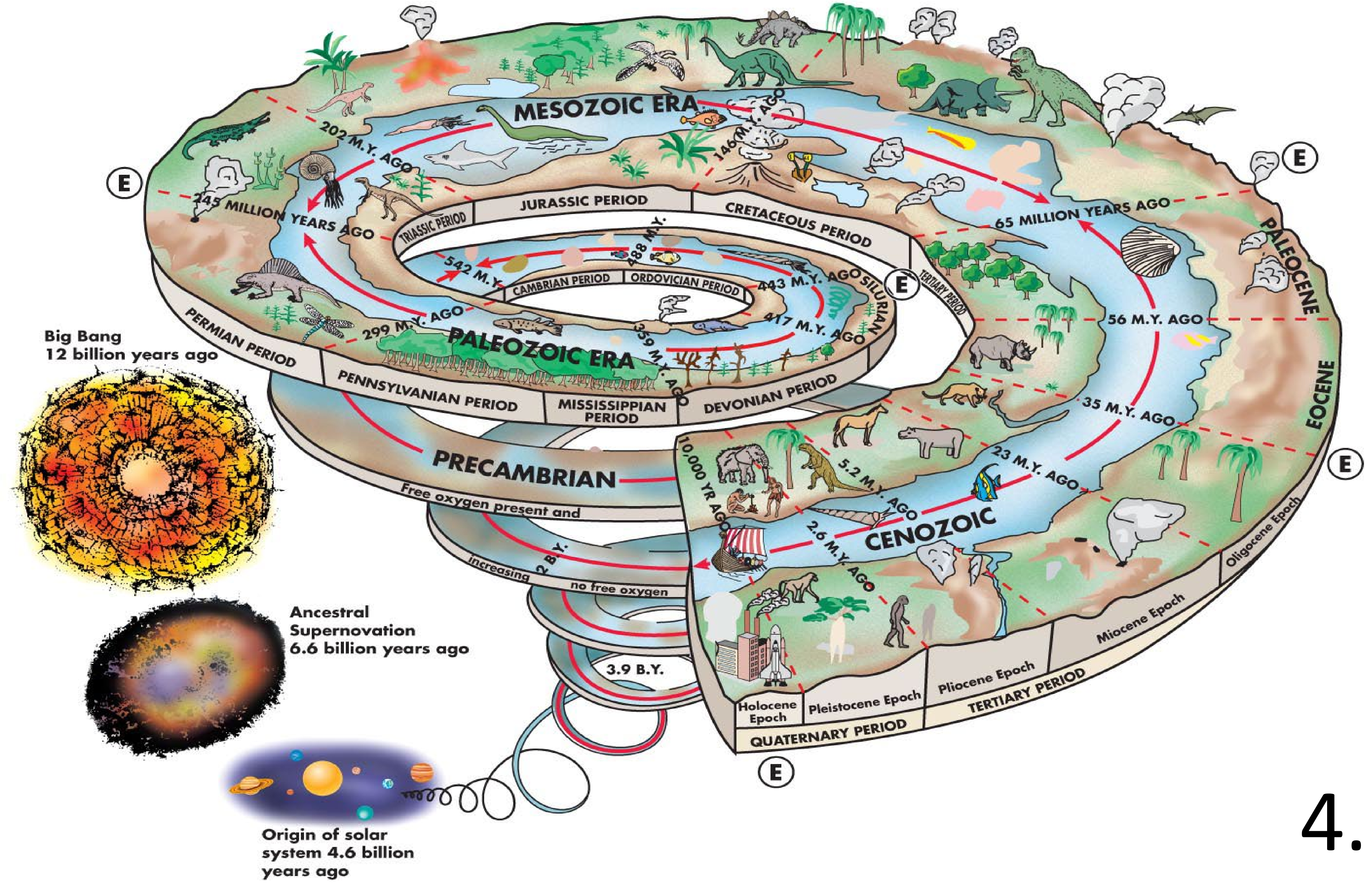
Energy Flux through Ecosystems

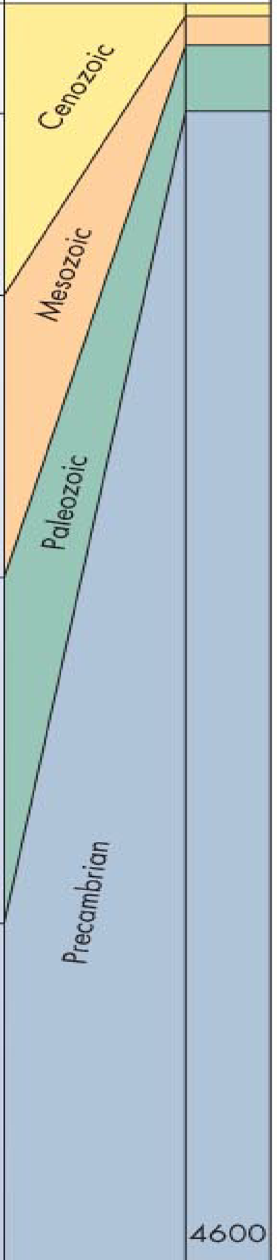

Big Bang
12 billion years ago
Ancestral
Supernovation
6.6 billion years ago
Origin of solar
system 4.6 billion
years ago
3.9 B.Y.
2 B.Y.
Free oxygen present and
increasing
no free oxygen
PRECAMBRIAN
542 M.Y.
488 M.Y.
443 M.Y. AGO
417 M.Y. AGO
359 M.Y. AGO
299 M.Y. AGO
245 MILLION YEARS AGO
202 M.Y. AGO
146 M.Y. AGO
65 MILLION YEARS AGO
56 M.Y. AGO
35 M.Y. AGO
23 M.Y. AGO
5.2 M.Y. AGO
2.6 M.Y. AGO
10,000 YR AGO
CAMBRIAN PERIOD
ORDOVICIAN PERIOD
SILURIAN
DEVONIAN PERIOD
MISSISSIPPIAN
PERIOD
PENNSYLVANIAN PERIOD
PERMIAN PERIOD
PALEOZOIC ERA
TRIASSIC PERIOD
JURASSIC PERIOD
CRETACEOUS PERIOD
MESOZOIC ERA
TERTIARY PERIOD
PALEOCENE
EOCENE
Oligocene Epoch
Miocene Epoch
Pliocene Epoch
TERTIARY PERIOD
Pleistocene Epoch
Holocene
Epoch
QUATERNARY PERIOD
CENOZOIC
E
E
E
E
E

4.6 Ga

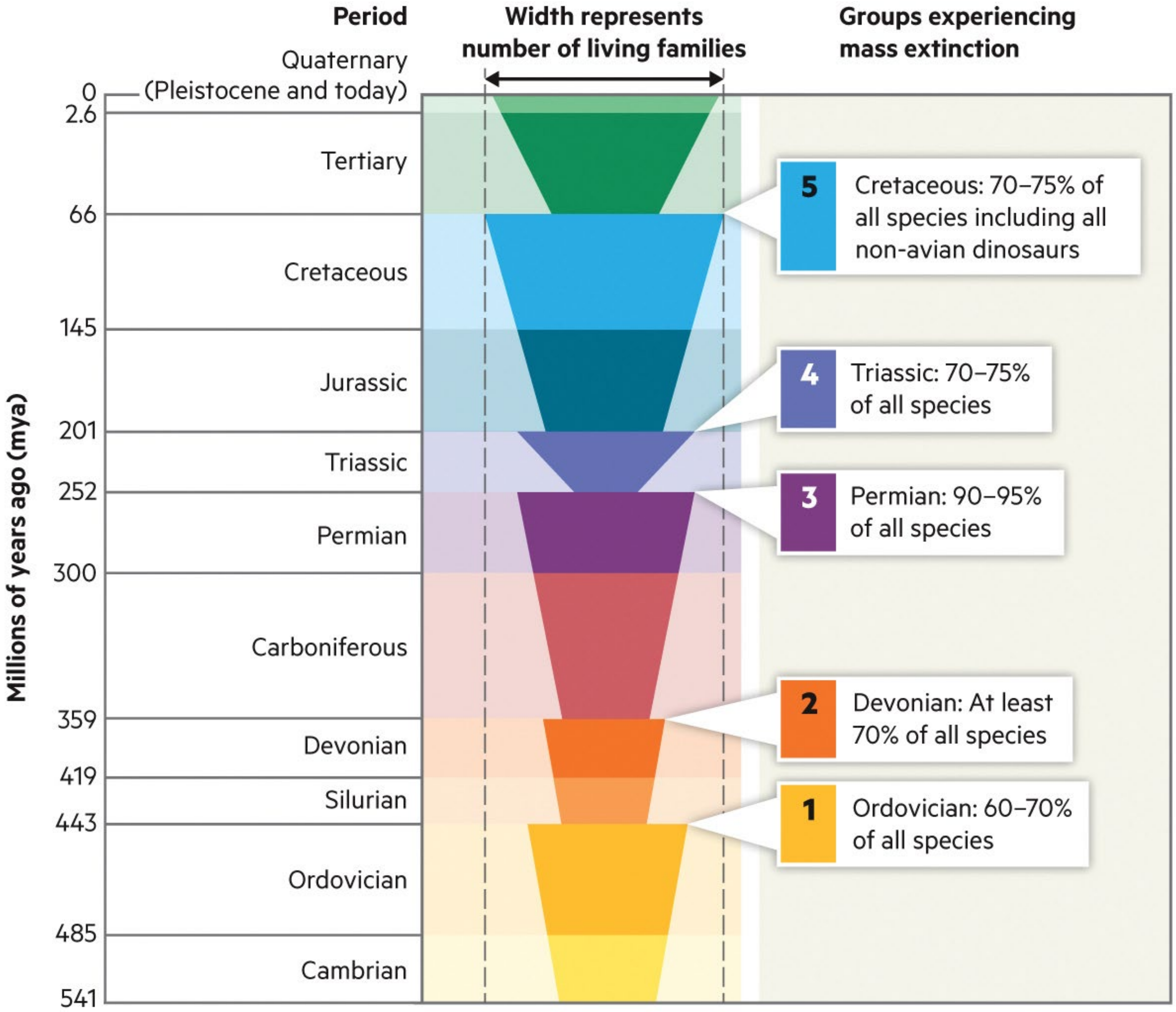
TABLE 1.2 Geologic Time with Important Events

Era	Period	Epoch	Million Years before Present	Events: Life	Events: Earth	Million Years before Present
Cenozoic	Quaternary	Holocene	0.01	• Extinction event • Modern humans	Ice Age Formation of Transverse Ranges, CA	
		Pleistocene	2.6	• Early humans		2.6
	Tertiary	Pliocene	5.2		Formation of Andes Mountains	
		Miocene	23	• Grasses	Collision of India with Asia forming Himalayan Mountains and Tibetan Plateau	
		Oligocene	34	• Whales		
		Eocene	56	• Extinction event		
		Paleocene	65	• Mammals expand	Rocky Mountains form	65
Mesozoic	Cretaceous		146	• Dinosaur extinction[1], extinction event • Flowering plants	Emplacement of Sierra Nevada Granites (Yosemite National Park)	
	Jurassic		202	• Birds	• Supercontinent Pangaea begins to break up	
	Triassic		251	• Mammals • Dinosaurs		251
Paleozoic	Permian		299	• Extinction event • Reptiles	• Ice Age	
	Carboniferous		359	• Trees (coal swamps)	Appalachian Mountains form	
	Devonian		416	• Extinction event		
	Silurian		444	• Land plants		
	Ordovician		488	• Extinction event • Fish		
	Cambrian		542	• Explosion of organisms with shells		542
Precambrian				• Multicelled organisms	• Ice Age	
			2500	• Free oxygen in atmosphere and ozone layer in stratosphere	• Ice Age	
			3500	• Primitive life (first fossils)		
			4000		• Oldest rocks	
			4600		• Age of Earth	4600

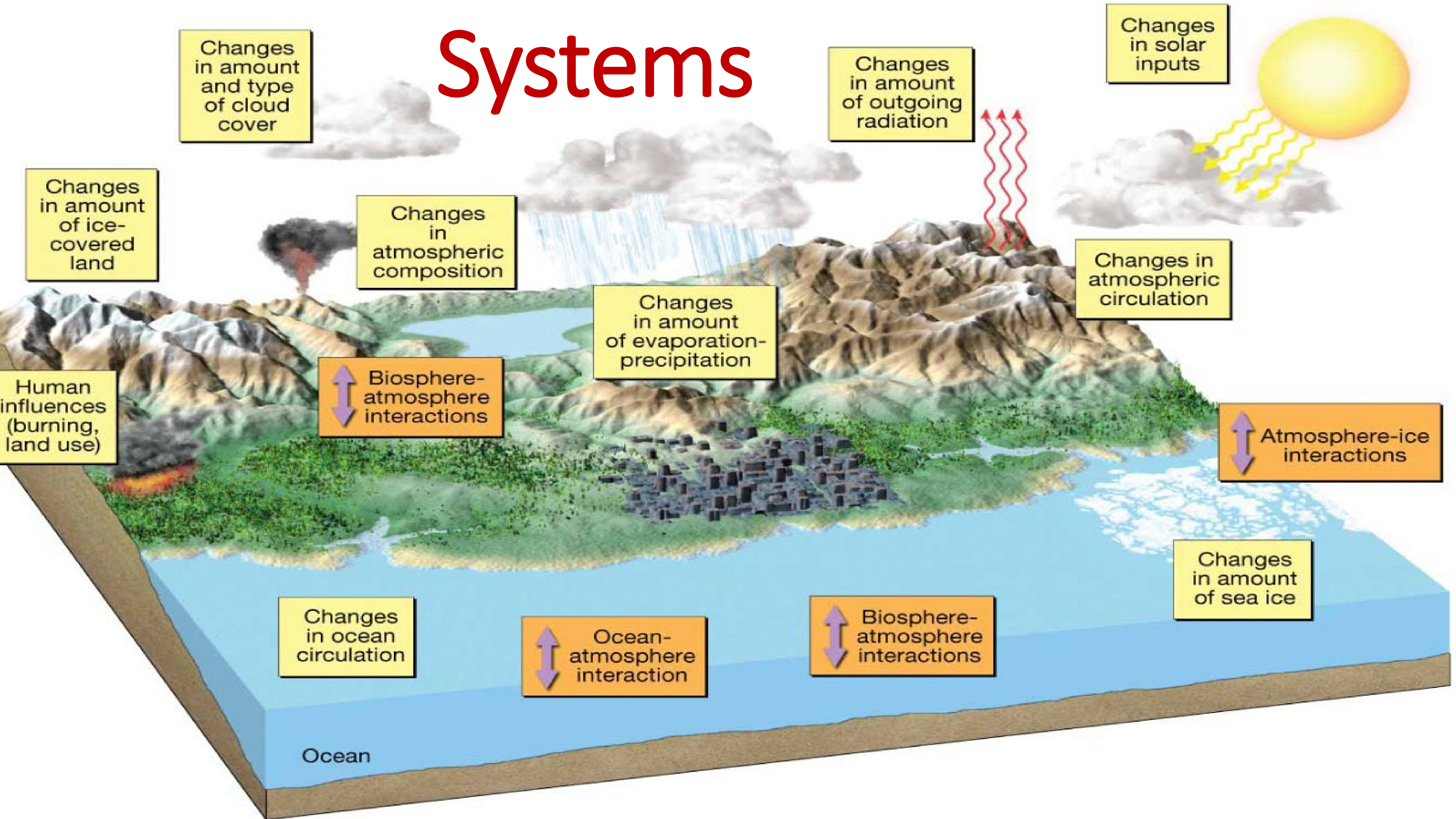
True Scale (Million Years before Present)



Mass Extinctions



Systems


Changes in amount and type of cloud cover
Changes in amount of outgoing radiation
Changes in solar inputs
Changes in amount of ice-covered land
Changes in atmospheric composition
Changes in atmospheric circulation
Changes in amount of evaporation-precipitation
Human influences (burning, land use)
Biosphere-atmosphere interactions
Atmosphere-ice interactions
Changes in amount of sea ice
Changes in ocean circulation
Ocean-atmosphere interaction
Biosphere-atmosphere interactions
Ocean

Earth – A System

Components

- Atmosphere
- Hydrosphere
- Biosphere
- Lithosphere

Anthropogenic manipulation

Systems contain components that mutually adjust, so that changes in one part of the system bring about changes to other parts.

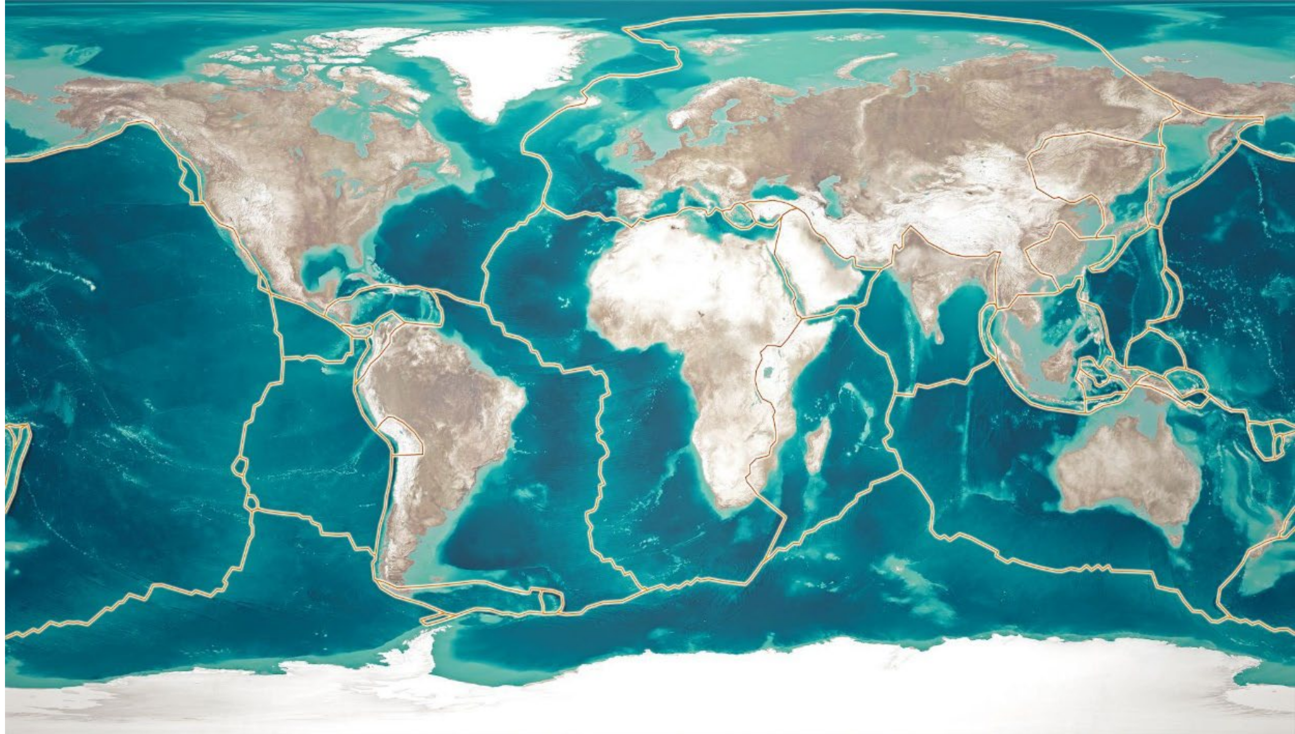
Earth System Types

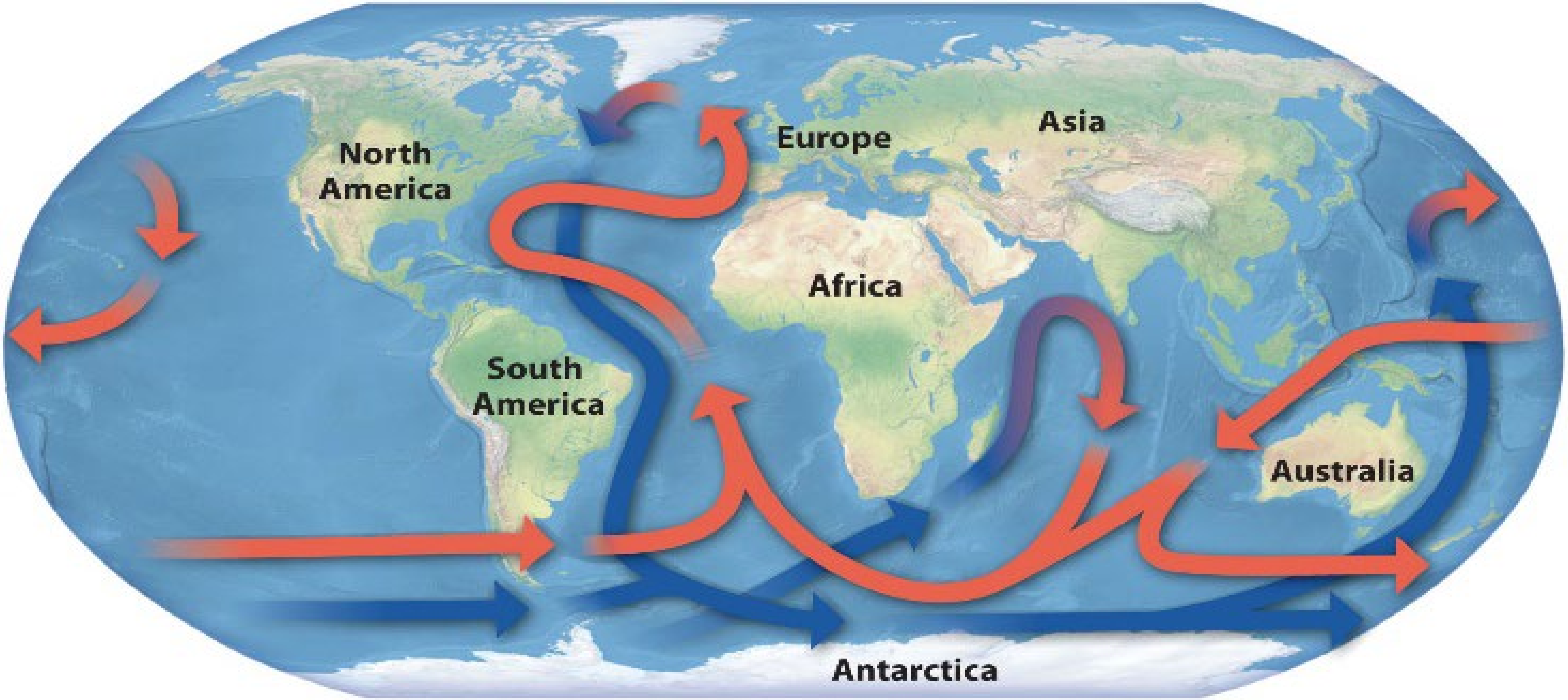
- Open – A system that exchanges material and energy with its surroundings.
- Sun's energy
  - Some is absorbed/received
  - Some is reflected

- Closed – Most of the Earth's material is continuously recycled.
- Mass/material is neither gained or lost just changed.
- Rock and Water cycles

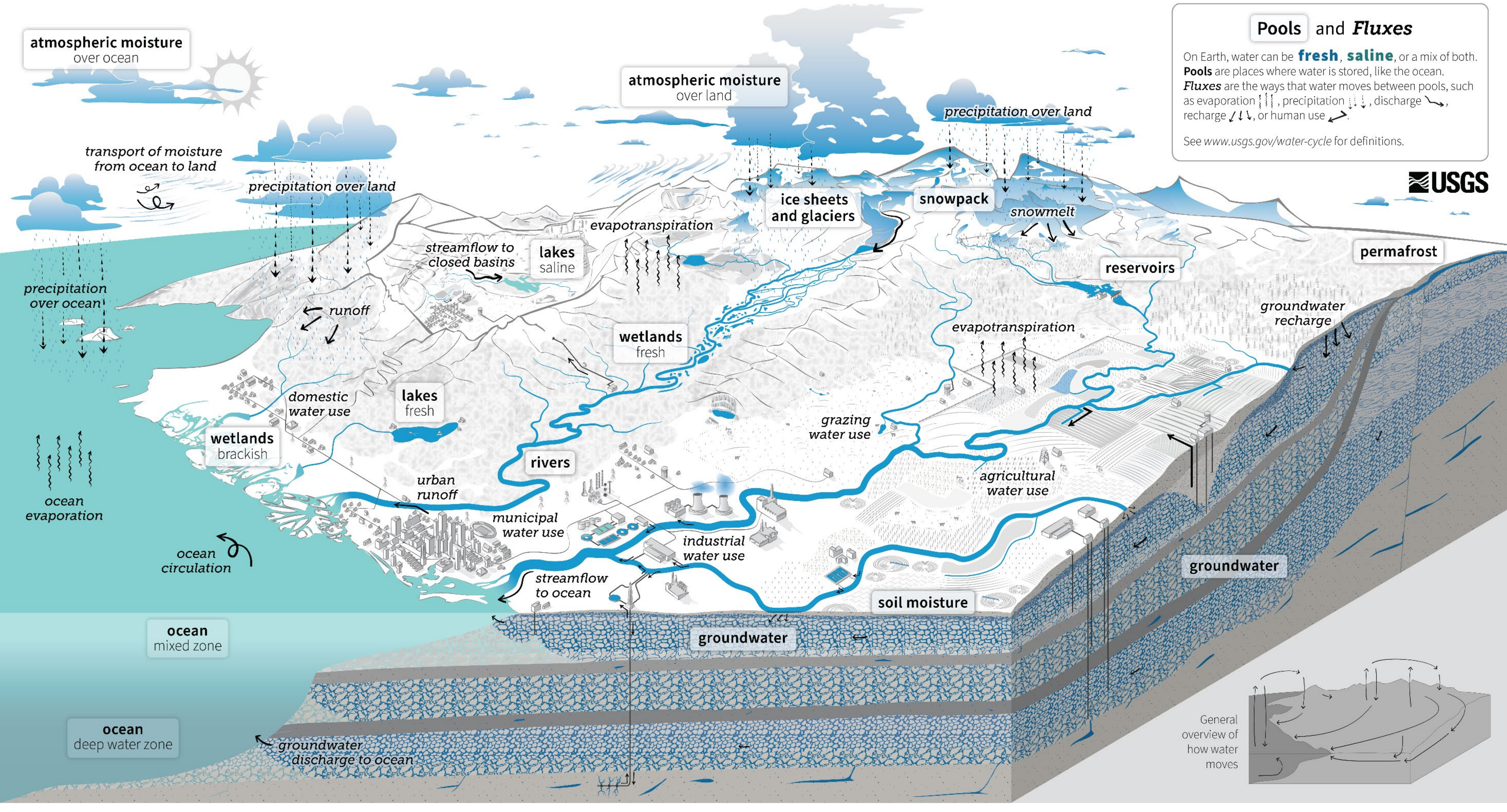
Plate tectonics

- Geologic time/movements
  - 2 to 20cm per year
- Major changes
  - Continent to ocean basin position
  - Ocean currents
  - Potential increased earthquake volcanoes





Ocean thermohaline circulation involves sinking of cold, salty water at the poles (shown in blue). This sinking water produces deep cold currents and shallow warm surface currents (shown in red).

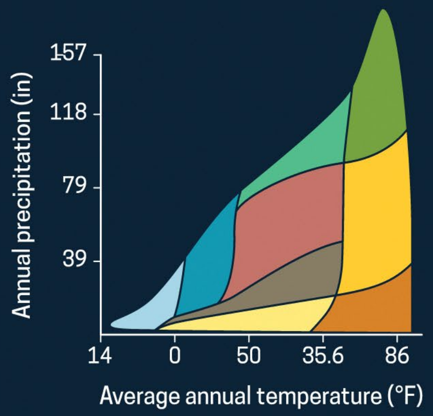

Pools and Fluxes
On Earth, water can be fresh, saline, or a mix of both.
Pools are places where water is stored, like the ocean.
Fluxes are the ways that water moves between pools, such as evaporation, precipitation, discharge, recharge, or human use.
See www.usgs.gov/water-cycle for definitions.
USGS
atmospheric moisture
over ocean
transport of moisture from ocean to land
precipitation over land
precipitation over ocean
atmospheric moisture
over land
ice sheets and glaciers
snowpack
precipitation over land
snowmelt
evapotranspiration
streamflow to closed basins
lakes
saline
runoff
wetlands
fresh
reservoirs
permafrost
groundwater recharge
evapotranspiration
domestic water use
lakes
fresh
wetlands
brackish
grazing water use
rivers
ocean evaporation
urban runoff
agricultural water use
municipal water use
industrial water use
ocean circulation
streamflow to ocean
groundwater
soil moisture
ocean
mixed zone
groundwater
ocean
deep water zone
groundwater discharge to ocean
General overview of how water moves

AT A GLANCE

The Earth's Biomes

Biomes are geographic areas with similar types of biological communities and ecosystems. Terrestrial biomes are categorized by characteristic vegetation, which is related to the temperature and precipitation of the region. This map of Earth shows the locations of the nine major biomes, coded by color. The opposite page provides brief profiles of each.

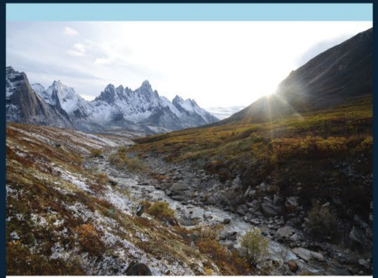
- Tundra
- Taiga or Boreal
- Temperate Rain Forests
- Temperate Deciduous Forests
- Temperate Grasslands
- Deserts
- Woodlands & Shrublands
- Tropical Rain Forests
- Tropical Deciduous Forests & Savannas



Biome Conditions

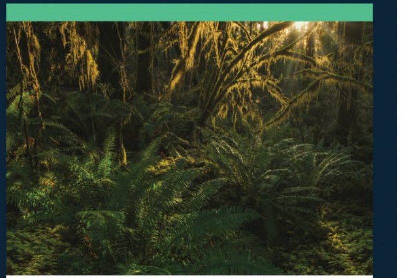
This graph shows the range of average annual temperatures and precipitation for each biome.

Adapted from Whittaker (1975).

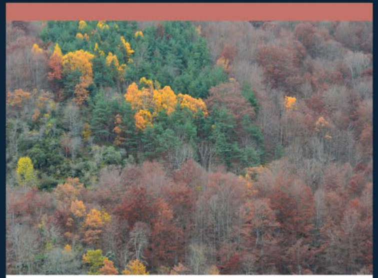


Tundra
The coldest biome, it receives very little precipitation. It is characterized by permanently frozen soil, or permafrost, and treeless expanses populated by mosses, lichens, and low shrubs.

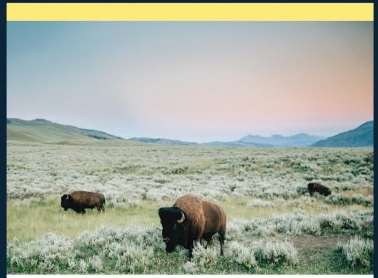
Taiga or Boreal
These cool, wet forests located between 50° N and 60° N contain stands of relatively short coniferous trees, like spruces and firs.



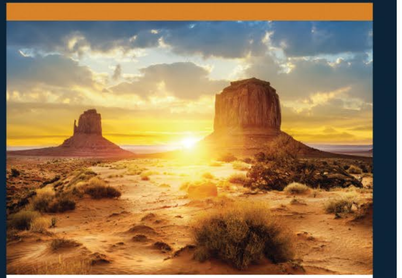
Temperate Rain Forests
Common along the Pacific Northwest coast of North America, they receive lots of precipitation and support large trees like Douglas firs and redwoods, with abundant ferns below.



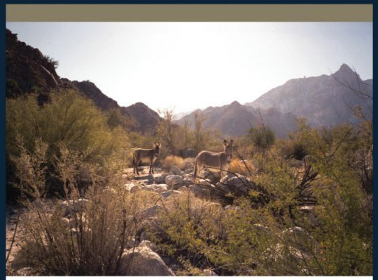
Temperate Deciduous Forests
Covering much of eastern North America and western Europe, they are dominated by trees that lose their leaves seasonally, like maples, oaks, and birches.



Temperate Grasslands
Often called prairies, they sweep across the midwestern United States. Low levels of precipitation limit tree growth, so grasses dominate.

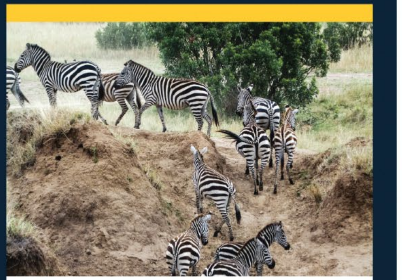


Deserts
Plants here, like short juniper or cacti, are adapted to the low precipitation and high evaporation rates by deep roots and/or the ability to store water.



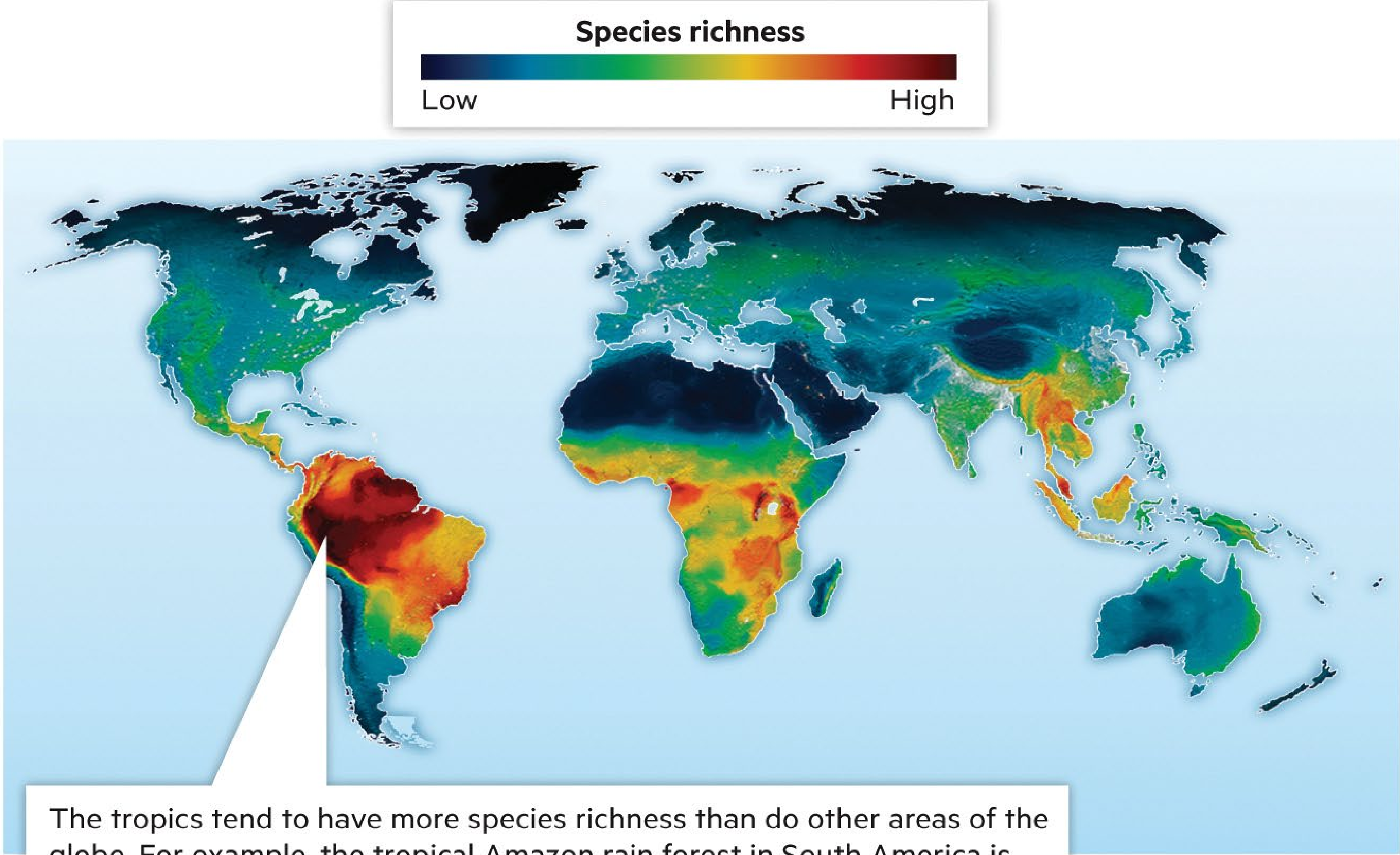
Woodlands & Shrublands
Called chaparral in North America, these experience mild, moist winters and summer droughts. Drought-resistant shrubs and small trees, like eucalyptus and acacia, characterize them.

Tropical Rain Forests
These span the equator, where high temperatures and heavy rainfall support a high diversity of plant species. Taller trees form a canopy, and shorter plants tangle in an understory below.



Tropical Deciduous Forests & Savannas
These are located beyond 10° N to 10° S and experience a dry season. Trees typically lose their leaves during this season of low precipitation. Savannas are grasslands with scattered trees and shrubs.

(top left): Saraporn/Shutterstock; (top center): GoodMoodPhoto/Shutterstock; (top right): Inigo Cia Da Riva/Stocksy; (center left): Juan Vilata/Alamy Stock Photo; (center): Christian Gideon/Stocksy; (center right): Ventdusud/Shutterstock; (bottom left): Molly Steele/Stocksy; (bottom center): STILLFX/Shutterstock; (bottom right): Gabriel Ozon/Stocksy



The tropics tend to have more species richness than do other areas of the globe. For example, the tropical Amazon rain forest in South America is estimated to host nearly 1 in 10 of all the planet's species—including at least 40,000 plant species, 1,300 bird species, and 3,000 fish species.

Energy through Systems

Ecosystems
Environments
Landscapes

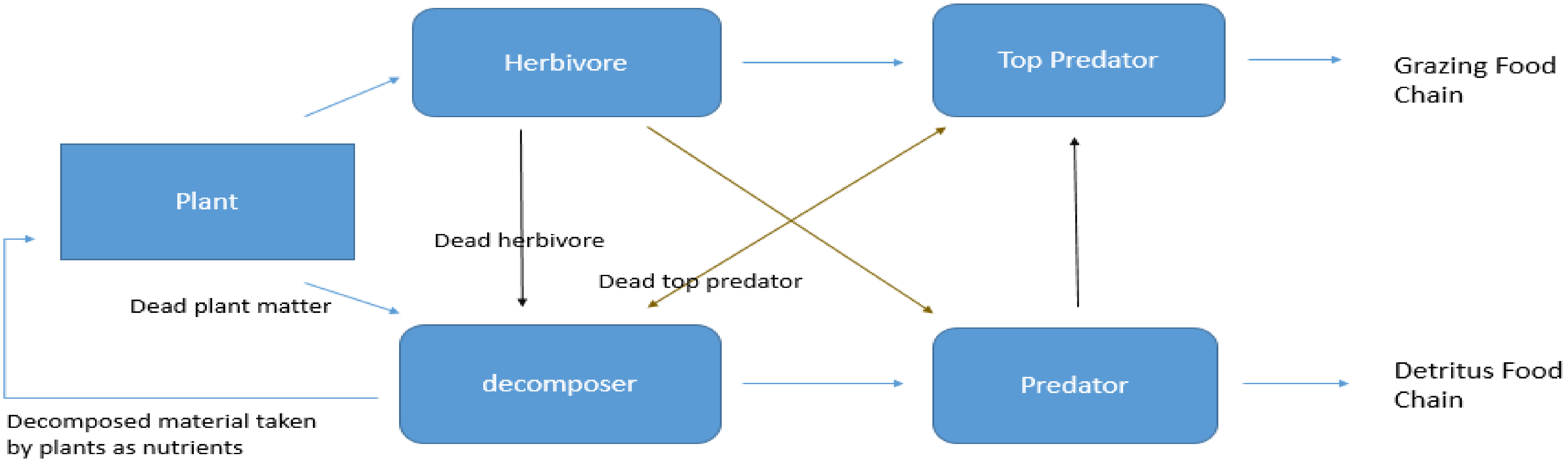
Characterizing, modeling, interpreting Earth System requires…

1. Calculating energy and mass balance ‘budgets’

2. Quantifying changes in energy sources
   a. Intensities
   b. Distributions

3. An understanding of the Earth's oceans! They are very important in understanding energy distribution, storage, and transfer throughout all systems.

4. Recognize and account for humanity's ability to concentrate energy and power (energy per unit of time)



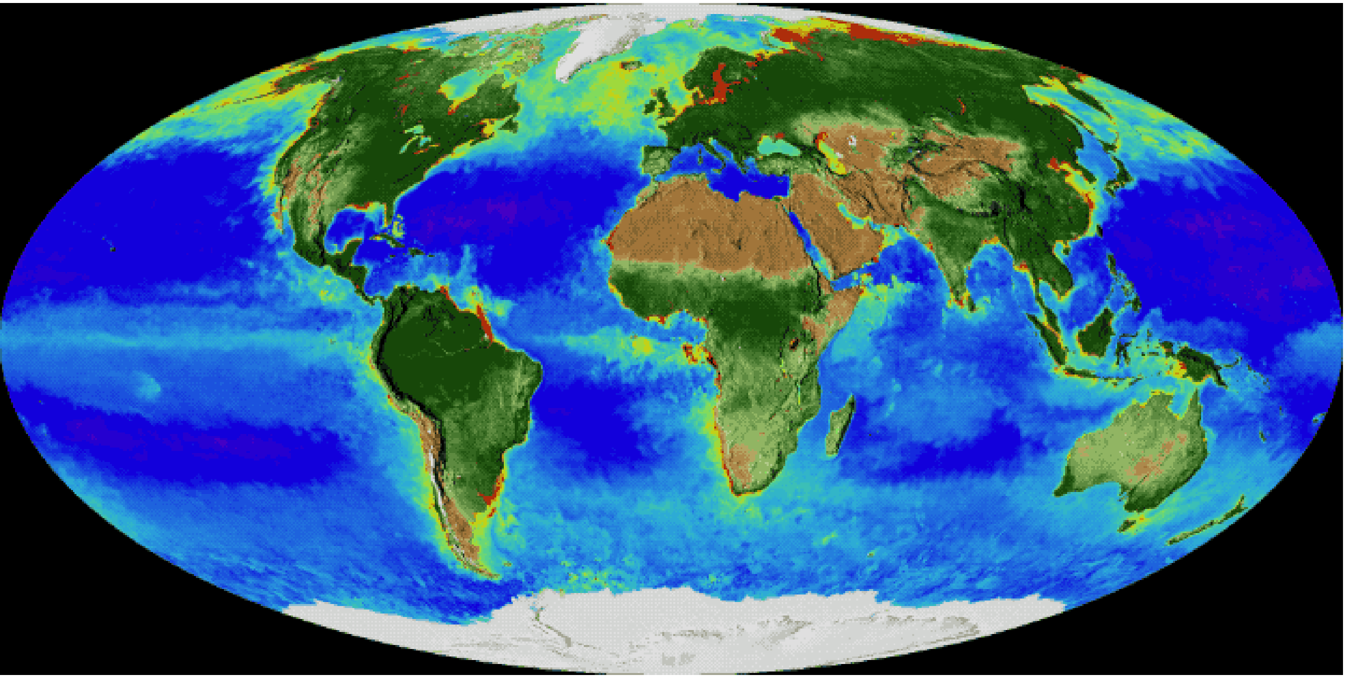
Principle of Environmental Unity

"Anything affects Everything else"

"Everything affects Everything else"

Gaia Hypothesis – Earth as an organism

James Lovelock



1. Life significantly affects planetary environments.
2. Life affects environments for the planets betterment.
3. Life deliberately OR consciously controls the global environment.

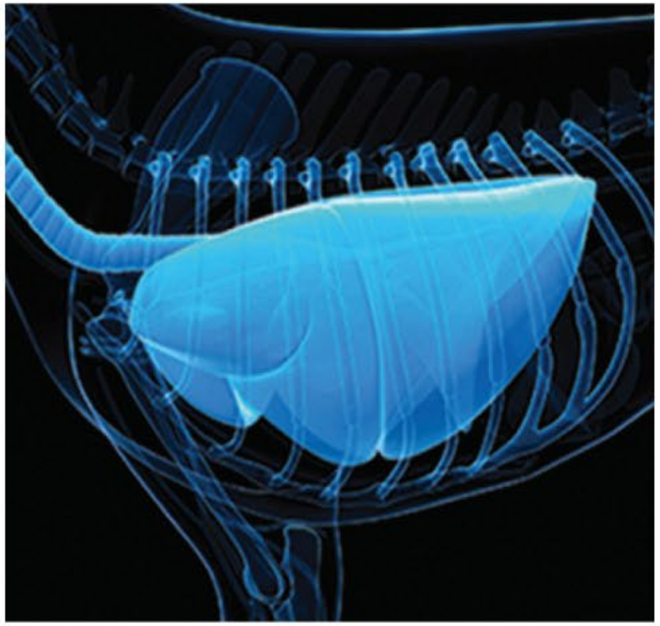
Ecosystem

Community

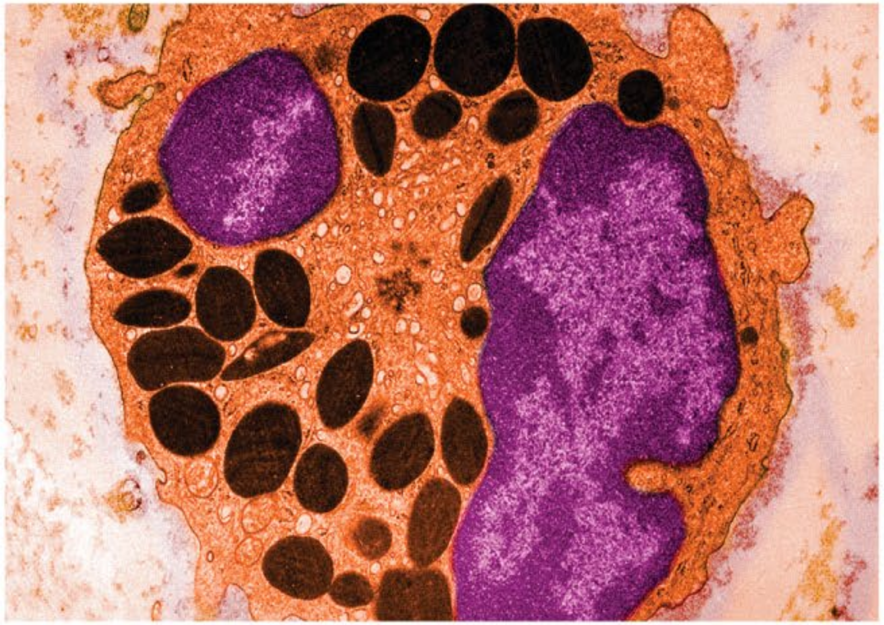
Population/Species

Organism

Tissue/Organ



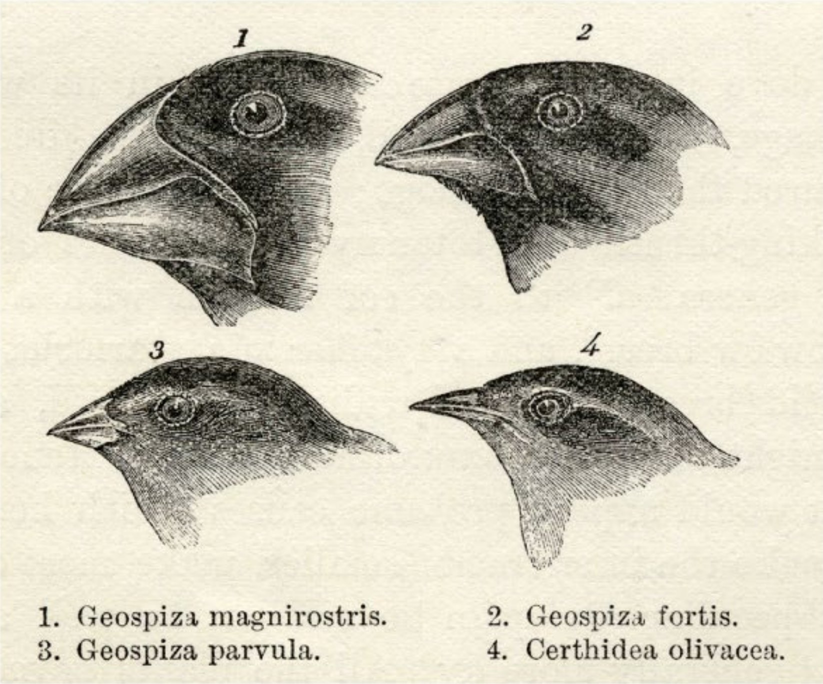
Cell



(top left): Mark Windom/Stocksy; (top center): Tom Uhlman/Alamy Stock Photo; (top right): Bildagentur Zoonar GmbH/Shutterstock; (bottom left): FOTOimage Montreal/Shutterstock; (bottom center): Science Photo Library/Alamy Stock Photo; (bottom right): Cultura Creative (RF)/Alamy Stock Photo

Life, water, land & change

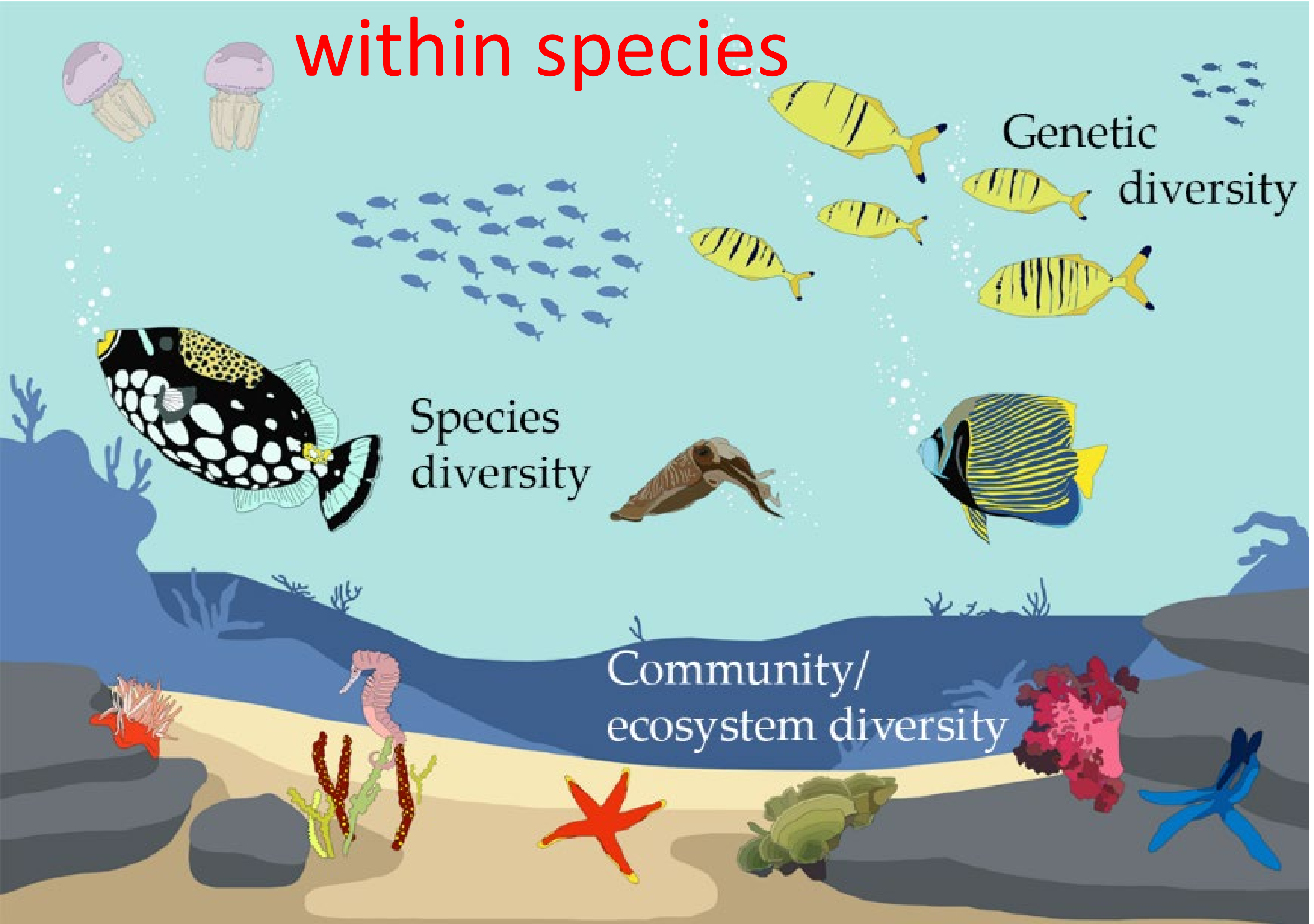
- Habitat
- Natural selection
- Adaptive radiation
- Evolution
  - Misconceptions



Biodiversity

Indicators of environmental health

Of species AND within species



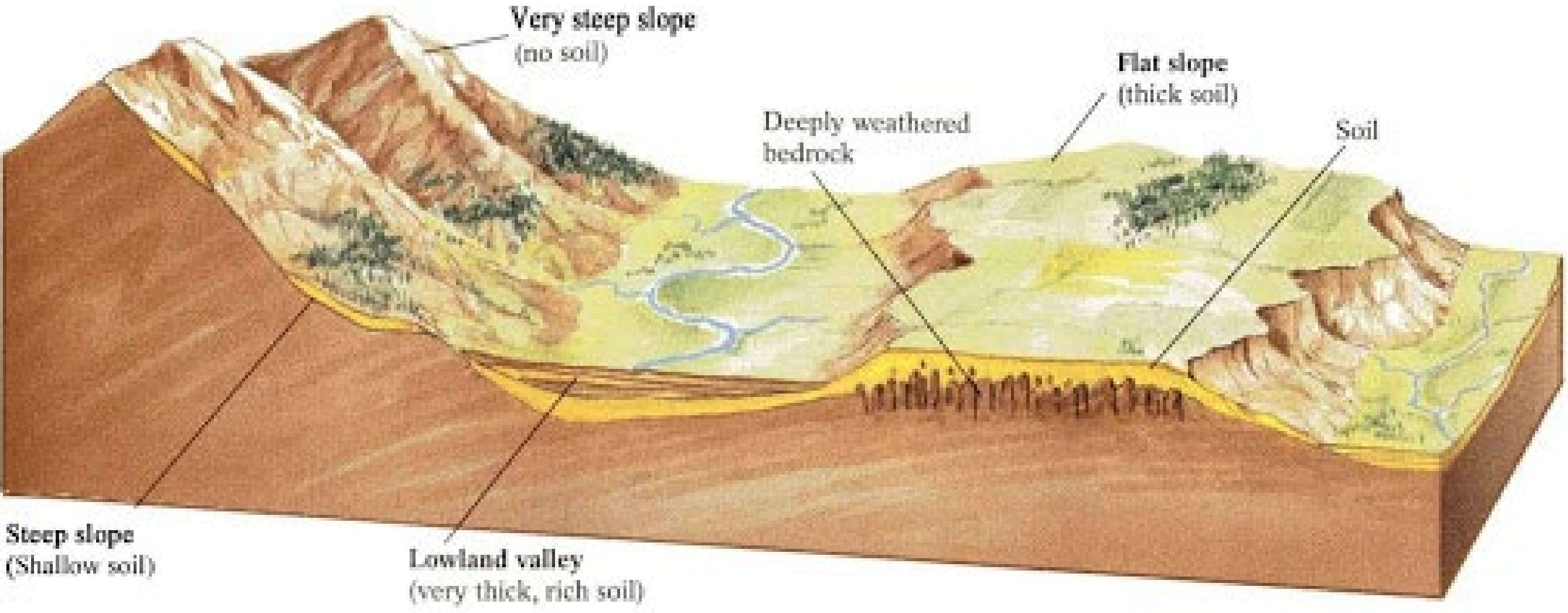
Number of species in an environment or ecological community.

Richness

Geology's influence in Biodiversity

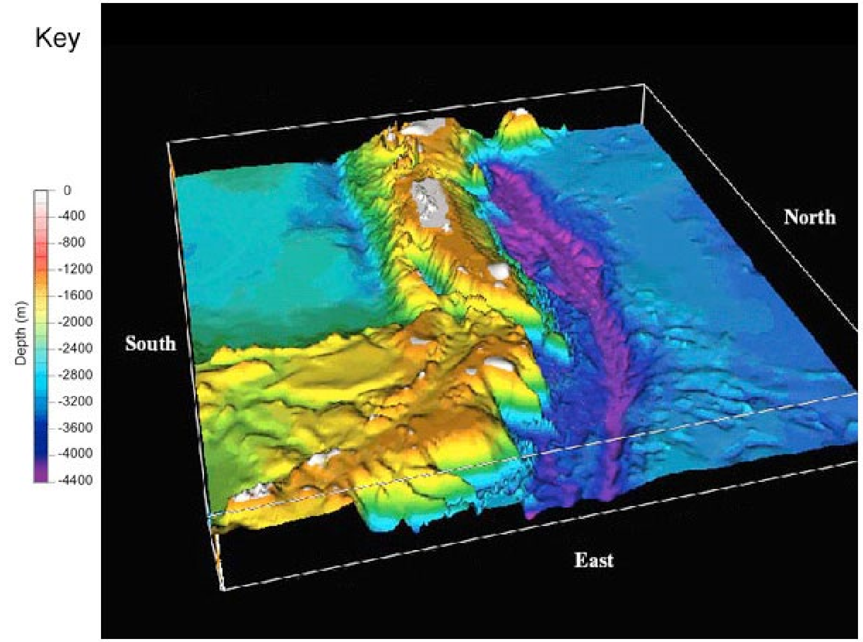
Small scale

Minerals available to soil development



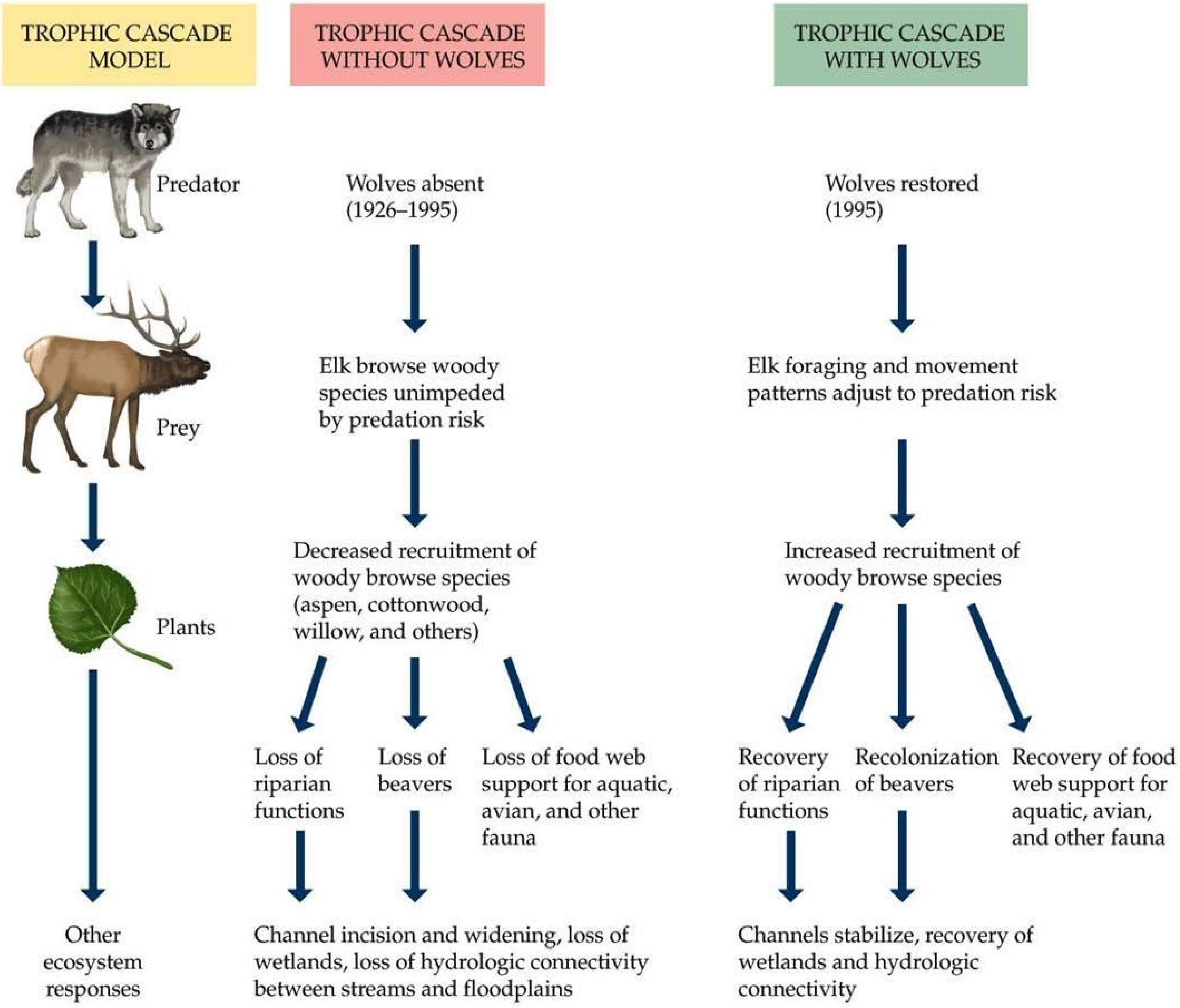
Large scale

Plate tectonics to ocean bathometry and currents



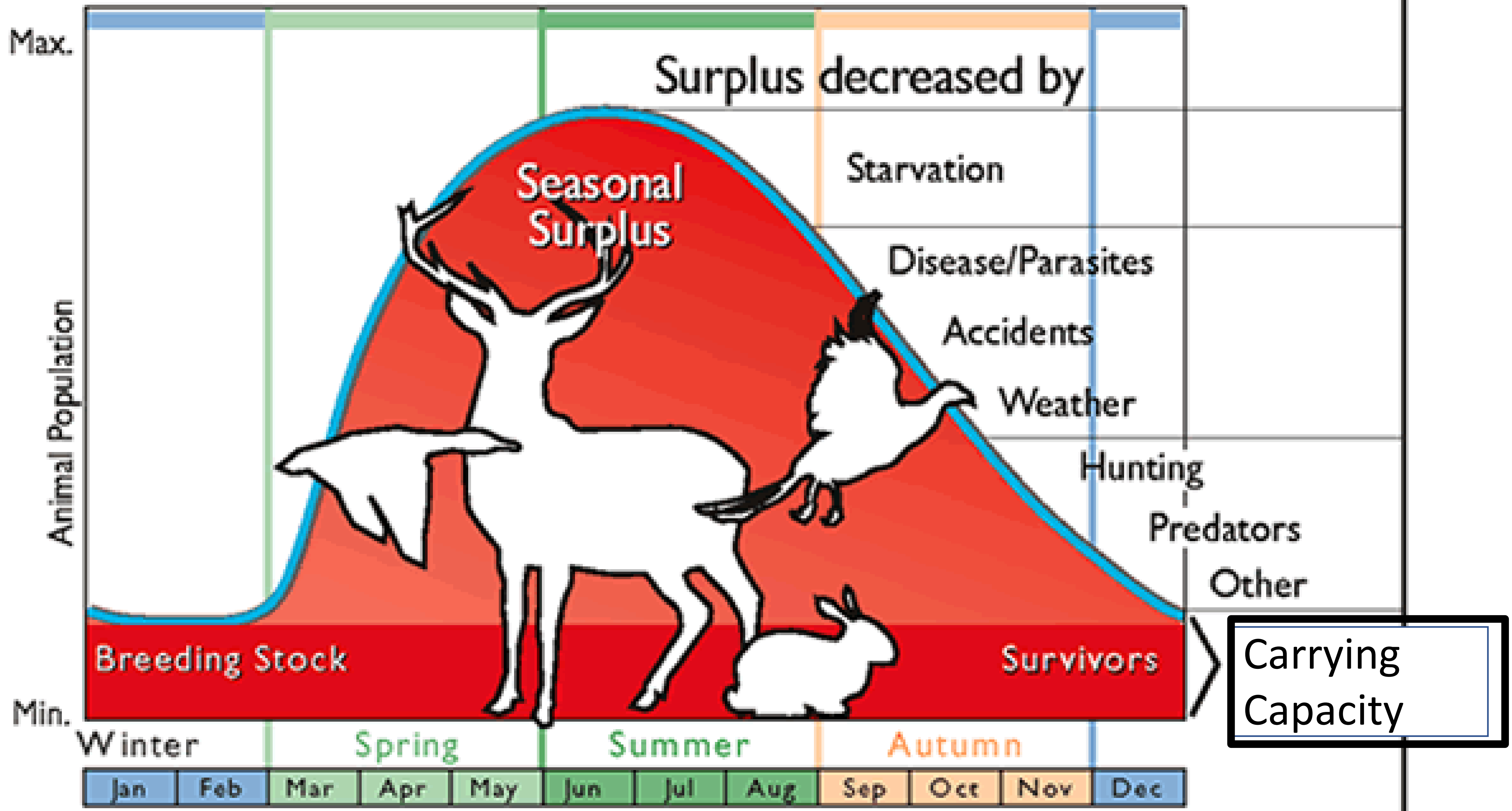
Biodiversity's role in Geology

Keystone species – Two or more organisms interacting in complex ways that affect other organism and their environments.

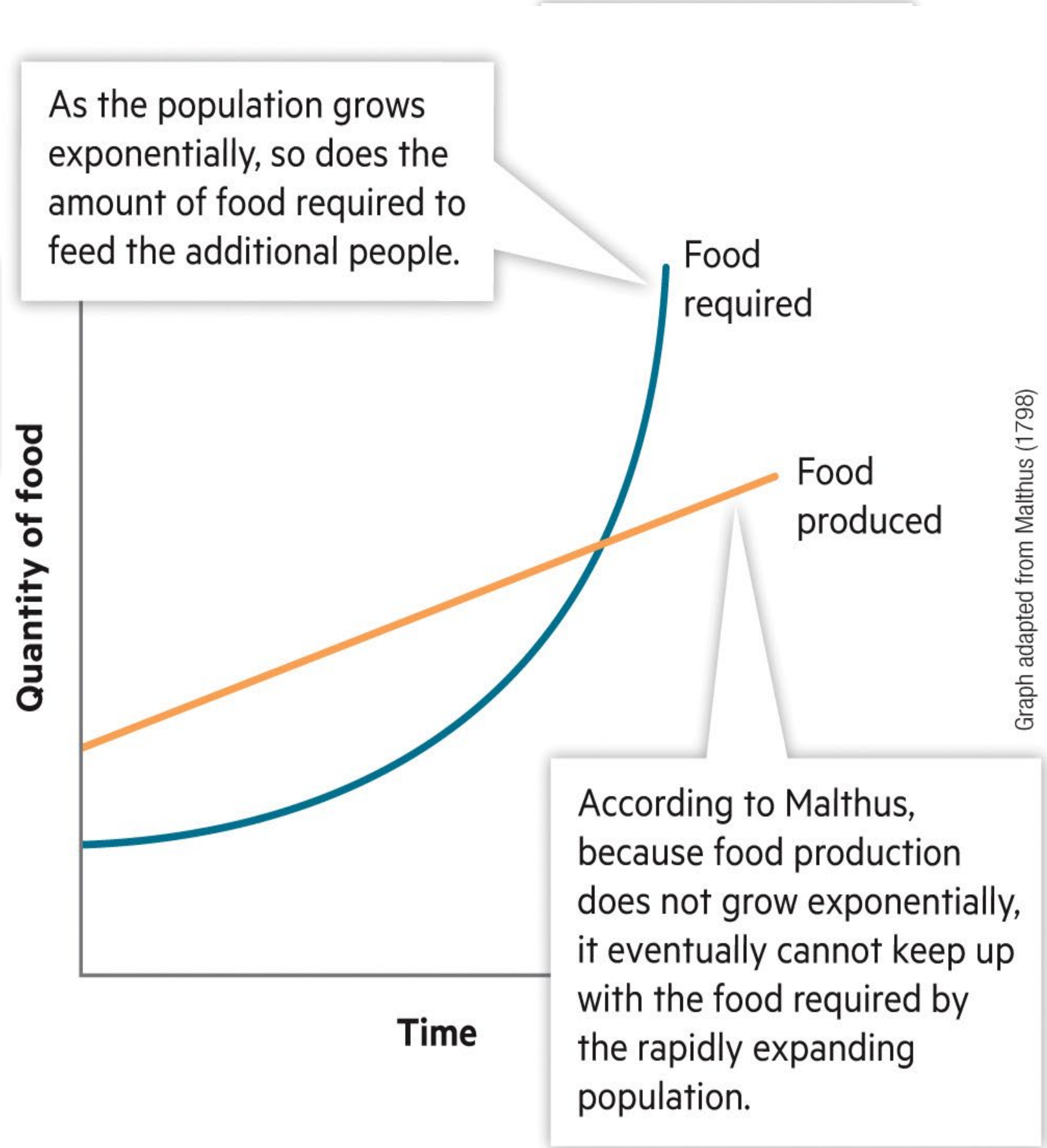


Yellowstone

(top left): Ian Macrae Young/Alamy Stock Photo; (bottom left): DJ40/Shutterstock; (right): Greg Vaughn/Alamy Stock Photo


Max.
Surplus decreased by
Starvation
Disease/Parasites
Accidents
Weather
Hunting
Predators
Other
Seasonal Surplus
Animal Population
Breeding Stock
Survivors
Carrying Capacity
Min.
Winter
Spring
Summer
Autumn
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Human population



GL Archive/Alamy Stock Photo

TABLE 1.3 How We Became 6 Billion heading to 8+ billion 2050 est. 9.7 billion

40,000–9,000 B.C.: Hunters and Gatherers	Population density about 1 person per 100 km^2 of habitable areas;[1] total population probably less than a few million; average annual growth rate less than 0.0001% (doubling time about 700,000 years)
9,000 B.C.–A.D. 1600: Preindustrial Agricultural	Population density about 1 person per 3 km^2 of habitable areas (about 300 times that of the hunter and gatherer period); total population about 500 million; average annual growth rate about 0.03% (doubling time about 2,300 years)
A.D. 1600–1800: Early Industrial	Population density about 7 persons per 1 km^2 of habitable areas; total population by 1800 about 1 billion; annual growth rate about 0.1% (doubling time about 700 years)
A.D. 1800–2000: Modern	Population density about 40 persons per 1 km^2; total population in 2000 about 6.1 billion; annual growth rate at 2000 about 1.4% (doubling time about 50 years)

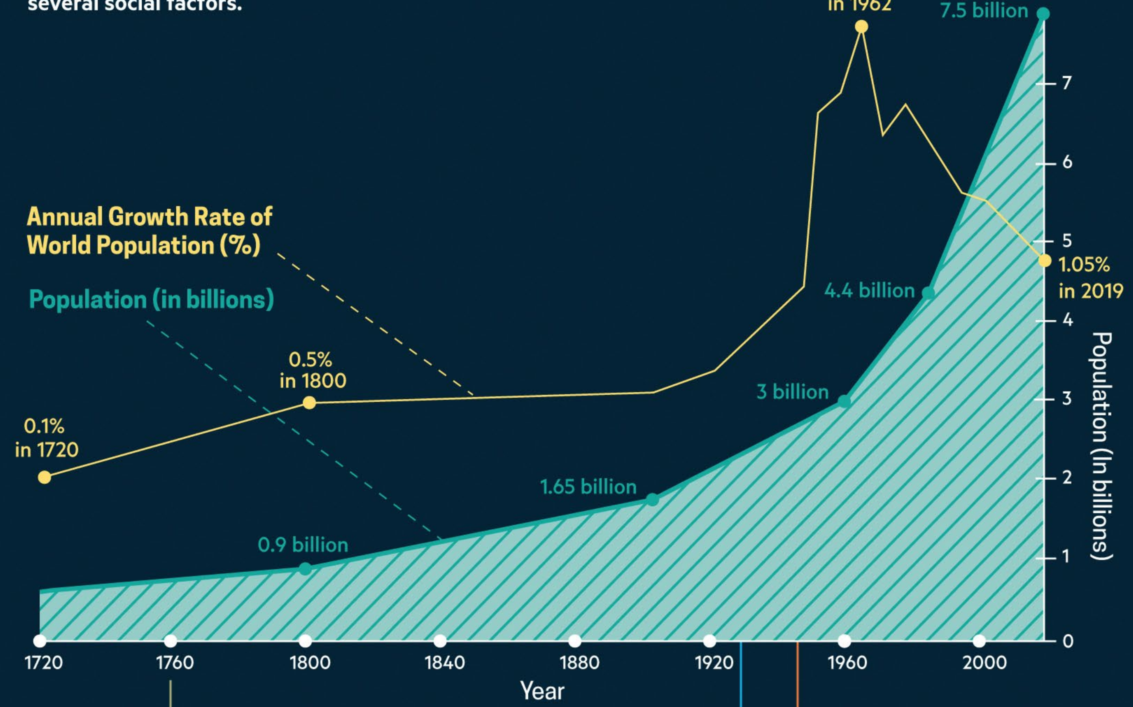
Societal Collapses

- Over consumption of resources
- Changing environmental conditions
- Social conflicts
- Tragedy of the Commons

AT A GLANCE

Global Population: Past, Present, and Future

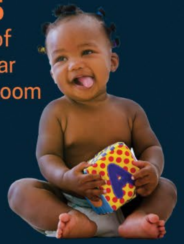
For most of human history, the number of humans on Earth was relatively small and steady, totaling well below 1 billion—a threshold that was not crossed until 1804. In recent centuries, and particularly in the last century, our population has skyrocketed. While the rate of population growth is slowing, future population projections—and their sustainability—depend on several social factors.



1760 Industrial Revolution begins

1928 Penicillin is discovered

1946 Start of postwar baby boom



United Nations Population Projections for 2100

UN estimates of future population growth (high, middle, and low) depend on assumptions made about the empowerment and health of women and girls that will affect fertility rates.

Current Population 8 billion

High: 16.5 billion

Decreased access to birth control and decline in status of women are coupled with improved maternal and infant health.

Middle: 11.5 billion

Current trends in access to birth control, education, employment, and health care for women remain unchanged.

Low: 7 billion

Significant improvement in access to birth control and education and employment opportunities for women occur.

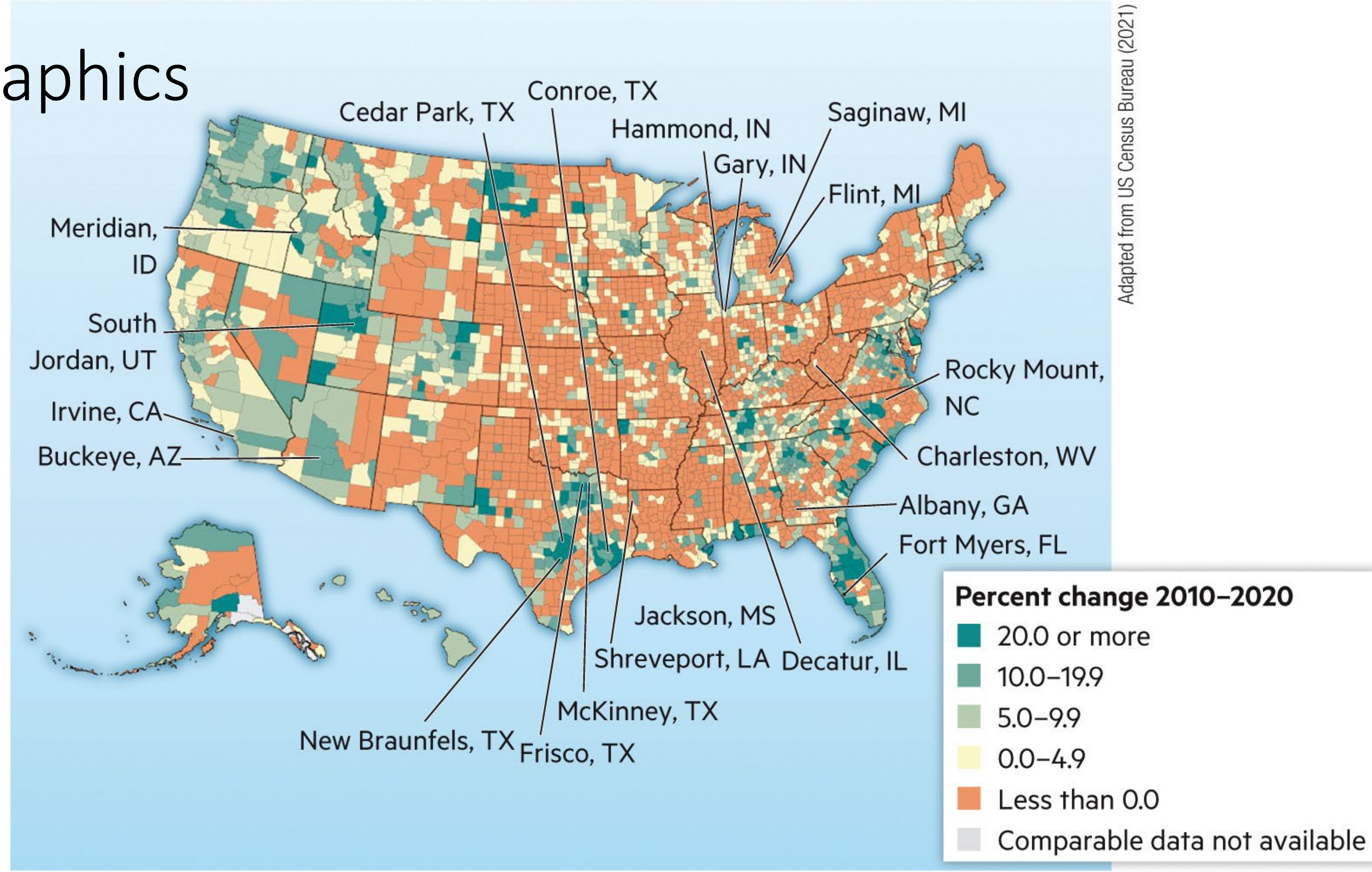
Growth variables

- Birth vs Death rates
- Agriculture efficiencies
- Health care advances
- Technology
- Urbanization

- Carrying capacity? – a function of human population and our ability to adapt to the environmental impacts associated with our consumption patterns.

Population Control Policies, Social Stratification & Inequality, Empowering Women

Demographics



Secondary Ed.

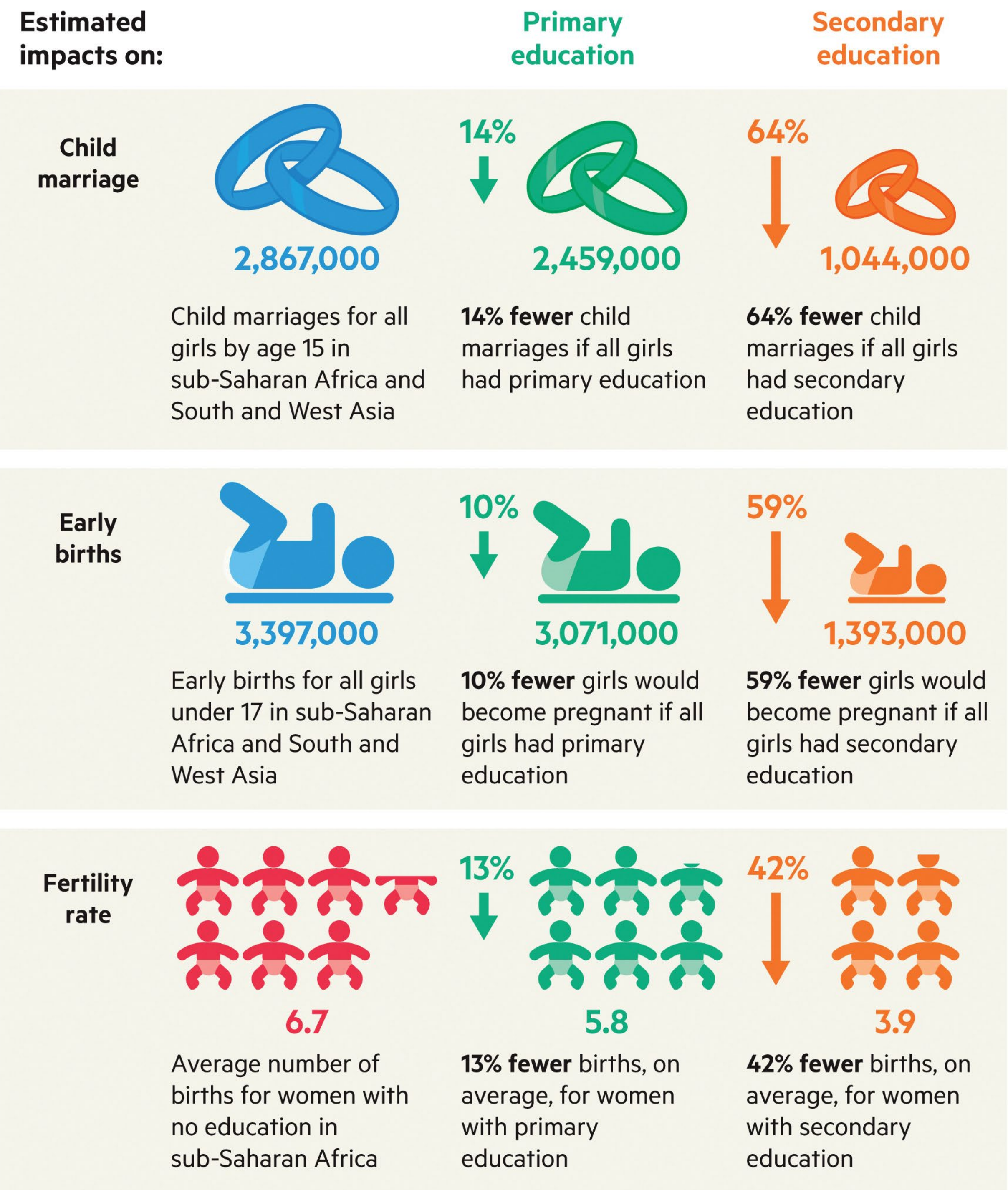
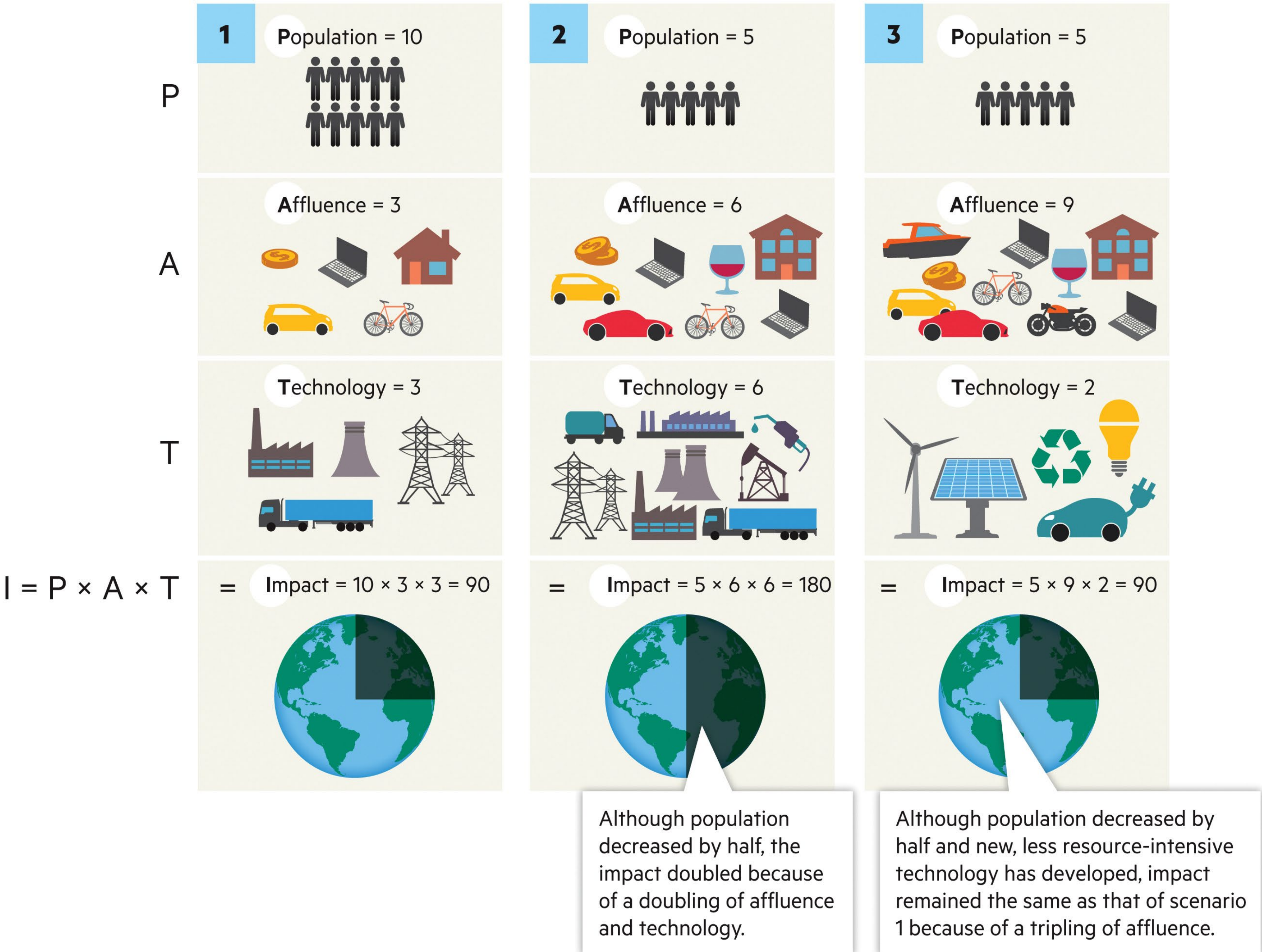


Figure from p. 183, Teaching and learning: achieving quality for all; EFA global monitoring report, 2013-2014, UNESCO. Director-General, 2009-2017 (Bokova, I.G.), writer of foreword (Paris: UNESCO, 2014). Reprinted by permission of UNESCO.

I = PAT: Three Scenarios



Population

Affluence

Technology

=

Impact

(a) High-income Country in 2012 **(b)**

Global Footprint Network®
Advancing the Science of Sustainability

Global Footprint Network

- https://www.footprintnetwork.org/

WATER FOOTPRINT®
CALCULATOR

https://watercalculator.org/footprint/the-hidden-water-in-everyday-products/