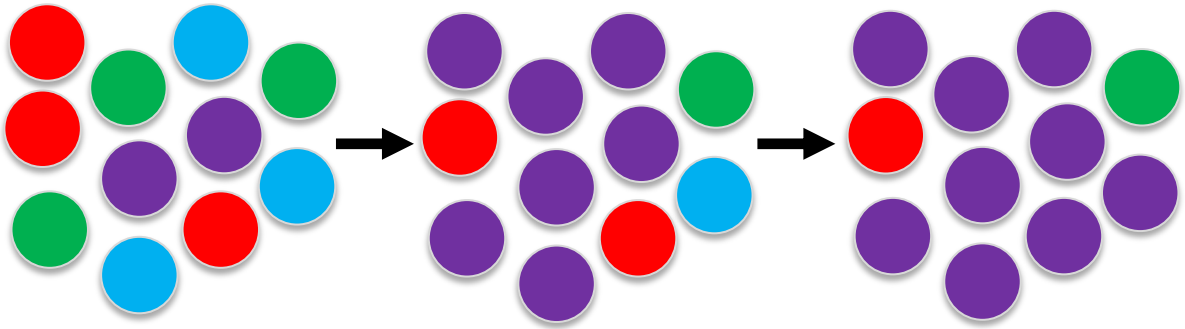
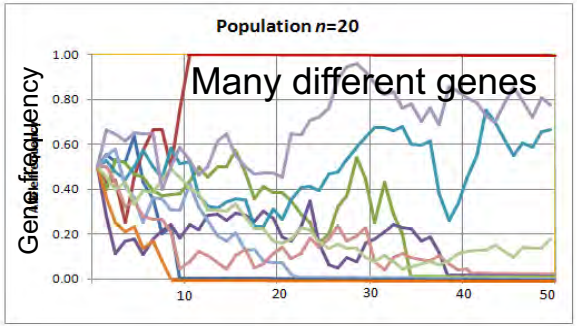
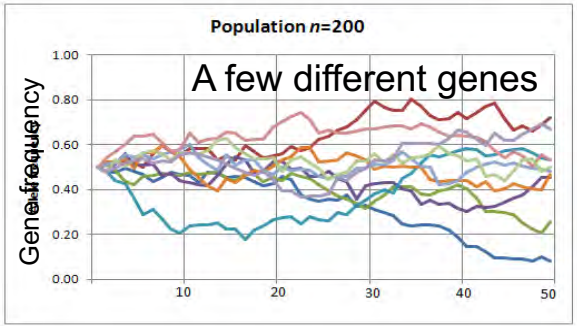
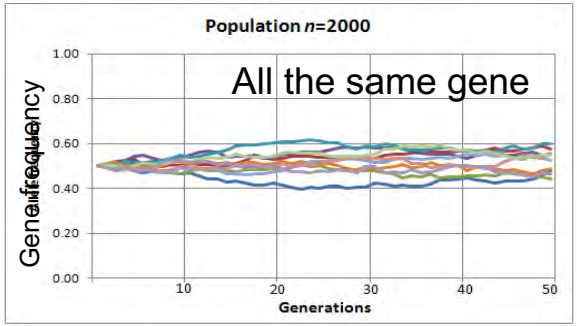


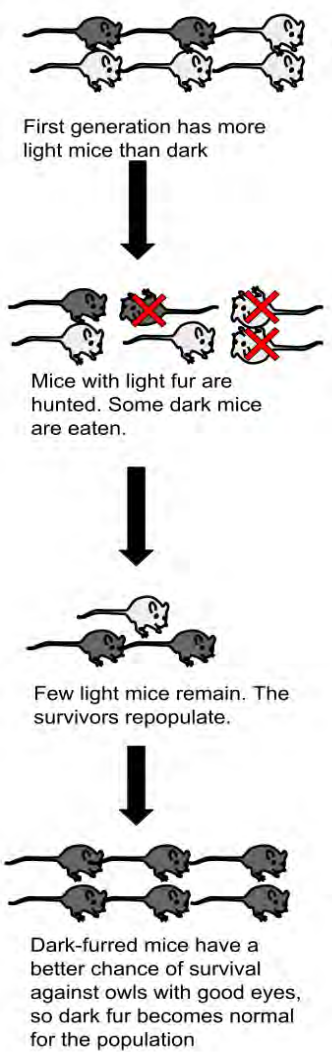
Image by Professor marginalia, Wikimedia Commons

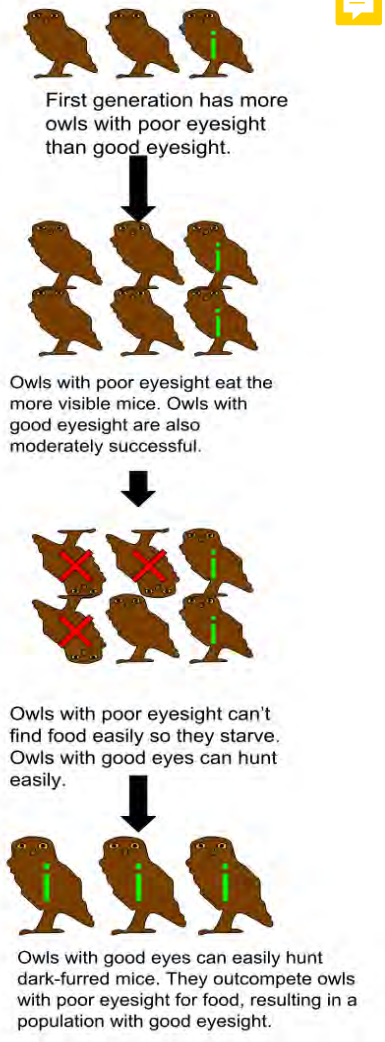






Natural Selection = the process by which organisms that are best adapted to a particular environment survive, reproduce and produce more offspring than lesser-adapted individuals. Offspring inherit their parent's genes and traits.





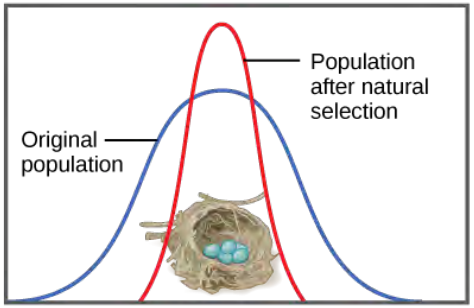
Natural Selection

a) Stabilizing selection
   - Favors the norm and selects against extremes

b) Directional selection
   - Continually favors a particular extreme of the trait (bigger, darker, etc.)

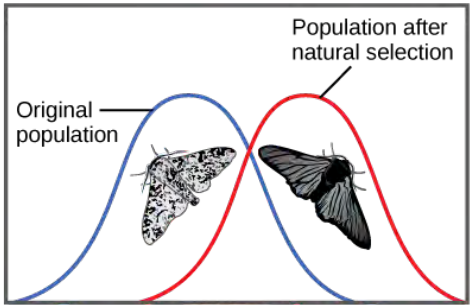
c) Disruptive selection
   - Favors the extremes and selects against intermediate forms

(a) **Stabilizing selection**



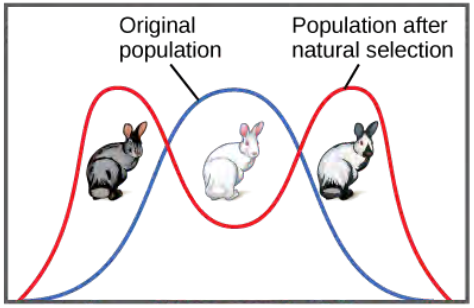
Robins typically lay four eggs, an example of stabilizing selection. Larger clutches may result in malnourished chicks, while smaller clutches may result in no viable offspring.

(b) **Directional selection**



Light-colored peppered moths are better camouflaged against a pristine environment; likewise, dark-colored peppered moths are better camouflaged against a sooty environment. Thus, as the Industrial Revolution progressed in nineteenth-century England, the color of the moth population shifted from light to dark, an example of directional selection.

(c) **Diversifying selection**



In a hyphothetical population, gray and Himalayan (gray and white) rabbits are better able to blend with a rocky environment than white rabbits, resulting in diversifying selection.

Definitions from Environmental Science for a Changing World textbook

Image by CFCF, Wikimedia Commons

Adaptation = a characteristic that allows an individual survive and reproduce

Populations within a biome have shared adaptations that allow them to live in that particular biome. Adaptations can lead to changes in an individual's physical appearance (structural) or changes in behavior (behavioral).

Physical adaptations

- Physical adaptations are those that affect an organism's physical features such as the beak of a bird. Encoded in the organism's DNA.
- Involves part of the organism's body such as its shape, color, coverings, movement, size, etc.
- Occur over an extended period of time. Result from changes in an organism's DNA that controls changes in its physical traits.

Webbed Feet

Strong Beak

Camouflage

Scales

Behavioral adaptations

- Behavioral adaptations are those that affect the activities that an organism performs in order to survive and reproduce.
- Can be something an organism is born with and contained within their DNA (e.g., instinct) or something that is learned (e.g. mother teaches offspring to fish).
- Behavioral changes can occur rapidly.

Defense Mechanisms

Migration

Hibernation

Mating Dances/Calls

Populations need genetic diversity to evolve.

Genetic diversity = total number of genes and traits among individuals of a single population.

The greater genetic diversity a population has the better able it will be to adapt to changes in its environment.

Image by Ville Koistinen, Wikimedia Commons

Objective 3: Recognize the biodiversity that is present within biomes and identify the resiliency that this diversity provides.

Earth currently has about 1.8 million identified species. But there are millions of species not yet discovered. Scientists estimate Earth has between 3 – 100 million species that are still not known.

Species Identification Gap

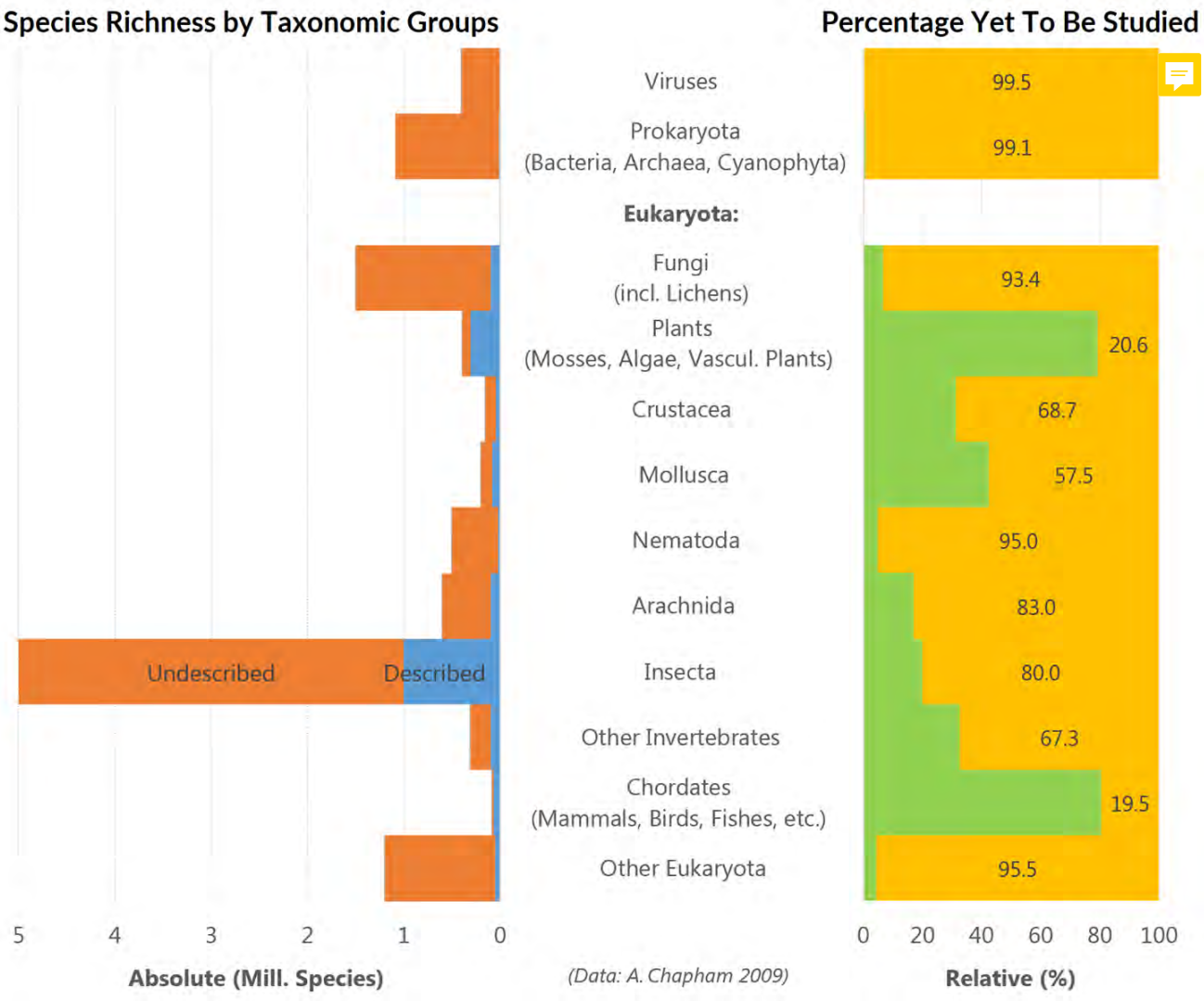


Image by Greg Hagedorn, Wikimedia Commons

Biodiversity = the immense variety of life on Earth

- Includes diversity within species, between species, and ecosystems.
- Provides connections between individual species and between species and the environment.
- Forms a foundation for ecosystem services that support human health and well-being.

Types of Biodiversity

- **Genetic Diversity** – total number of genetic traits within a single species or population (e.g., humans red hair, yellow hair, brown hair).
- **Species Diversity** – total number of different populations within a community (e.g., elk, moose, black bear, cougar).
- **Population Diversity** – species diversity, their distribution and range.
- **Diversity of Ecosystems** – population diversity plus all abiotic factors (e.g., water, elevation, temperature).

Biodiversity Hotspot = a biologically rich area on Earth that contains numerous endangered and endemic species

Biodiversity Hotspots:

- Make up less than 3% of Earth's land area.
- Contain more than 40-50% of all Earth's plant and animal species.
- Are typically in tropical biomes, isolated terrestrial biomes or isolated marine biomes.
- Are threatened by human activities (e.g., urbanization, burning fossil fuels, plastic waste).

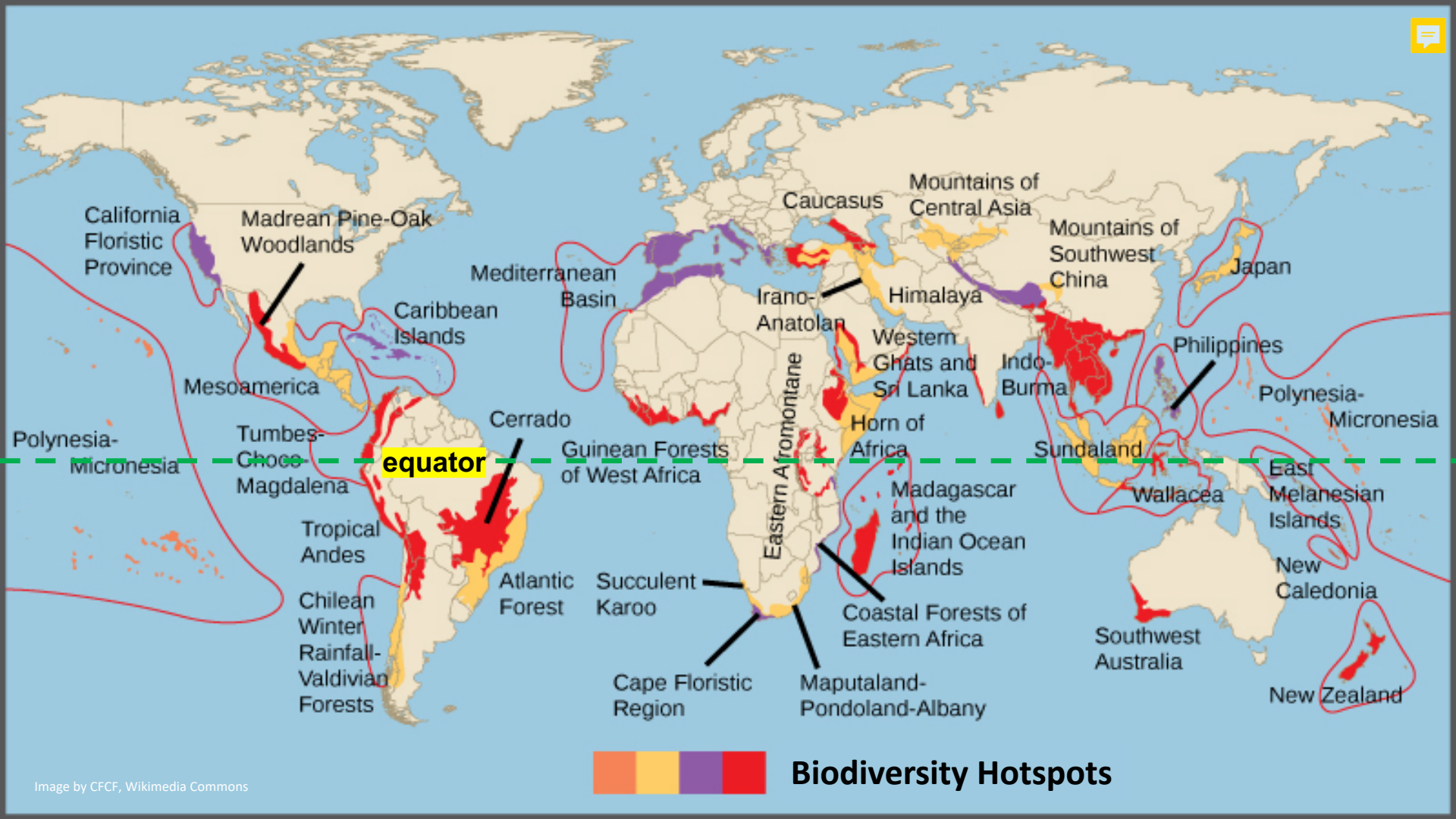
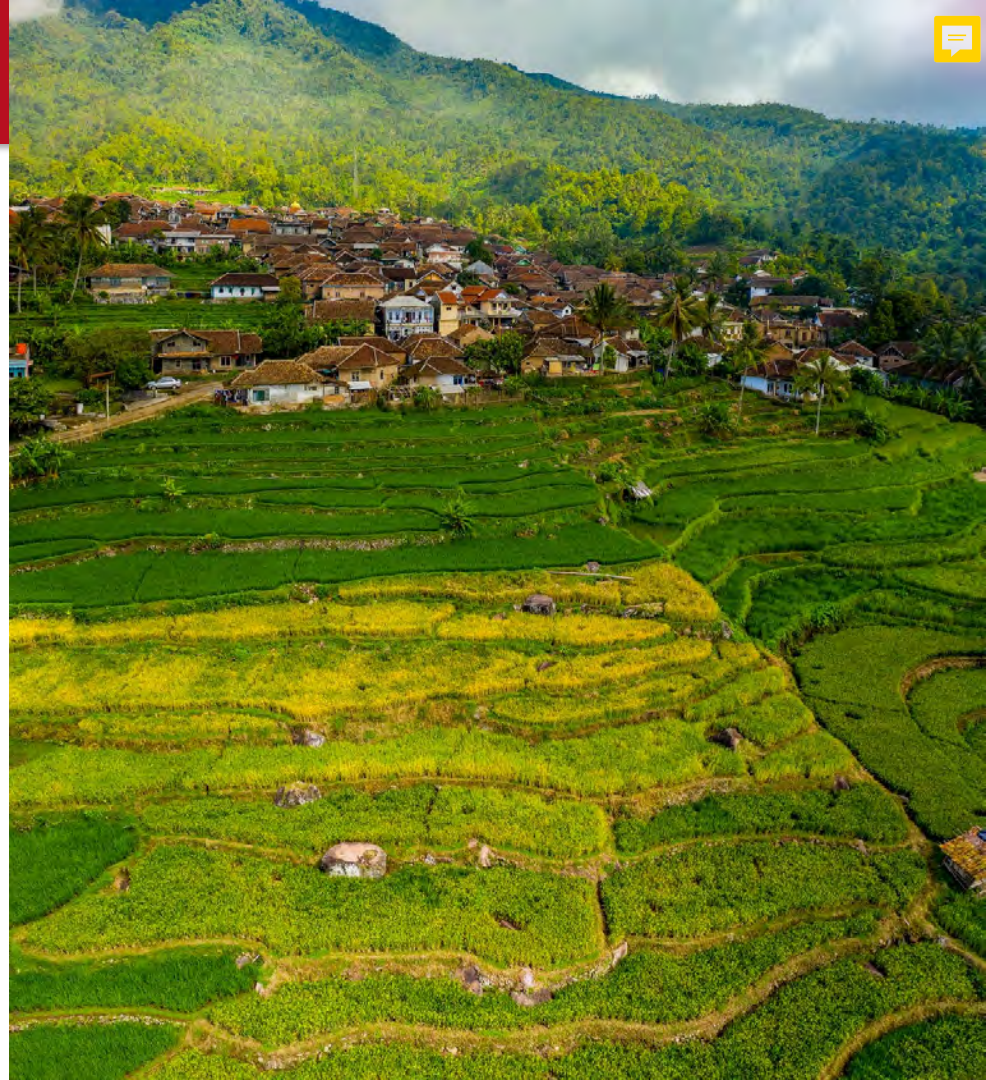


Image by CFCF, Wikimedia Commons

Biodiversity in managed ecosystems

When people think about biodiversity they usually think natural systems. But it is also extremely important to maintain biodiversity in human-managed ecosystems, as well.

- Farms
- Croplands
- Rangelands
- Aquaculture
- Parks
- Urban landscapes



Human Health

- Many medications are created using natural substances (e.g., plants extracts or ingredients, bacteria, fungi, animal venom).
- Many plants have natural medicinal purposes.
- Humans rely on medications and pharmaceuticals to treat and complete research to cure human diseases and illnesses that impact our wellbeing.

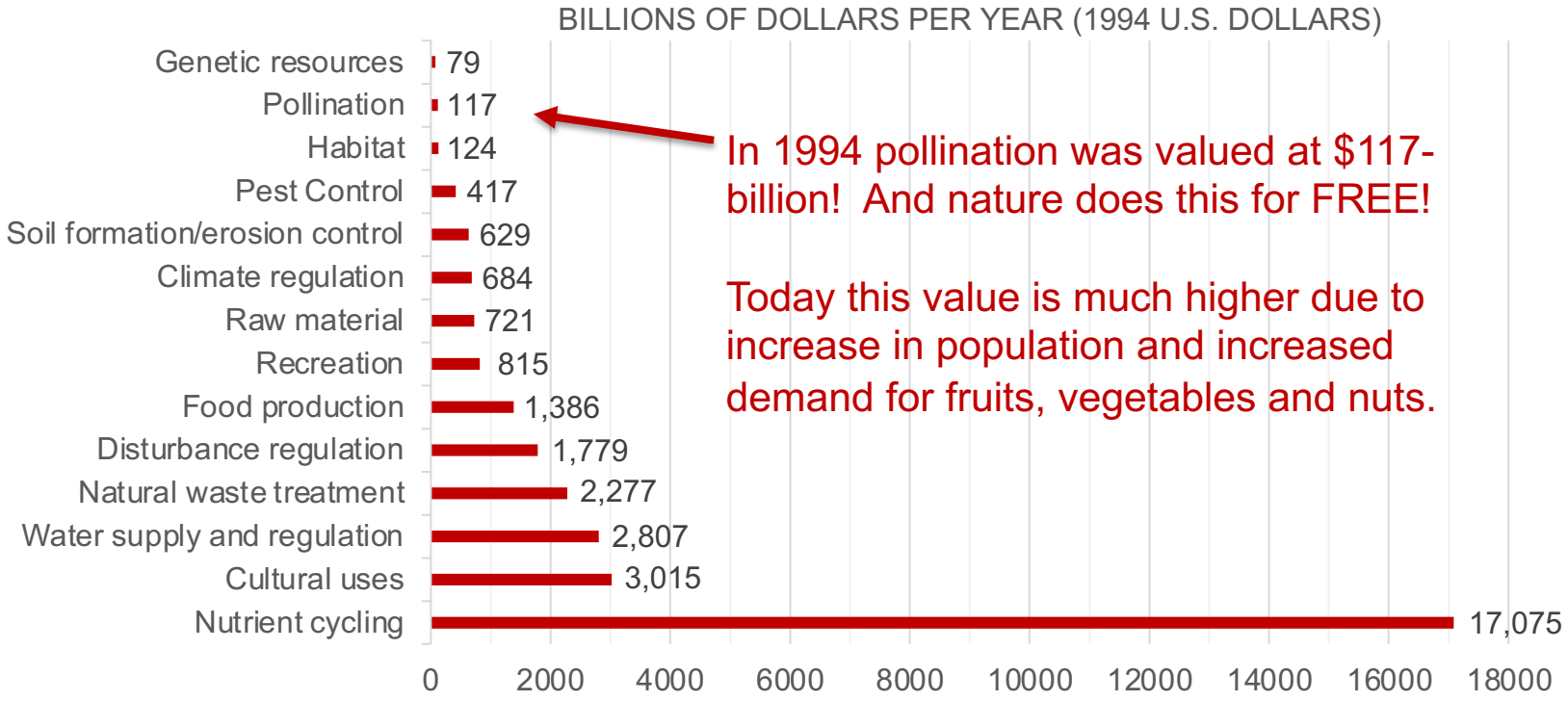
Agriculture

- Cultivated crops have been bred from wild ancestor species.
- Humans have grown accustomed to a wide variety of plant, animal, fungi food supplies.
- We require diverse varieties of crops based on our food demands, differing growing conditions, and resistance to pests.
- It is important to maintain genetic diversity of wild species to ensure our future food supply of domesticated plant species.

Ecosystem services = Earth's natural ecological processes that are essential for human life and well being.

Provisioning	Regulating	Social	Supporting
• Food • Water • Fiber • Fuel • Building materials	• Climate regulation • Pollination mitigation • Good air quality • Erosion control	• Spiritual • Aesthetic • Recreation • Education • Exercise • Relaxation	• Soil formation • Nutrient cycling • Photosynthesis • Water purification • Healthy living

Value of Ecosystem Services



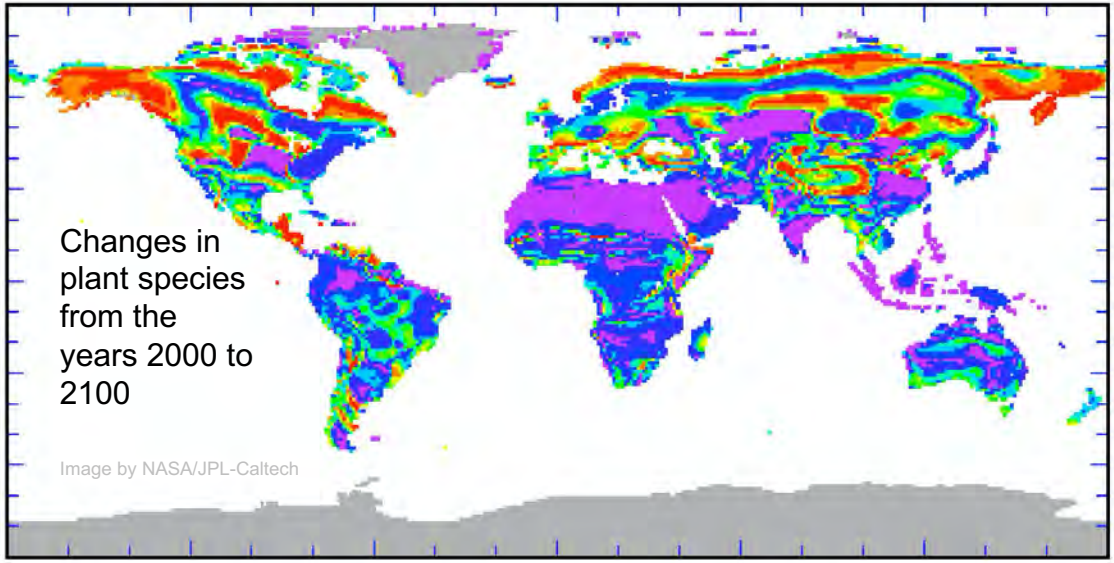
In 1994 pollination was valued at $117-billion! And nature does this for FREE!

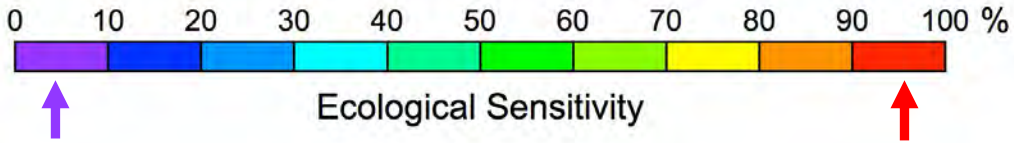
Today this value is much higher due to increase in population and increased demand for fruits, vegetables and nuts.

Data from Environmental Science for a Changing World textbook

Objective 4:
Identify current threats to biomes, biodiversity and ecosystem services.

21st Century Ecological Sensitivity 2





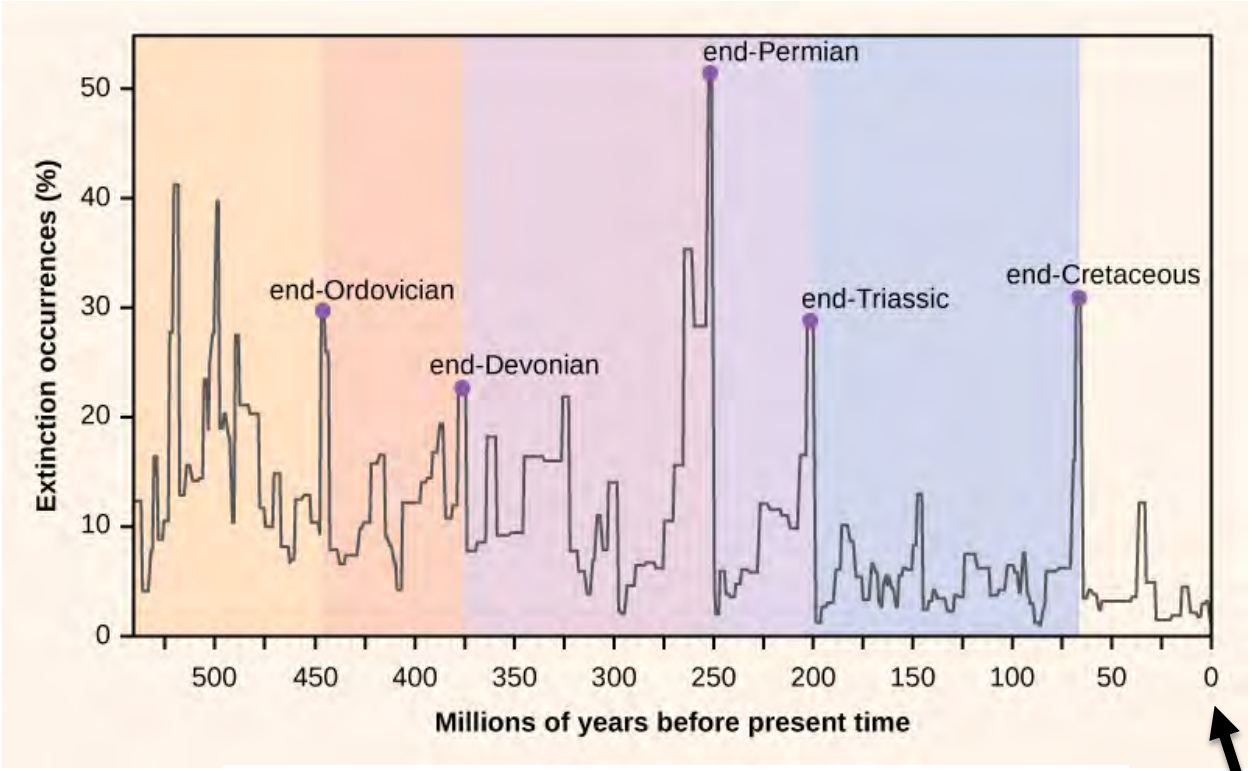
Human-induced climate change will likely cause little change to biome (purple).

Human-induced climate change will likely cause dramatic changes to biome (red).

The well-being of a biome and the adaptability of a biome's organisms is dependent on Earth's major climate patterns and the immediate climate (e.g., temperature and precipitation) within the smaller geographical area of the individual biome itself.

Earth's Biomes have constantly changed over time. But what TWO things are different today compared to past events?

1. Humans are present in great numbers: 8-billion humans on Earth.
2. Extinction rates are 10 to 10,000 times greater than background rates.

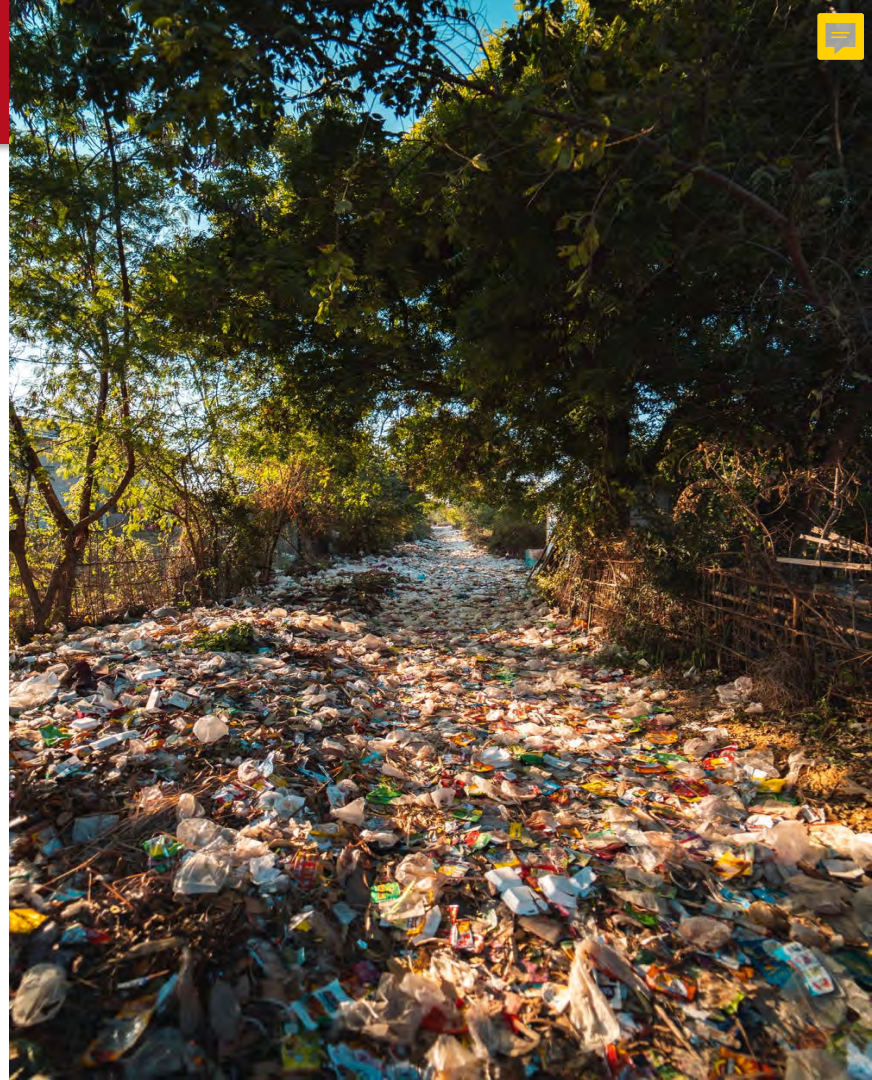


No humans on Earth for most of Earth's history

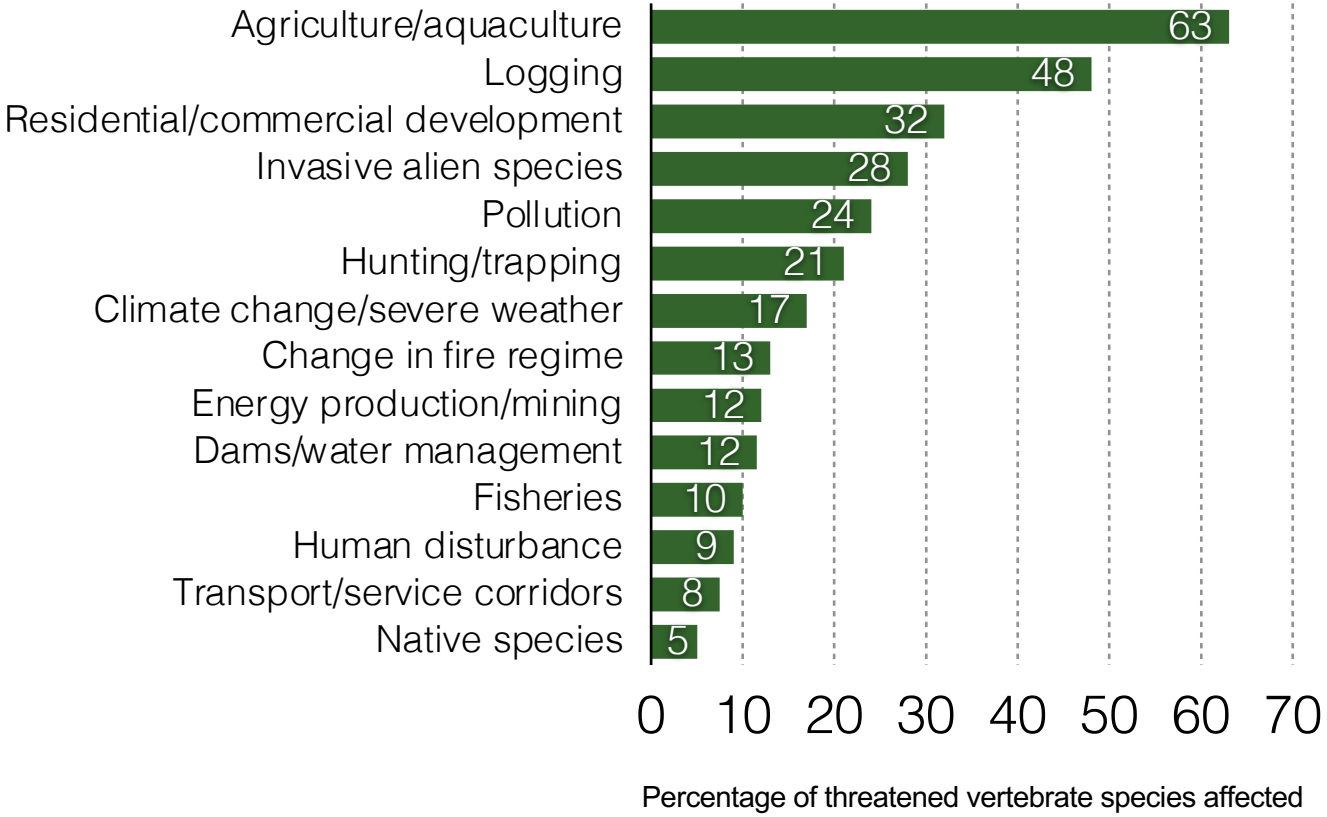
In about 200 years time human population explodes to 8-billion people

Major Threats to Biodiversity

- Habitat Loss
- Overharvesting of Natural Resources
- Pollution
- Invasive Species
- Climate Change
- Human Population Growth



Human Activities that Threaten Vertebrates



*Numbers add up to more than 100 because some species are affected by more than one threat

An **endangered species** is a species that is at a high risk of becoming extinct. This status is categorized by the International Union for Conservation of Nature (IUCN) Red List. Endangered is the second most severe status for wild populations before a species becomes extinct.

https://www.iucn.org

http://www.iucnredlist.org

How can we protect and preserve biodiversity?

- Pass legislation and form treaties
  - Kyoto Protocol, Paris Agreement, CITES
- Restore damaged ecosystems and biomes
  - Re-introducing species, removing invasive species
- Set aside areas of land and water to preserve and protect from human activity
  - Parks, wildlife preserves, wildlife sanctuaries
- Target individual species directly with captive breeding programs
  - Zoos, wildlife sanctuaries, aquariums
- Purchase and use locally grown and sourced products

How can we protect and preserve biodiversity?

Many of the threats to Earth's biodiversity come from humans. These are called anthropogenic threats.

Protecting and preserving Earth's biodiversity involves changing human **activities**, **behavior, beliefs** and **values**.

By making simple changes in your life, you can be part of the solution!