What is Environmental Systems Science?

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Overview

- Environmental Science
- Hydrological Cycle
- Carbon, Phosphorus Cycle
- Climate classification
- Human impact of Environment/Climate
- Video
  - IPCC - State of science
  - IPCC - Fifth Assessment Report
- Math Experiment 1

Note: Homework posted on website.

Environment: the total of our surroundings

Environment: the total of our surroundings

- All the things around us with which we interact:
  - Living things
    - Animals, plants, forests, fungi, etc.
  - Non-living things
    - Continents, oceans, clouds, soil, rocks
  - Our built environment
    - Buildings, human-created living centers
  - Social relationships and institutions

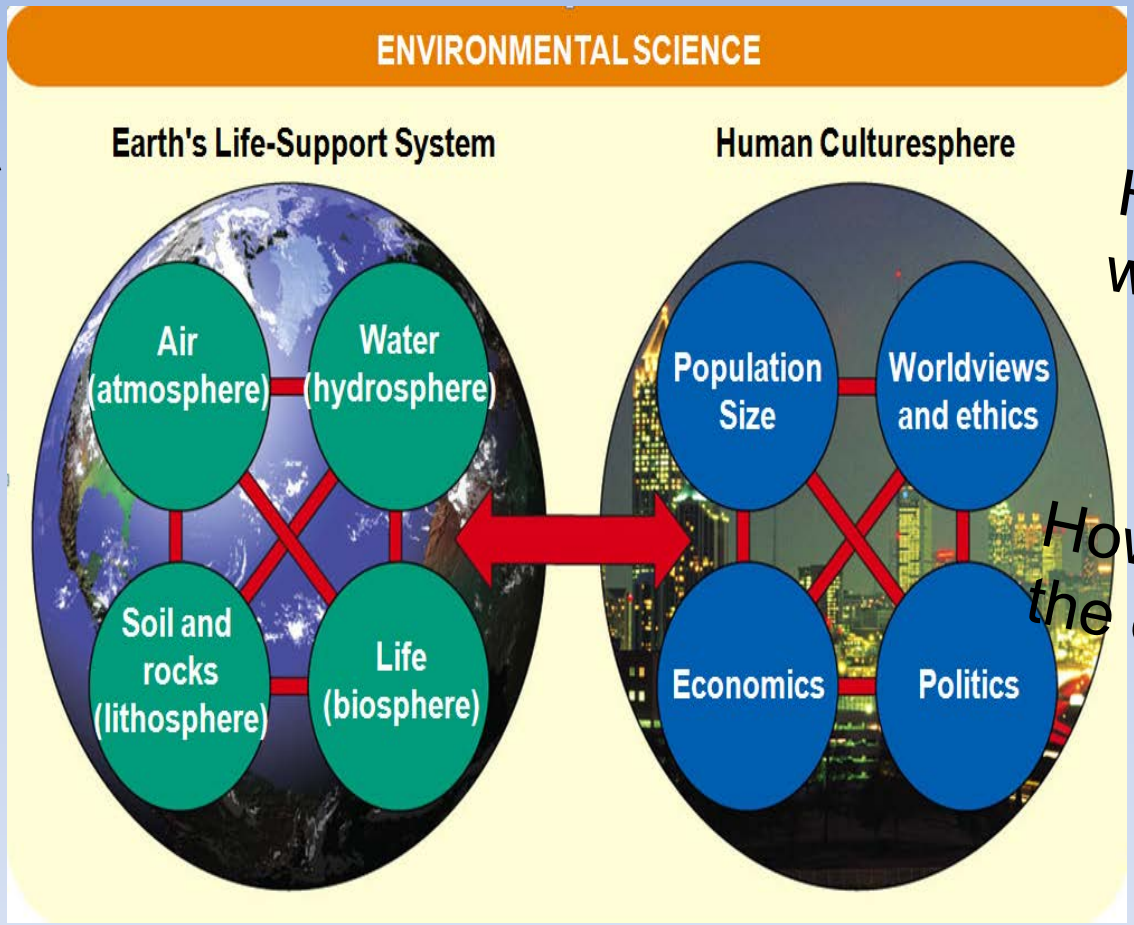
Why we need to study the Environmental Science?

- Humans depend completely on the environment for survival.
  - Enriched and longer lives, increased wealth, health, mobility, leisure time
- But natural systems have been degraded
  - Pollution, erosion, and species extinction
  - Environmental changes threaten long-term health and survival.
- Environmental science is the study of:
  - How the natural world works
  - How the environment affects humans and vice versa
- With environmental problems come opportunities for solutions.

What do we learn in Environmental Science?

How the environment affects us

How to live more sustainably



How nature works

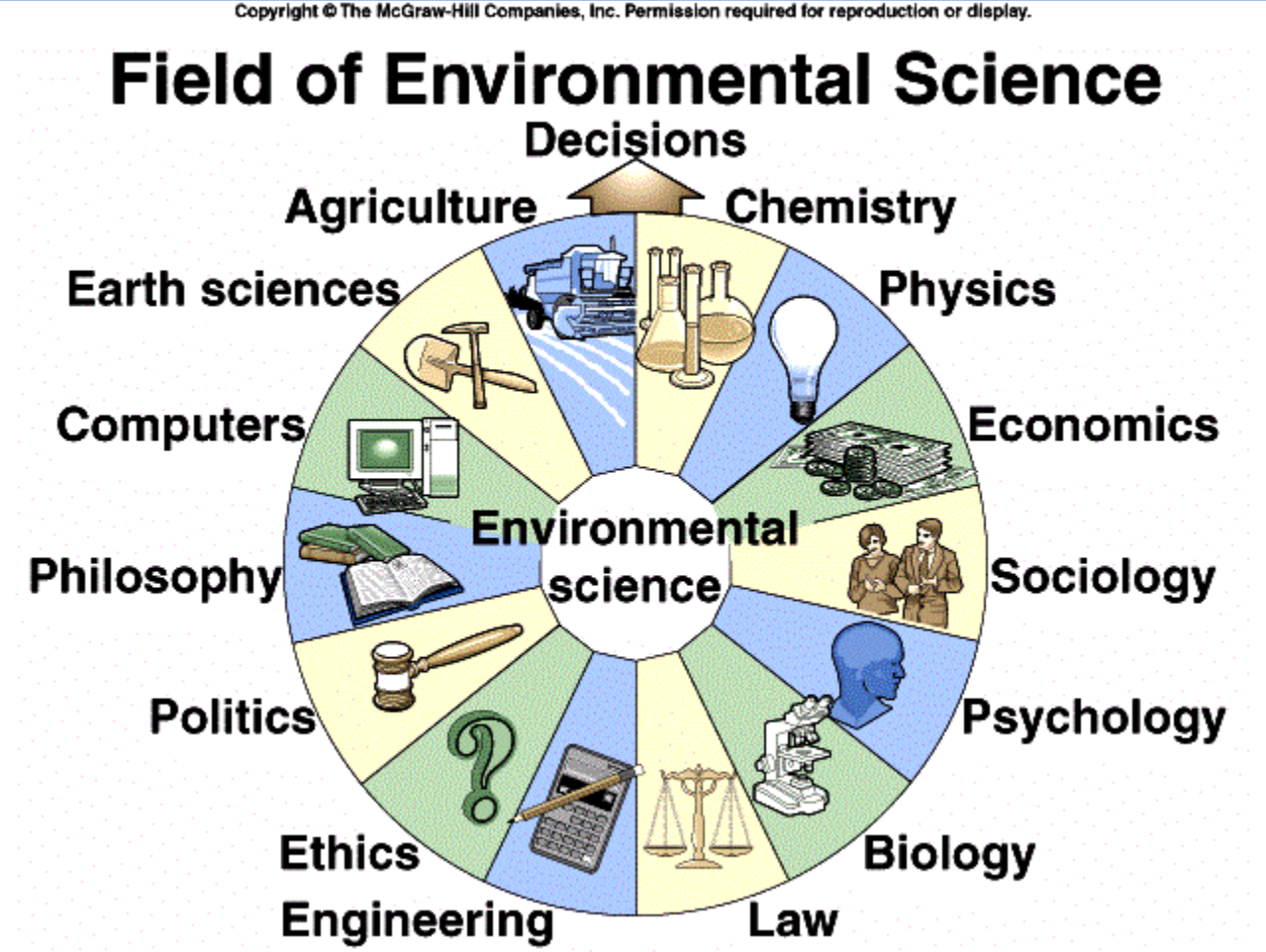
How we affect the environment

How to deal with environmental problems

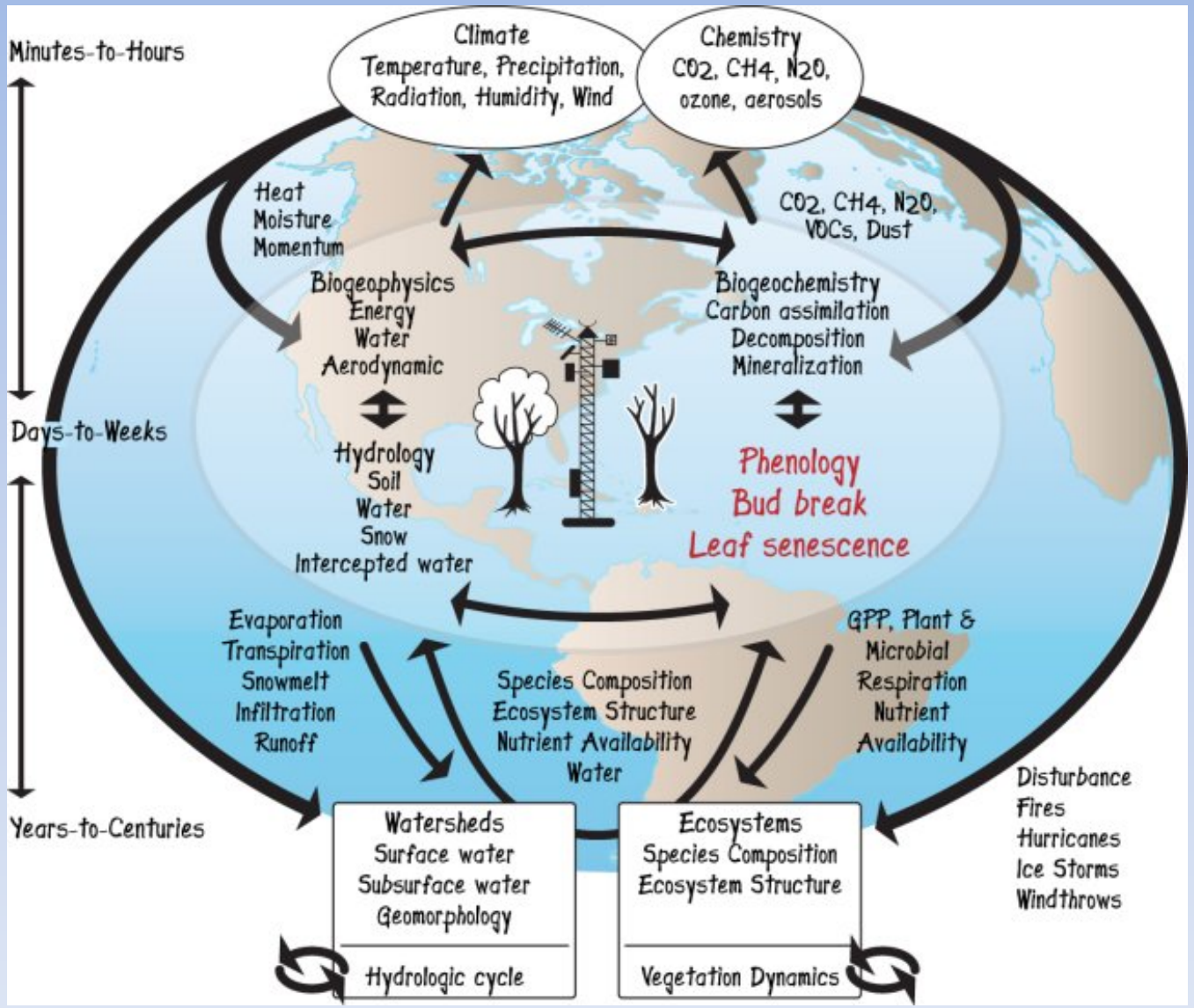
Difference between Ecology and Environmental Science

- **Ecology**
  - Study of relationships between living organisms and their environment
- **Environmental Science**
  - how nature works.
  - how the environment effects us.
  - how we effect the environment.
  - how we can live more sustainably without degrading our life-support system.

Environmental science

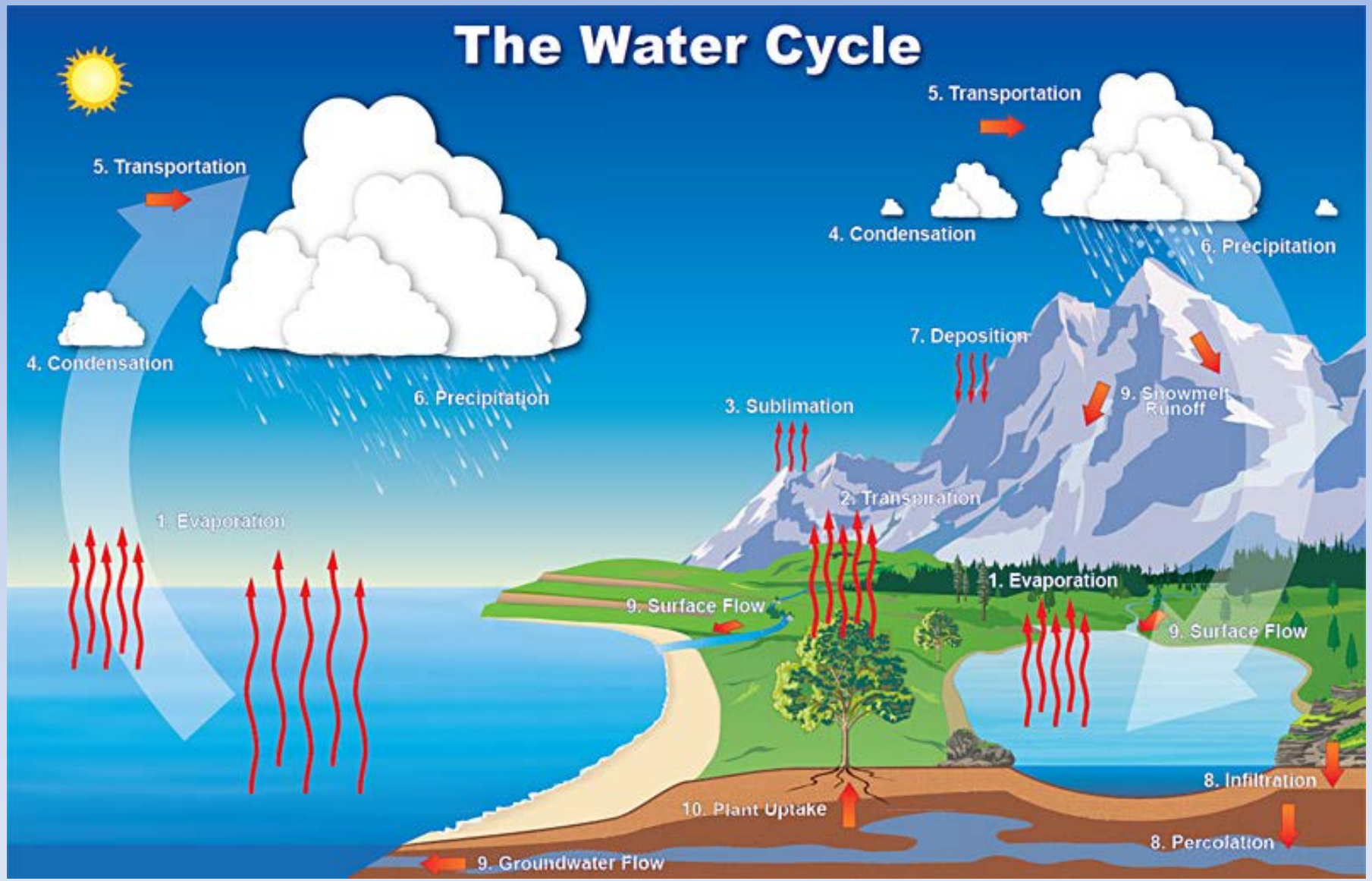


Phenology – An essential component of environmental science



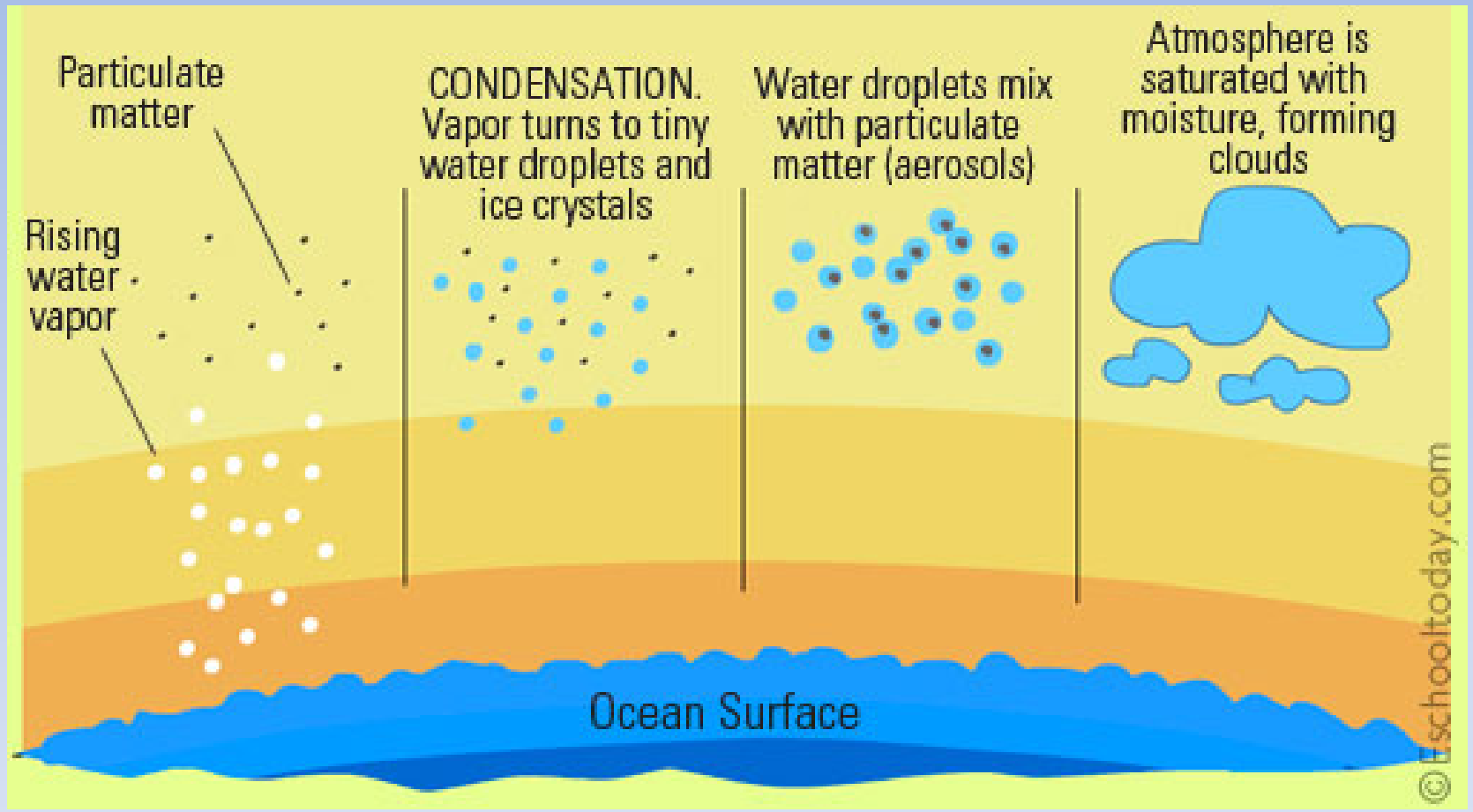
http://wwwpaztcn.wr.usgs.gov/rsch_highlight/articles/200610.html

Hydrological Cycle

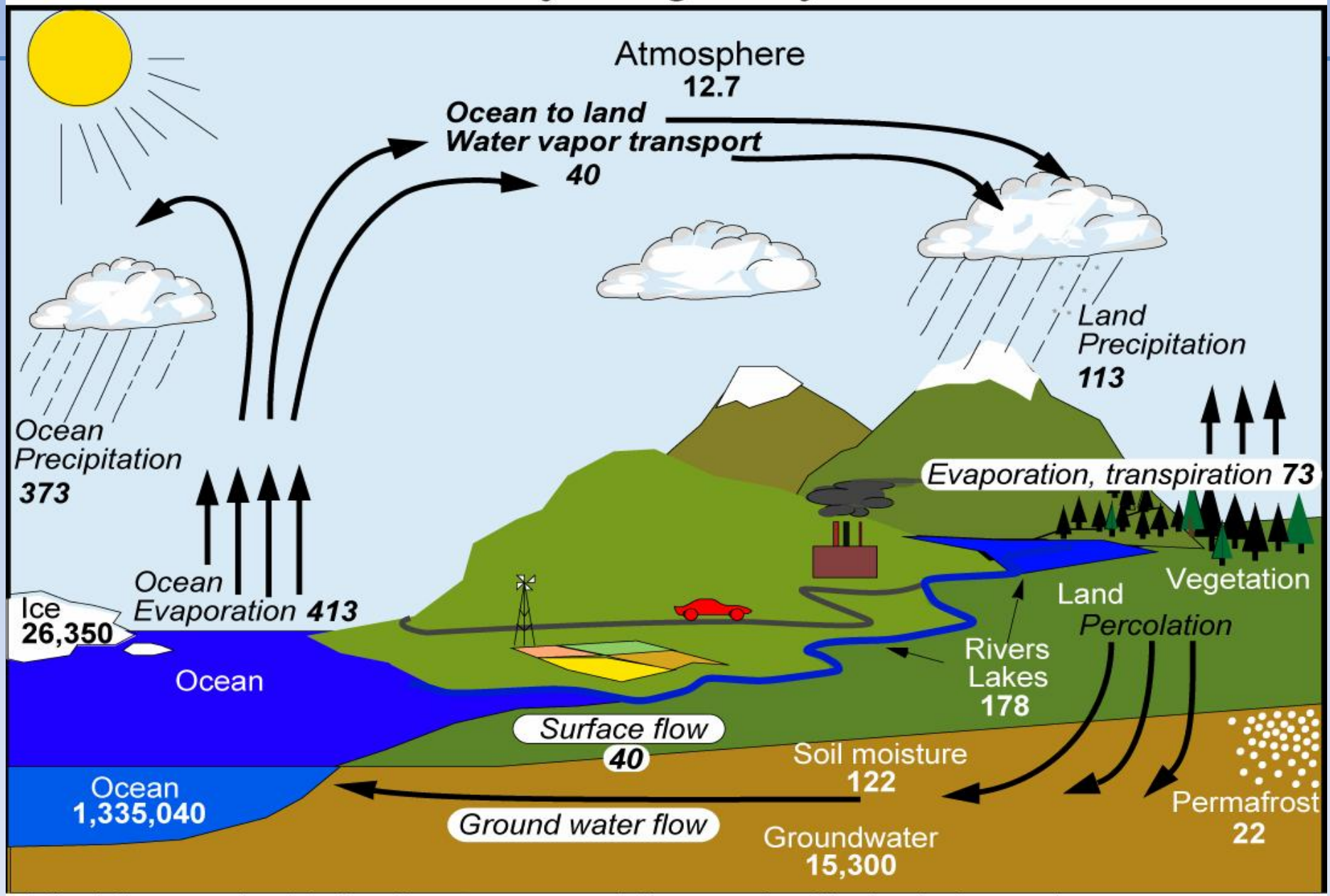

The Water Cycle
5. Transportation
4. Condensation
6. Precipitation
1. Evaporation
5. Transportation
4. Condensation
6. Precipitation
7. Deposition
3. Sublimation
9. Snowmelt Runoff
2. Transpiration
1. Evaporation
9. Surface Flow
9. Surface Flow
8. Infiltration
10. Plant Uptake
8. Percolation
9. Groundwater Flow

noaa.gov

Water cycle in atmosphere



Hydrological Cycle



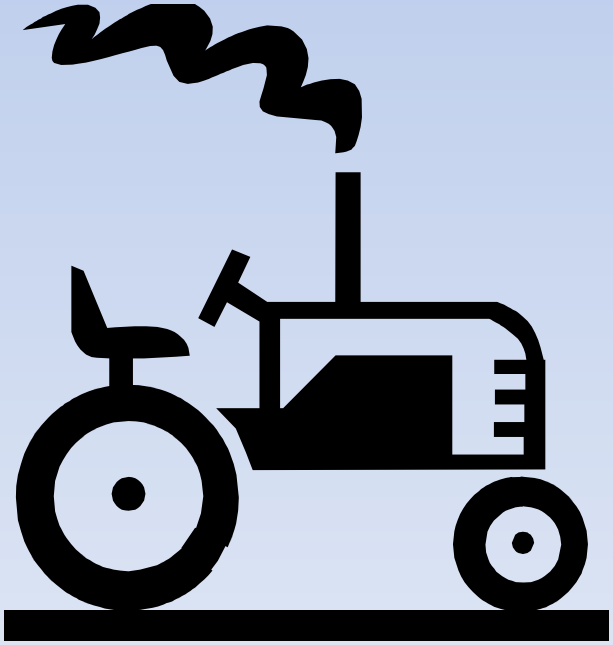
Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

The hydrologic cycle

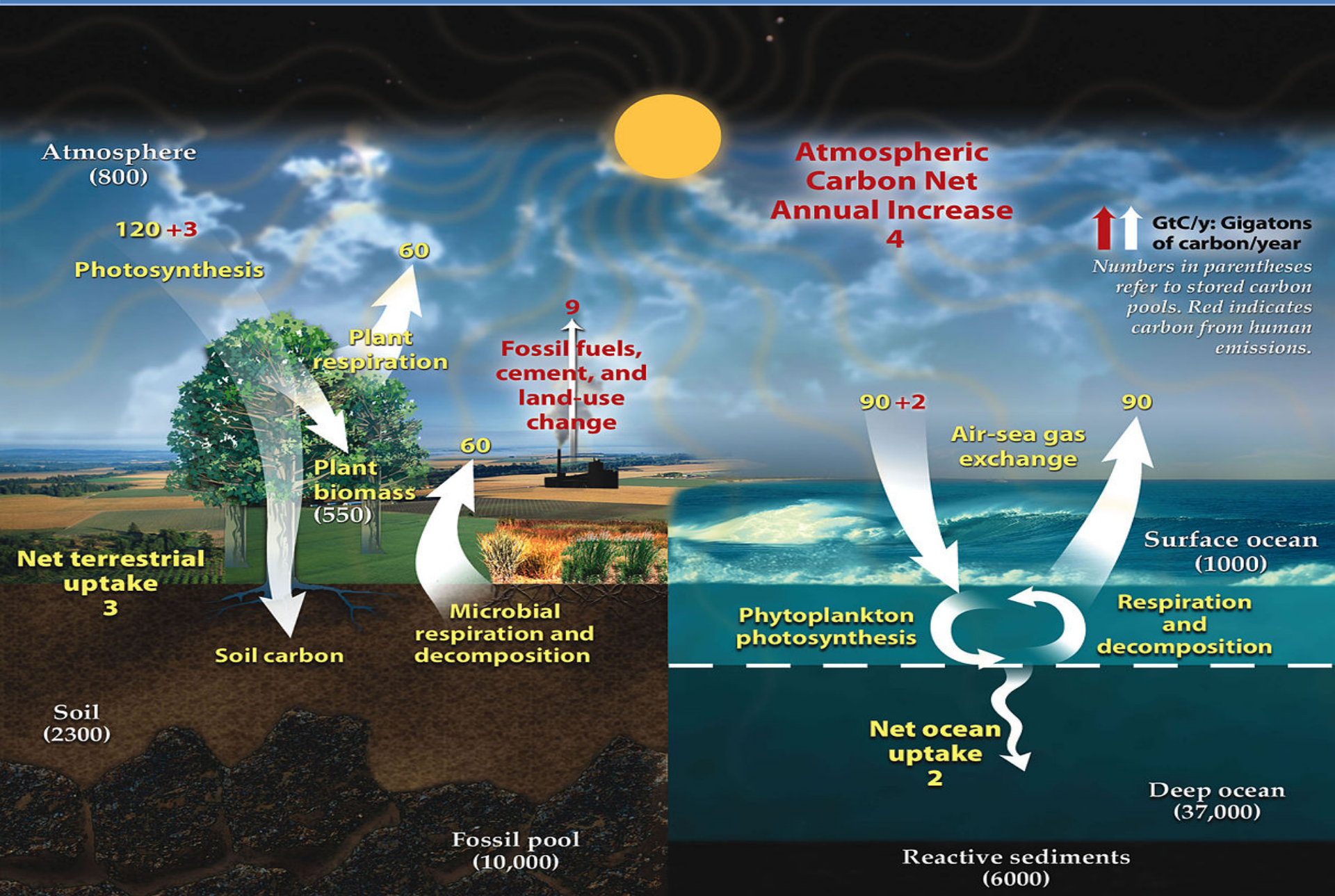
- Water is essential for biochemical reactions
  - It is involved in nearly every environmental system
- **Hydrologic cycle** = summarizes how liquid, gaseous and solid water flows through the environment
  - Oceans are the main reservoir
- **Evaporation** = water moves from aquatic and land systems into the atmosphere
- **Transpiration** = release of water vapor by plants
- **Precipitation, runoff,** and surface water = water returns to Earth as rain or snow and flows into streams, oceans, etc.

Pollution

- Any addition to air, water, soil, or food that threatens the health, survival, or activities of humans or other living organisms
- Solid, liquid, or gaseous by-products or wastes



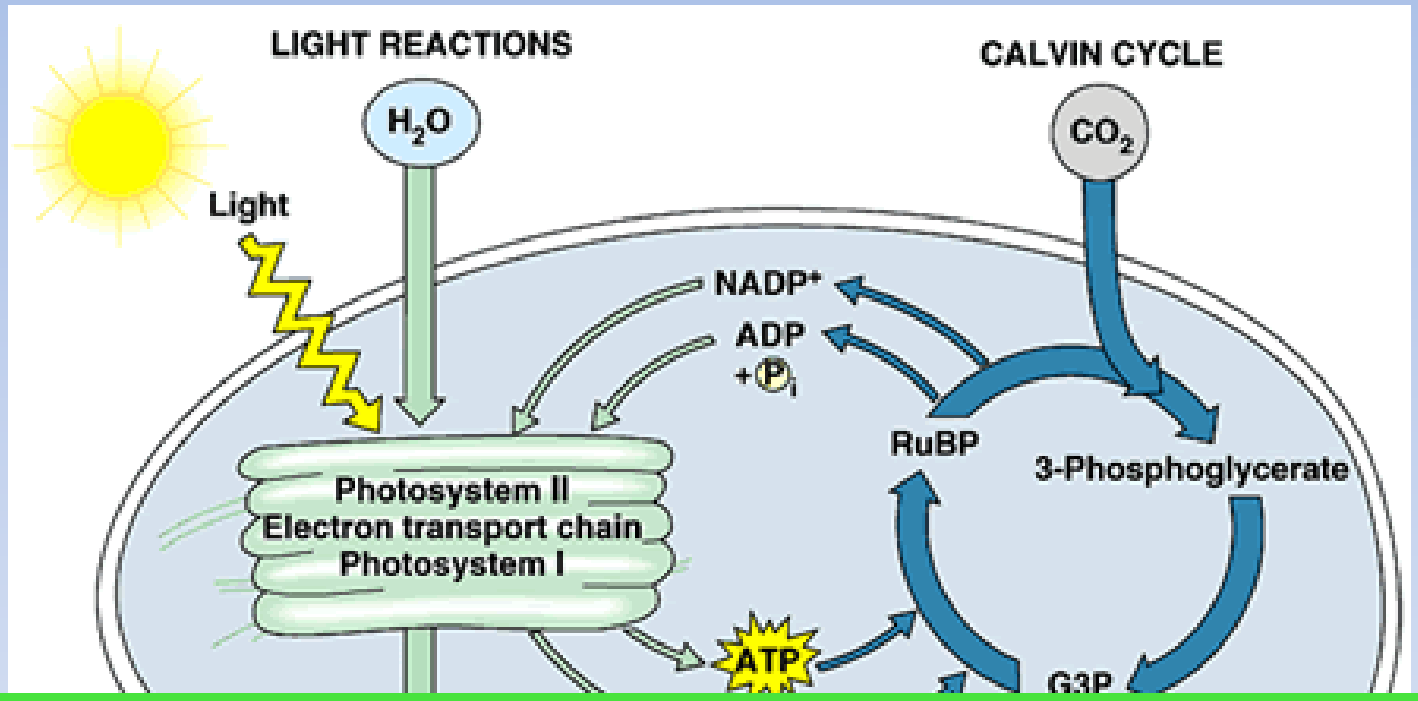
The Carbon Cycle



What if there is no CO2 release?

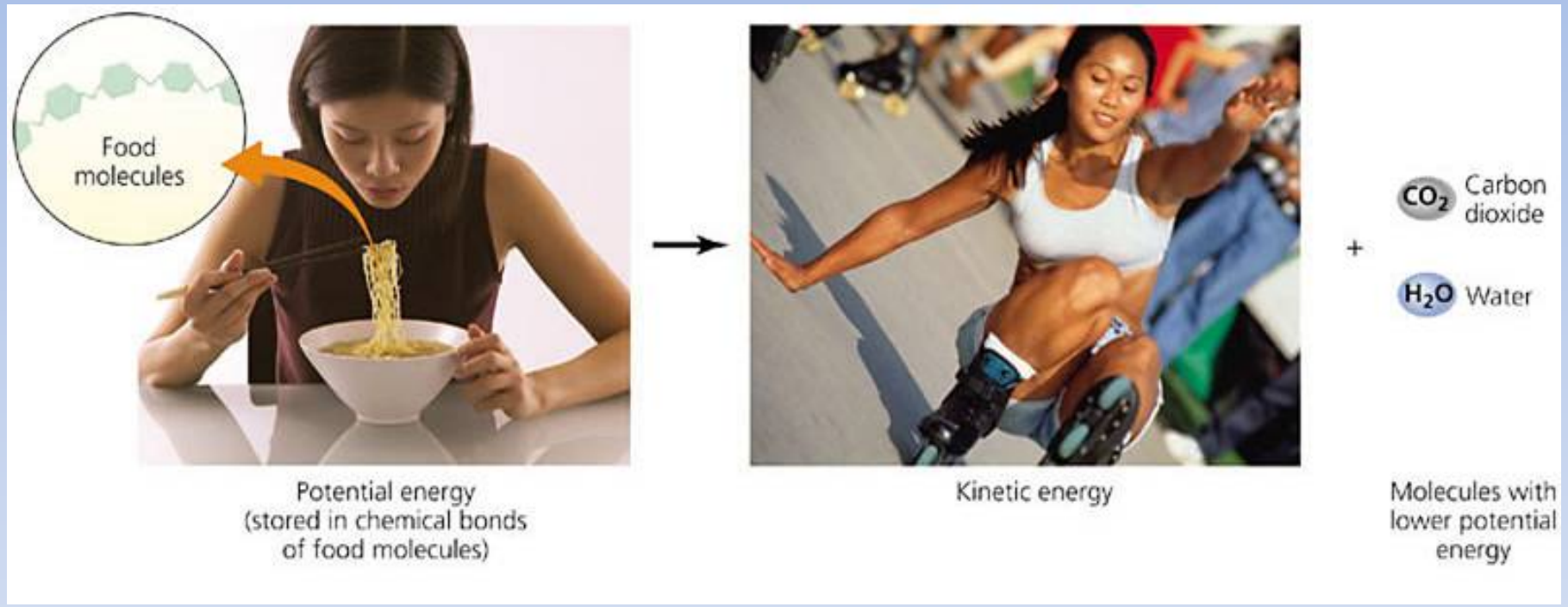
Reactions of Photosynthesis

Photosynthesis converts light energy into the chemical energy of sugars and other organic compounds. A series of chemical reactions that require carbon dioxide (CO_2) and water (H_2O) and store chemical energy in the form of sugar. Light energy drives the reactions > Oxygen (O_2) is a byproduct released into the atmosphere.



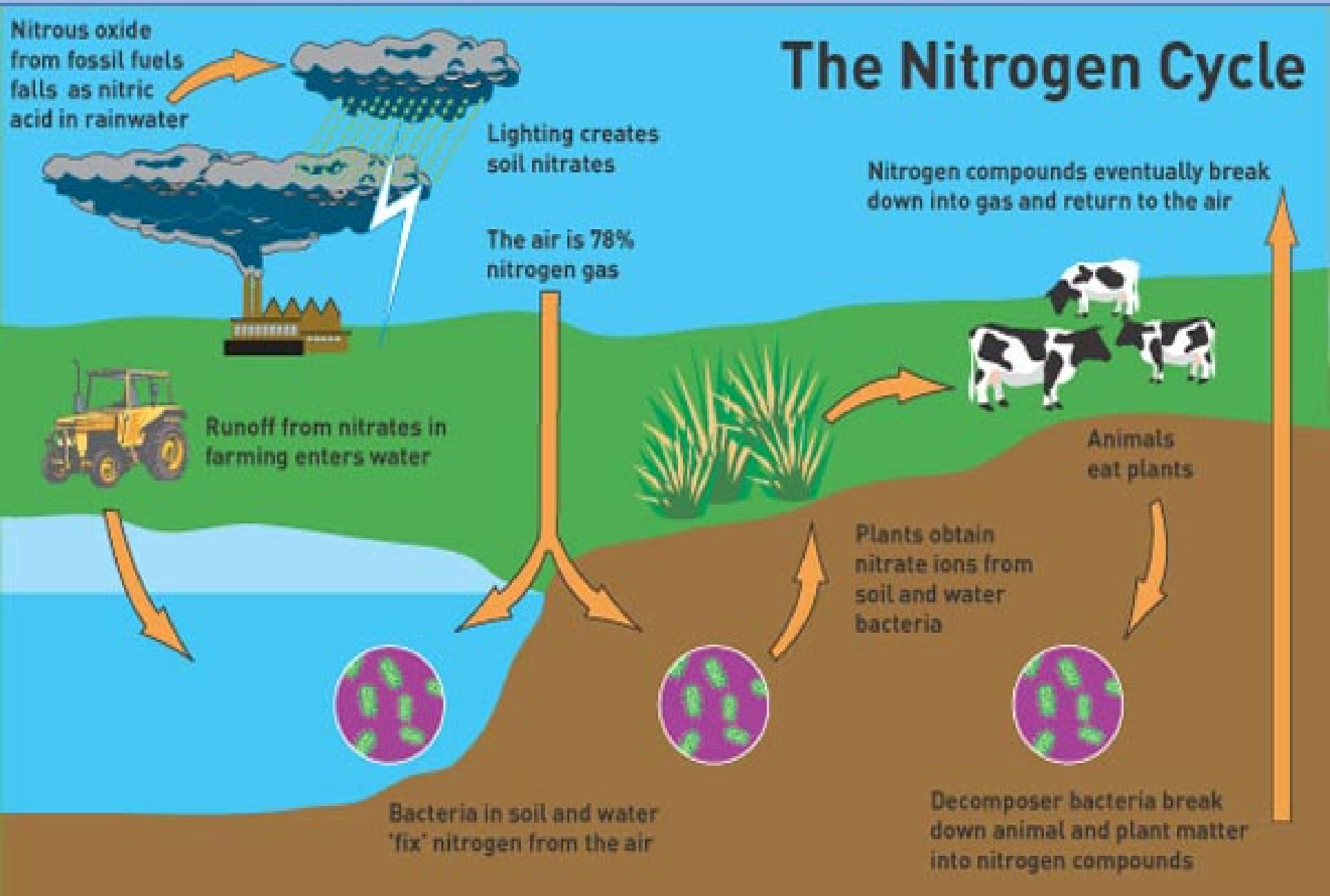
$$6\ CO_2 + 6\ H_2O + \text{energy from sun} \longrightarrow C_6H_{12}O_6\ (\text{sugar}) + 6\ O_2$$

Potential and kinetic energy



- Potential energy stored in food is converted to kinetic energy when we exercise.

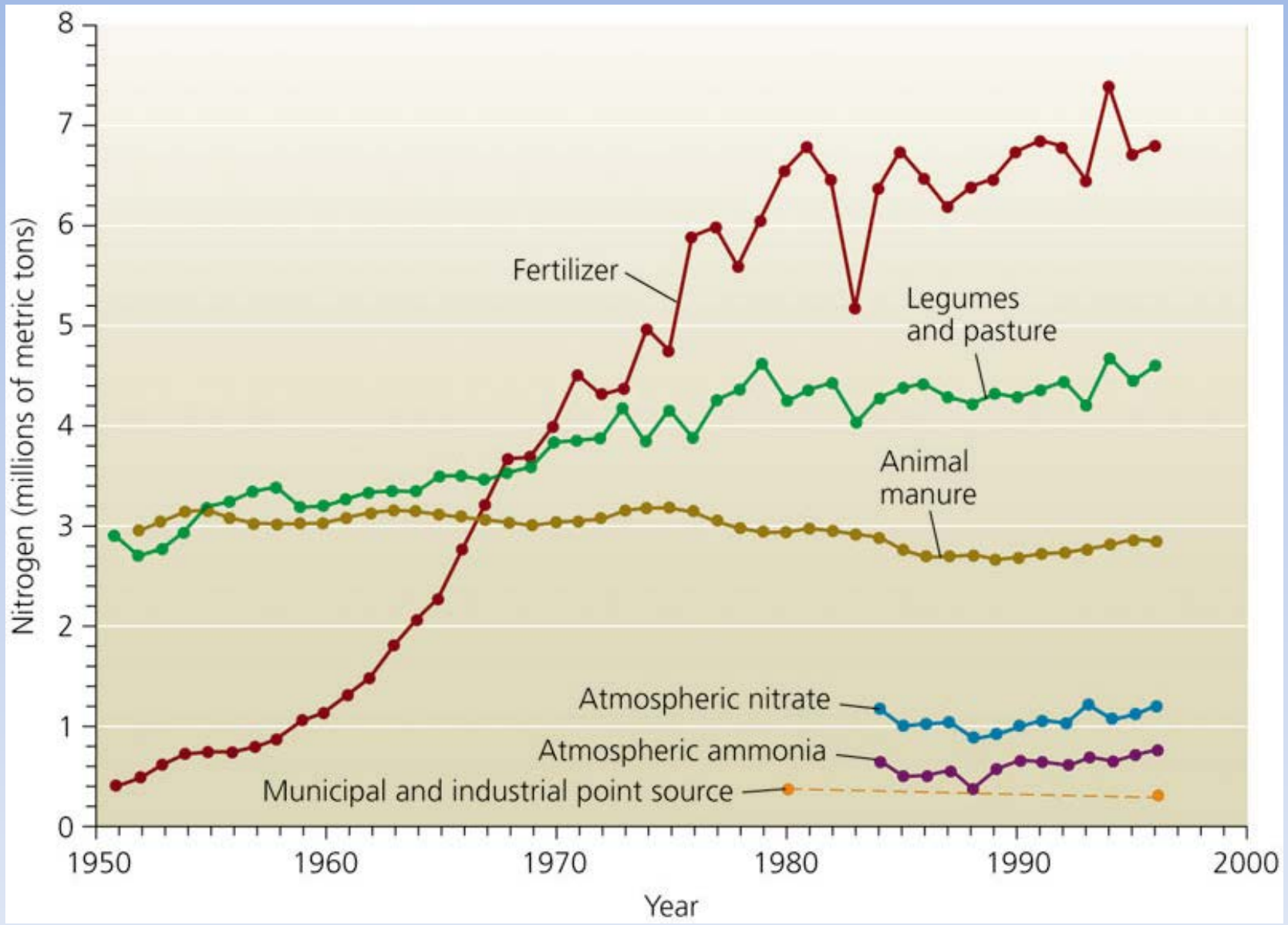
Nitrogen cycle



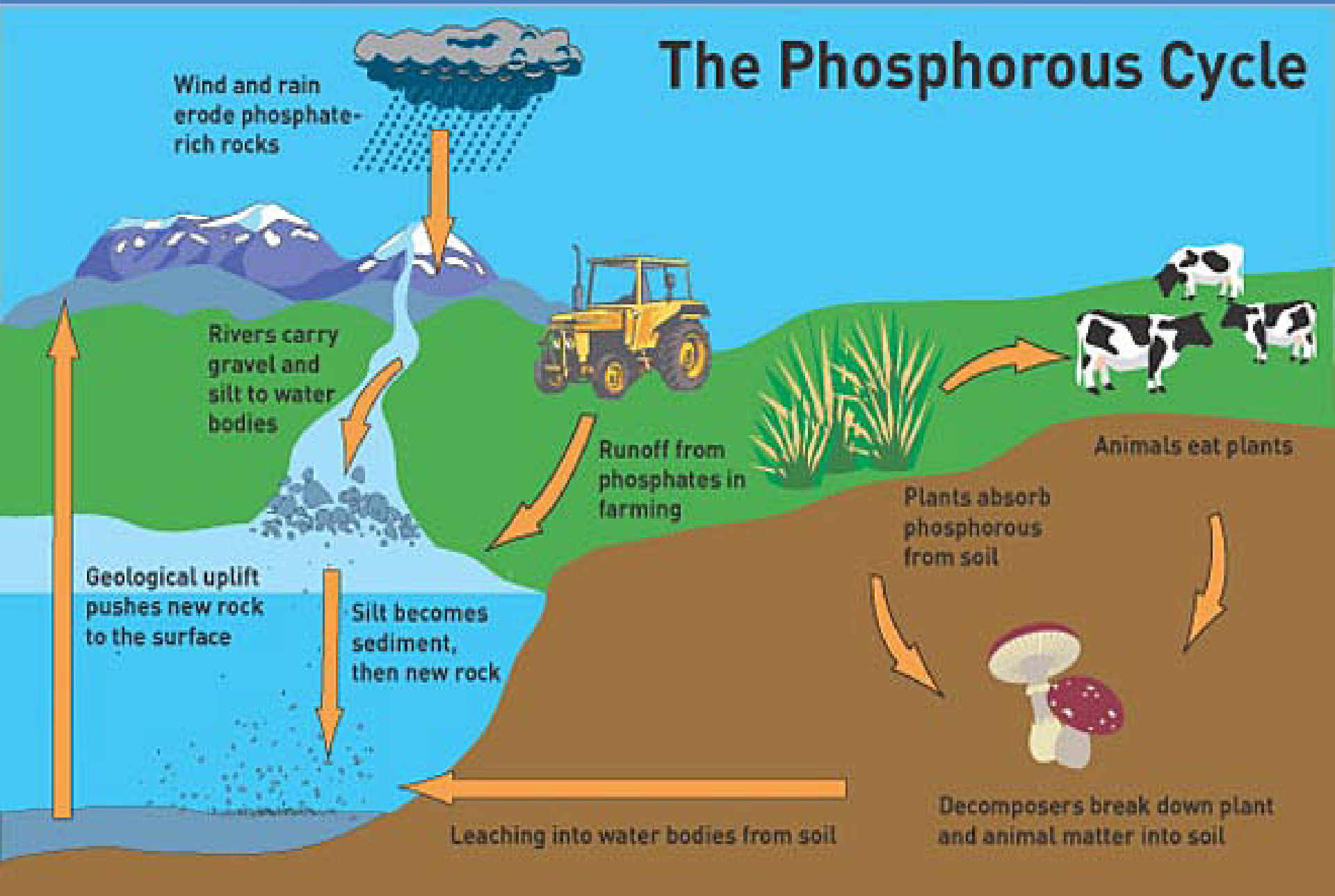
Nitrogen cycle - Definitions

- Nitrogen contained in proteins, DNA and RNA
- **Nitrogen fixation** = lightning or nitrogen-fixing bacteria combine (fix) nitrogen with hydrogen
  - To form ammonium
  - Which can be used by plants

Human impacts on the nitrogen cycle



Phosphorus cycle

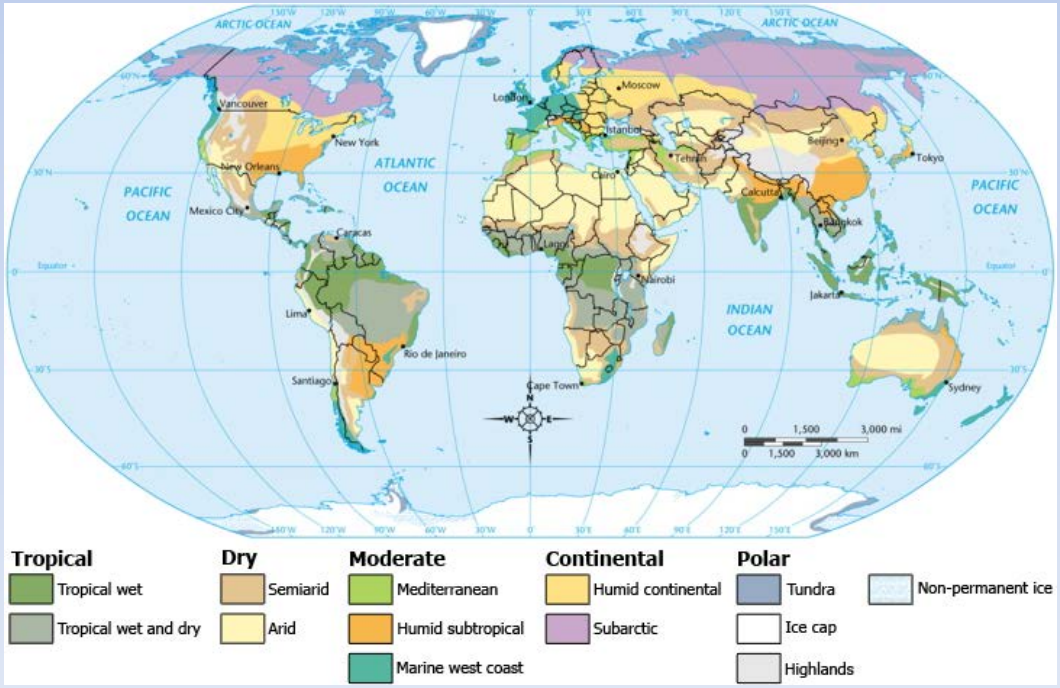


Climate

Climate is a measure of the average pattern of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time.
Climate classification systems include:

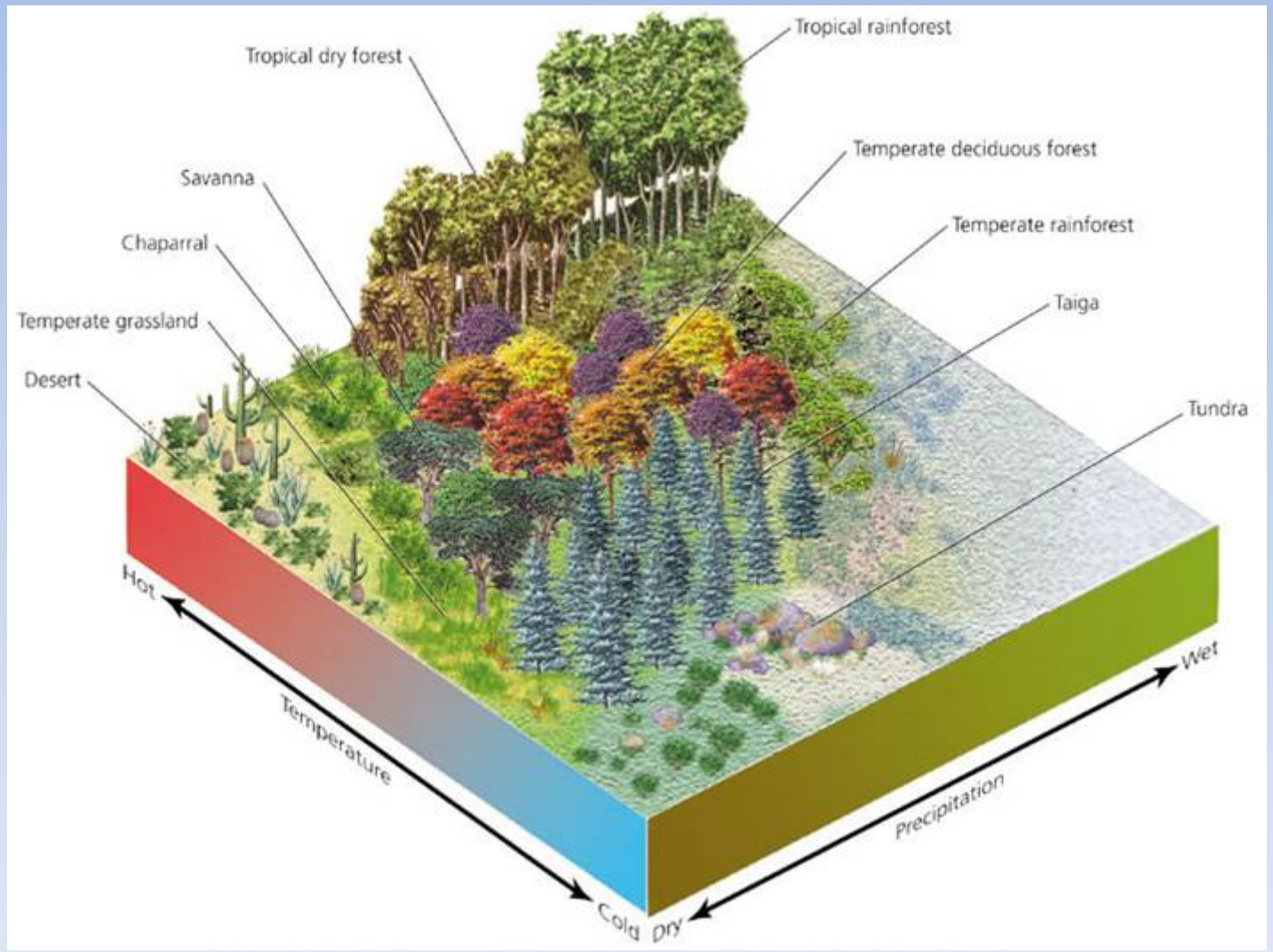
- Aridity index
- Köppen climate classification
- Holdridge Life Zone Classification System
- Trewartha climate classification

The most commonly used form of the Köppen classification has five primary types labeled A through E.



Climate and biomes

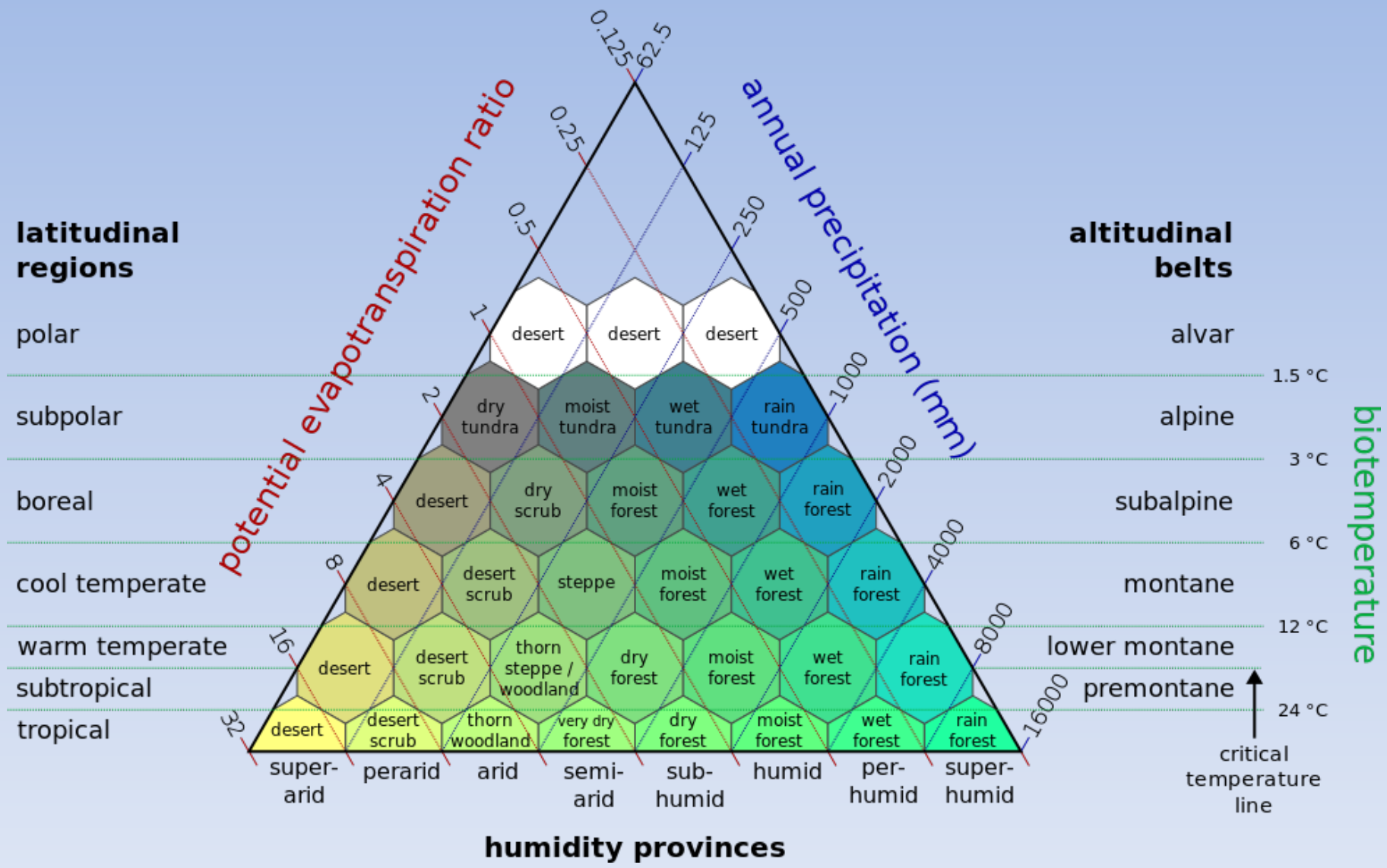
- *Biomes change with temperature and precipitation.*



Köppen climate classification

- Rain forests are characterized by high rainfall, > minimum normal annual rainfall between 1,750 millimetres (69 in) and 2,000 millimetres (79 in). Mean monthly temperatures exceed 18 C (64 F) during all months of the year.
- A monsoon is a seasonal prevailing wind which lasts for several months, ushering in a region's rainy season. Regions within North America, South America, Sub-Saharan Africa, Australia and East Asia are monsoon regimes.
- A tropical savanna is a grassland biome located in semiarid to semi-humid climate regions of subtropical and tropical latitudes, with average temperatures remain at or above 18 C (64 F) year round and rainfall between 750 millimetres (30 in) and 1,270 millimetres (50 in) a year. They are widespread on Africa, and are found in India, the northern parts of South America, Malaysia, and Australia.
- The humid subtropical climate zone where winter rainfall (and sometimes snowfall) is associated with large storms that the westerlies steer from west to east. Most summer rainfall occurs during thunderstorms and from occasional tropical cyclones. Humid subtropical climates lie on the east side continents, roughly between latitudes 20 and 40 degrees away from the equator.
- A humid continental climate is marked by variable weather patterns and a large seasonal temperature variance. More than three months of average daily temperatures above 10 C (50 F) and a coldest month temperature below −3 C (27F) and which is not arid or semiarid climate.
- An oceanic climate is typically found along the west coasts at the middle latitudes of all the world's continents, and in southeastern Australia, and is accompanied by plentiful precipitation year round.
- The Mediterranean climate regime resembles the climate of the lands in the Mediterranean Basin, parts of western North America, parts of Western and South Australia, in southwestern South Africa and in parts of central Chile. The climate is characterized by hot, dry summers and cool, wet winters.
- A steppe is a dry grassland with an annual temperature range in the summer of up to 40 C and during the winter down to −40 C (−40F).
- A subarctic climate has little precipitation, and monthly temperatures which are above 10 C (50 F) for one to three months of the year, with permafrost in large parts of the area due to the cold winters. Winters within subarctic climates usually include up to six months of temperatures averaging below 0 C (32F)
- Tundra occurs in the far Northern Hemisphere, north of the taiga belt, including vast areas of northern Russia and Canada.
- A polar ice cap, or polar ice sheet, is a high-latitude region of a planet or moon that is covered in ice. Ice caps form because high-latitude regions receive less energy as solar radiation from the sun than equatorial regions, resulting in lower surface temperatures.
- A desert is a landscape form or region that receives very little precipitation. Deserts usually have a large diurnal and seasonal temperature range, with high or low, depending on location daytime temperatures (in summer up to 45 C or 113 F), and low nighttime temperatures (in winter down to 0 C or 32 F) due to extremely low humidity. Many deserts are formed by rain shadows, as mountains block the path of moisture and precipitation to the desert.

Leslie Holdridge's Life Zone Classification system



Brainstorm

- With your partner/group, brainstorm at least 10 ways in which destruction to the environment and depletion of resources can affect our overall well being as a population.

Environmental Sustainability

Natural resources: vital to human survival

substances and energy sources needed for survival

Renewable natural resources

- Sunlight
- Wind energy
- Wave energy
- Geothermal energy

- Fresh water
- Forest products
- Agricultural crops
- Soils

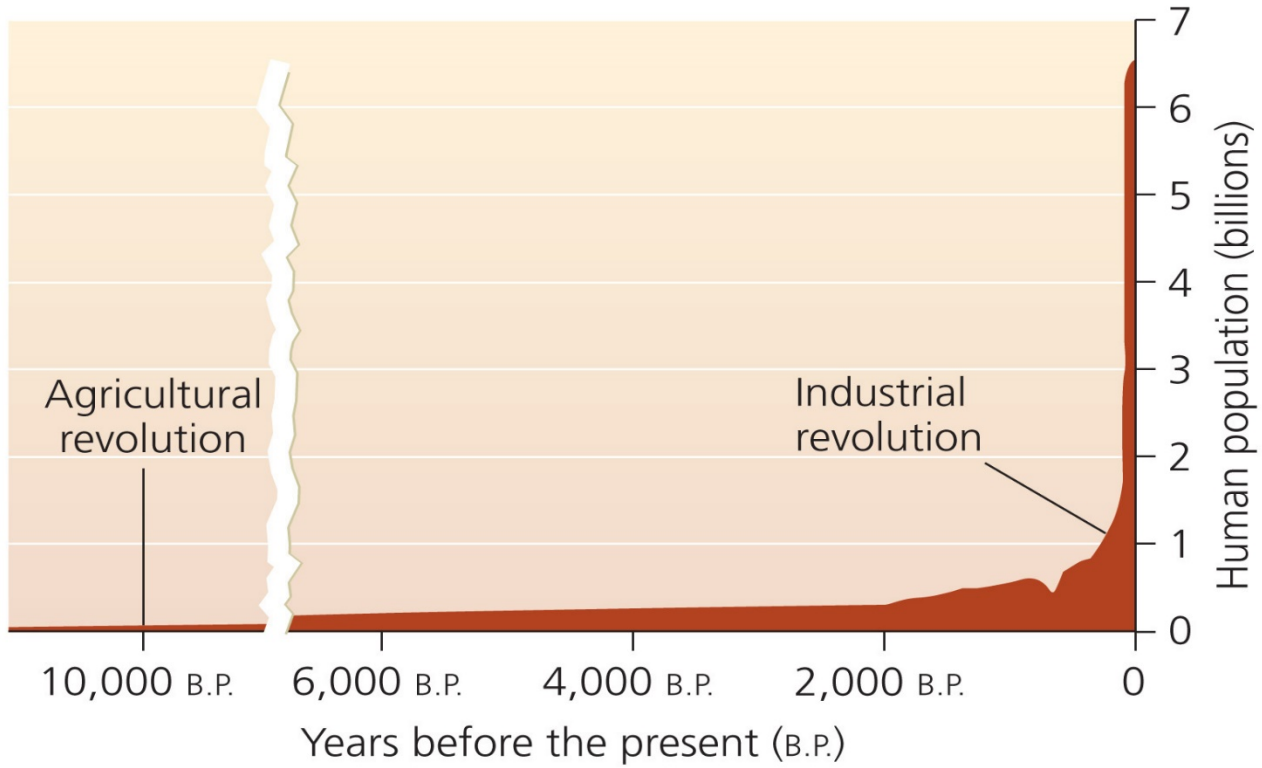
Nonrenewable natural resources

- Crude oil
- Natural gas
- Coal
- Copper, aluminum, and other metals

- **Perpetually available:** sunlight, wind, wave energy
- **Renewable over short periods of time:** timber, water, soil, wildlife?
    - These can be destroyed
- **Non-renewable resources:** Oil, coal, minerals
    - These can be depleted

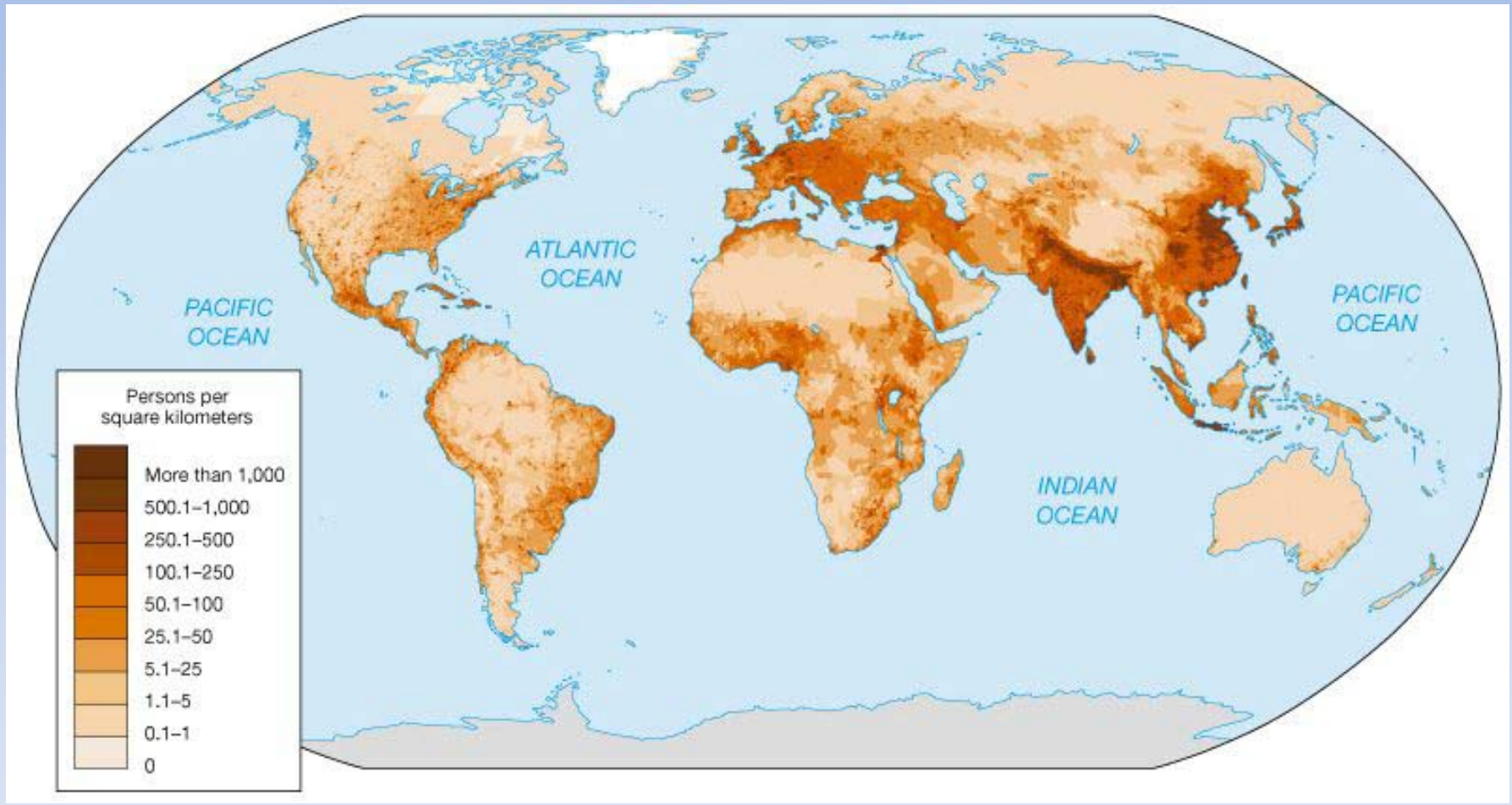
Global human population growth

- More than 6.7 billion humans
- Why so many humans?



(a) World population growth

World Population Distribution



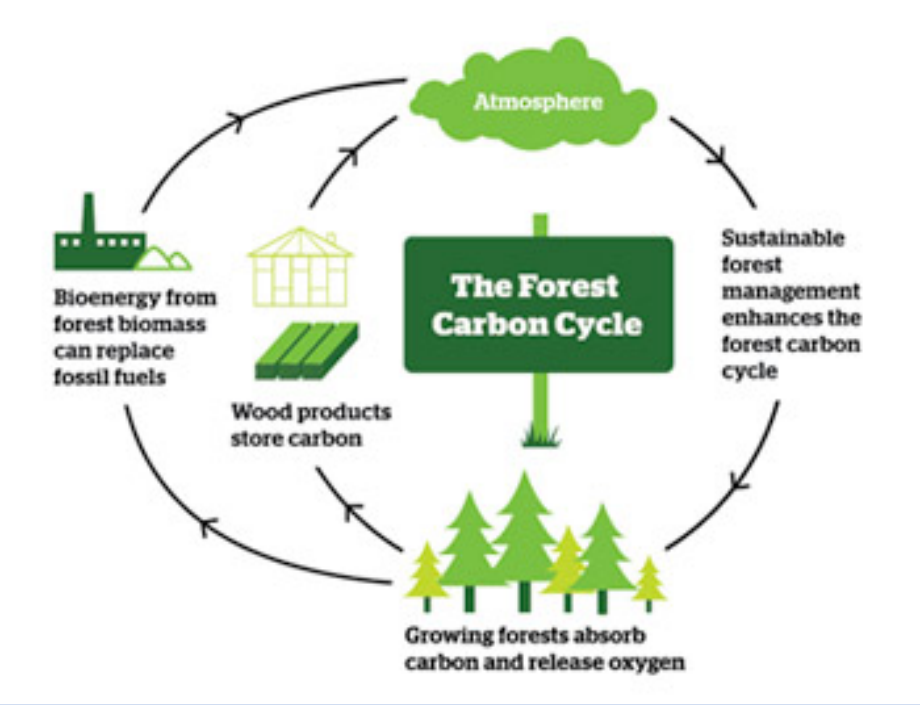
Sustainability: a goal for the future

- How can humans live within the planet's means?
- **Sustainability**
  - Leaves future generations with a rich and full Earth
  - Conserves the Earth's natural resources
  - Maintains fully functioning ecological systems
- **Sustainable development**: the use of resources to satisfy current needs without compromising future availability of resources

Nonrenewable Resources

- **Nonrenewable/Exhaustible Resources**
  - Exist in a fixed quantity in the earth's crust and can be used up
- **Mineral**
  - Any hard, usually crystalline material that is formed naturally
- **Reserves**
  - Known deposits from which a usable mineral can be profitably extracted at current prices

Nonrenewable Resources

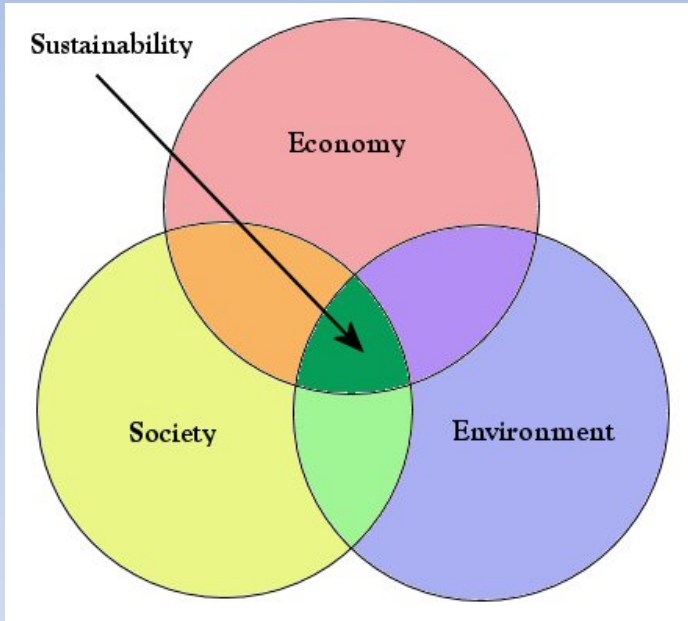


1. **Recycling**
   - Collecting and reprocessing a resource *into new products*
2. **Reuse**
   - Using a resource over and over *in the same form*

Will we develop in a sustainable way?

- The **triple bottom line**: sustainable solutions that meet
  - Environmental goals
  - Economic goals
  - Social goals

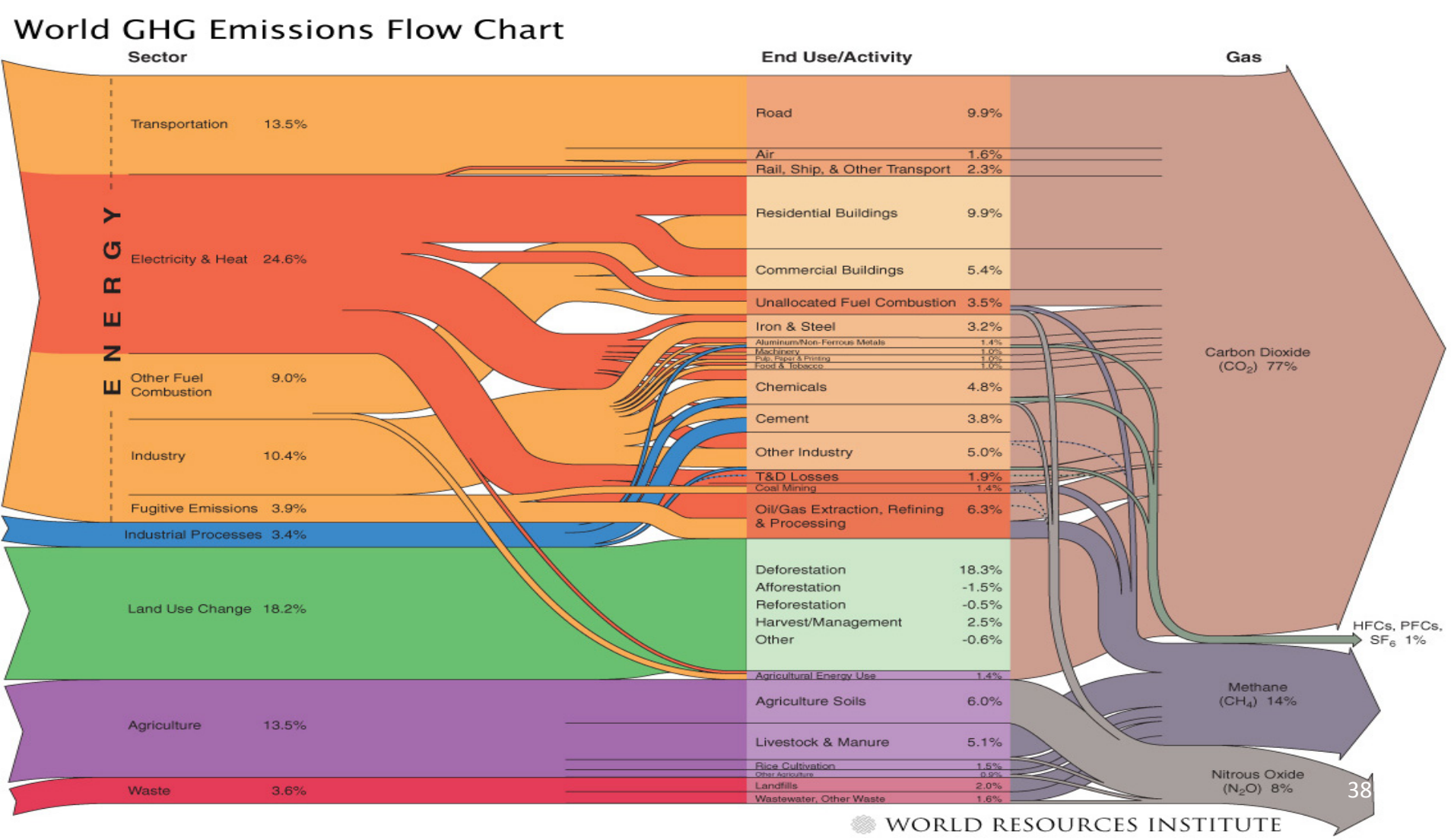
- Requires that humans apply knowledge from the sciences to
  - Limit environmental impacts
  - Maintain functioning ecological systems



Carbon Footprint

CO_2e

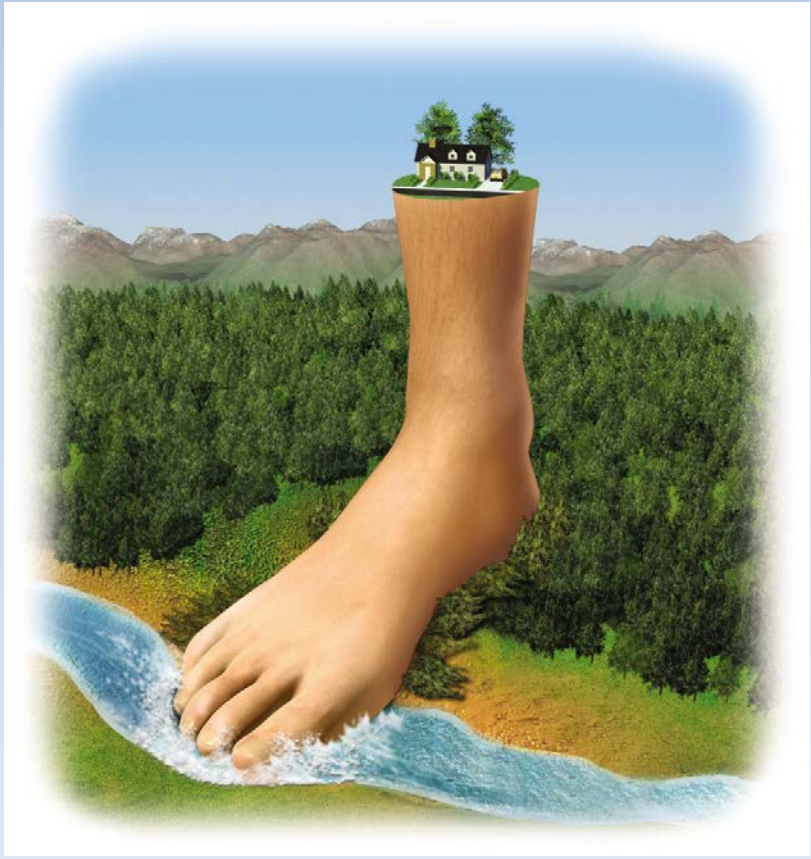
- Total climate change impact of all greenhouse gasses caused by item or activity



The “ecological footprint”

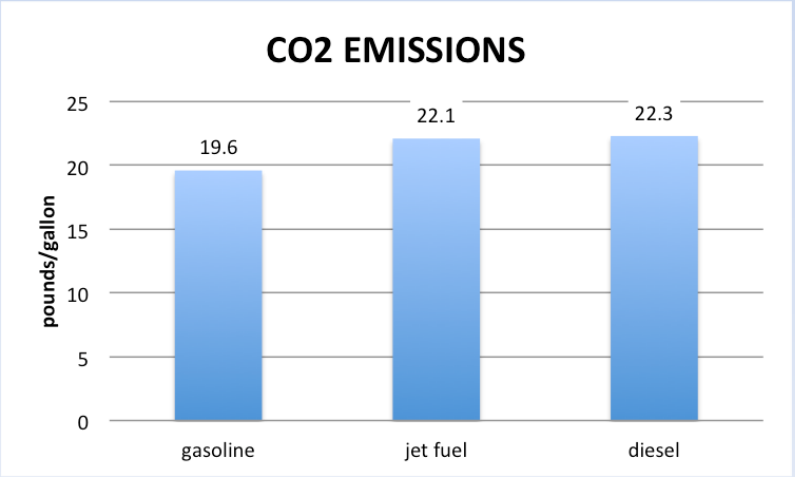
- The environmental impact of a person or population
  - Amount of biologically productive land + water
  - For resources and to dispose/recycle waste
- Overshoot: humans have surpassed the Earth’s capacity to support us

We are using 30% more of the planet’s resources than is available on a sustainable basis!



Direct vs. indirect emissions

- Direct emissions of an item
  - Manufacturing process
  - Transportation of item to retailer
- Indirect emissions
  - Everything else
  - Example: offices in the factory use paper clips made of steel that were mined and have their own carbon footprint

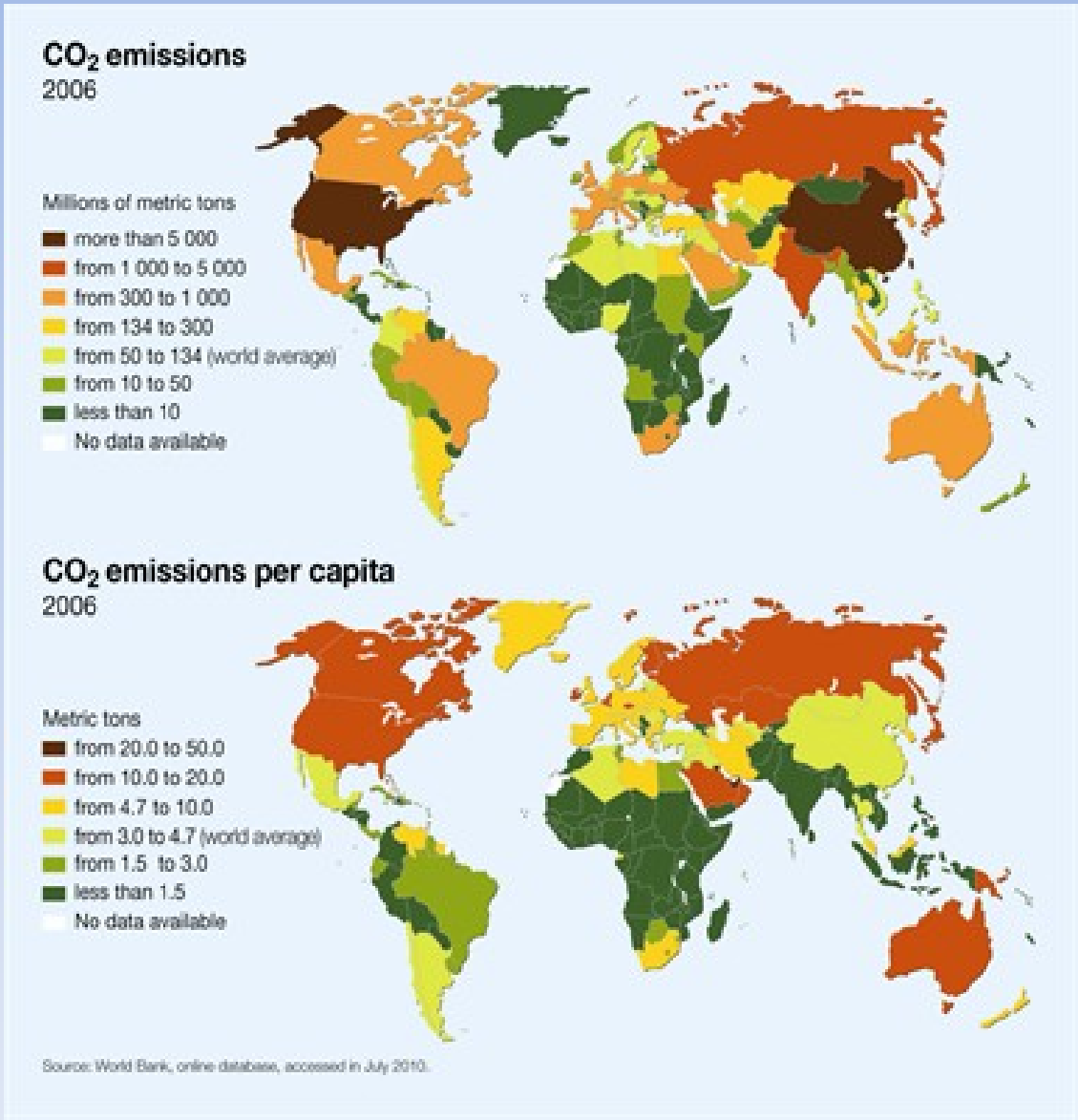


Context for numbers

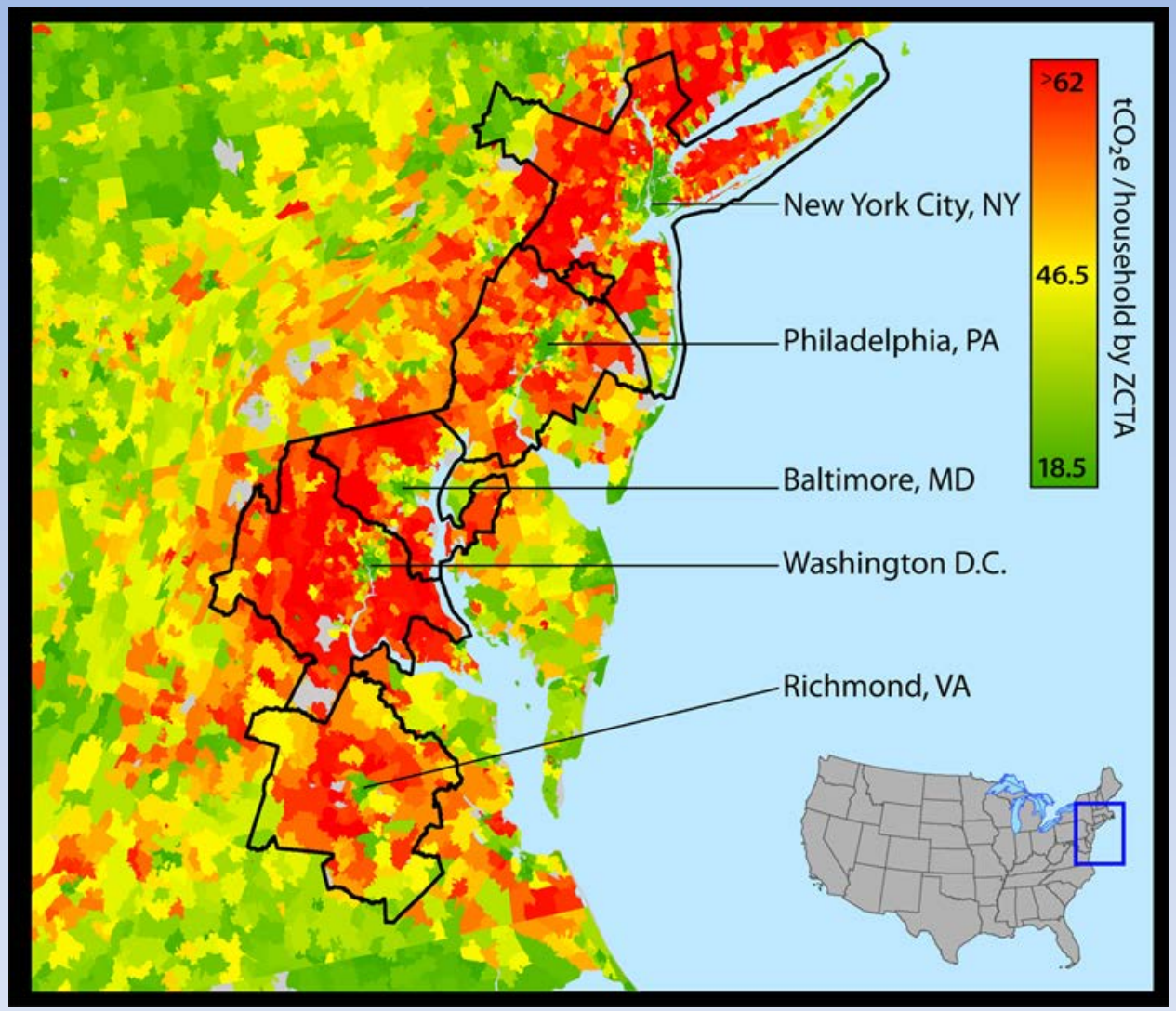
- 1 gram of CO2e would be produced if you burned a pea sized blob of gasoline
- 1 Kilogram (2 lbs) of CO2e would be produced if you burned 2 cups of gasoline
- 1 Ton of CO2e would be produced if you burned 60 gallons of gasoline

Context for numbers

- The average American has a carbon footprint of 28 tons CO2e / year
- World GHG emissions are 34 Gt CO2e / year
- The global average carbon footprint is ~6 tons CO2e / year / person



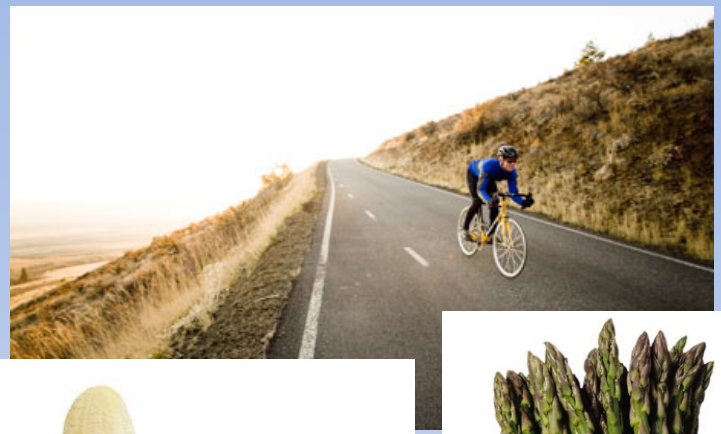
Carbon Footprint



http://coolclimate.berkeley.edu/carboncalculator

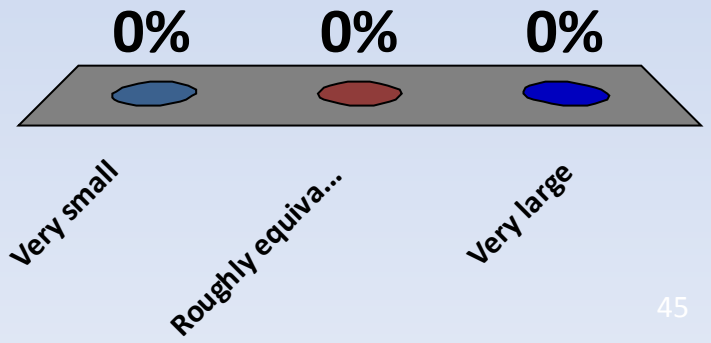
Cycling a mile

- Powered by bananas
  - 65g CO2e
- Powered by cereals with milk
  - 90g CO2e
- Powered by bacon
  - 200g CO2e
- Powered by cheeseburgers
  - 260g CO2e
- Powered by air-freighted asparagus
  - 2,800g CO2e
  - A hummer has a lower carbon footprint per mile



The carbon footprint of manufacturing a new car is _____ compared to the carbon footprint of driving that car over its lifetime

1. Very small
2. ✓ Roughly equivalent
3. Very large



Walking through a door

- Automatic door
  - 6.5 feet wide by 8 feet high
  - Stays open for 18 seconds
- Power from electric motors to open door is 1 g CO2e
  - If the temperature inside is equal to that outside then this is the entire carbon footprint
  - If it's cold outside (say 20 f) then the footprint jumps to 84 g CO2e because of the energy required to heat that air

Bananas

- Bananas have very low carbon footprints compared to other foods
  - Grown in natural sunlight (not in a heated greenhouse)
  - They don't spoil quickly
    - So instead of shipping them by plane, you can ship them by boat (1% the carbon footprint of flying)
  - No packaging
- Total = 80 g CO_2e if shipped from across the world

- San Francisco to LA and back (~800 miles)
  - Banana powered bike
    - 53 kg (117 lbs) CO2e
  - Bus
    - 66 kg (146 lbs) CO2e
  - Small efficient car
    - 330 kg (728 lbs) CO2e
  - Plane
    - 500 kg (1,100 lbs) CO2e
  - Large SUV
    - 1,100 (2,530 lbs) CO2e




A forest fire

- 2008 California forest fires
  - 231 million tons CO2e
- A certain portion of the carbon releases will be taken back over time as the forest re-grows

A bottle of water

- Most emissions come from packaging and transport
  - 80 g CO2e just from the plastic

A bottle of water

- Locally sourced and using local distribution
  - 110 g CO2e
- Traveling 600 miles by road
  - 215 g CO2e
- Bottled water is 1000X more carbon intensive than tap water
- The world consumes 53 billion gallons of bottled water a year which accounts for 1/6th of a percent of TOTAL world GHG emissions

Deforestation

- 32 million acres of rainforest are cleared per year
  - 17 percent of all human emissions
- Why?
  - 35-45% Small farms
  - 20-25% for cattle grazing
  - 15-20% Intensive agriculture
  - 10-15% logging
  - ~5% other (urbanization, mining, roads, ect.)

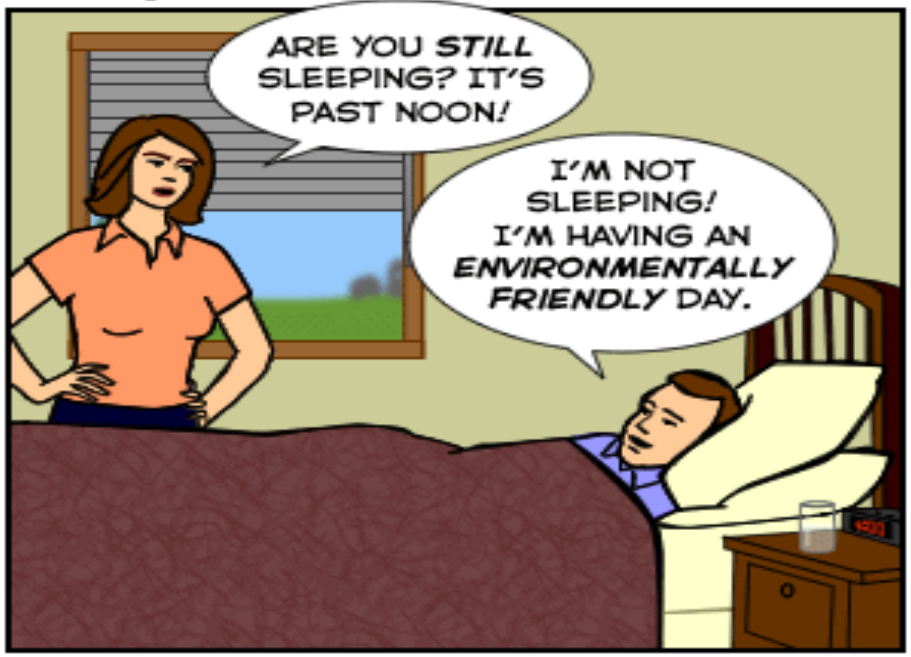
Using a cell phone

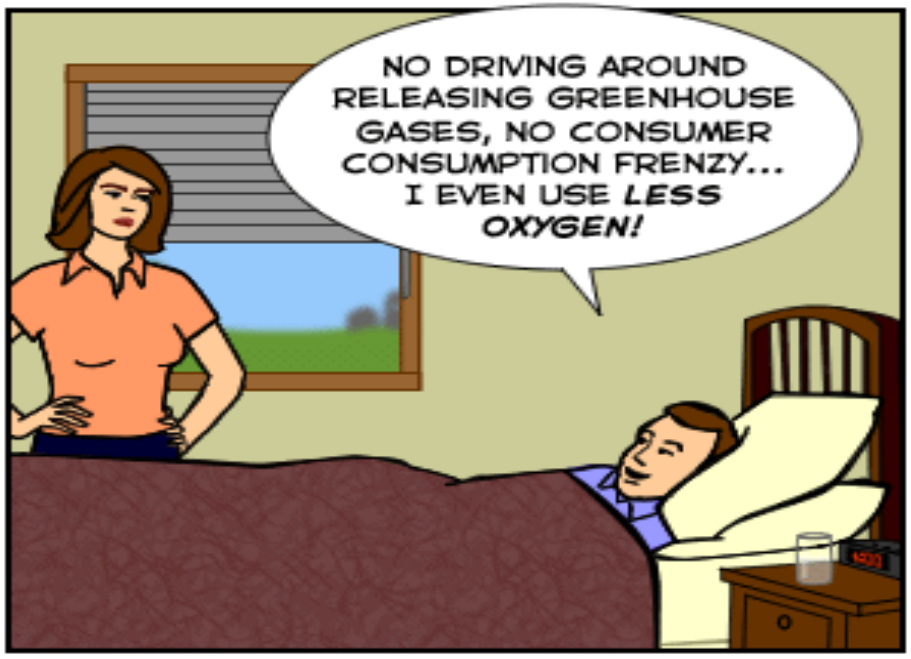
- As of 2009 there were 2.7 billion cell phones in use (almost half the world)
- Cell phone calls account for about 125 million tons CO2e
  - $1/4^{th}$ of a percent of global emissions
- Texting is a much lower carbon option

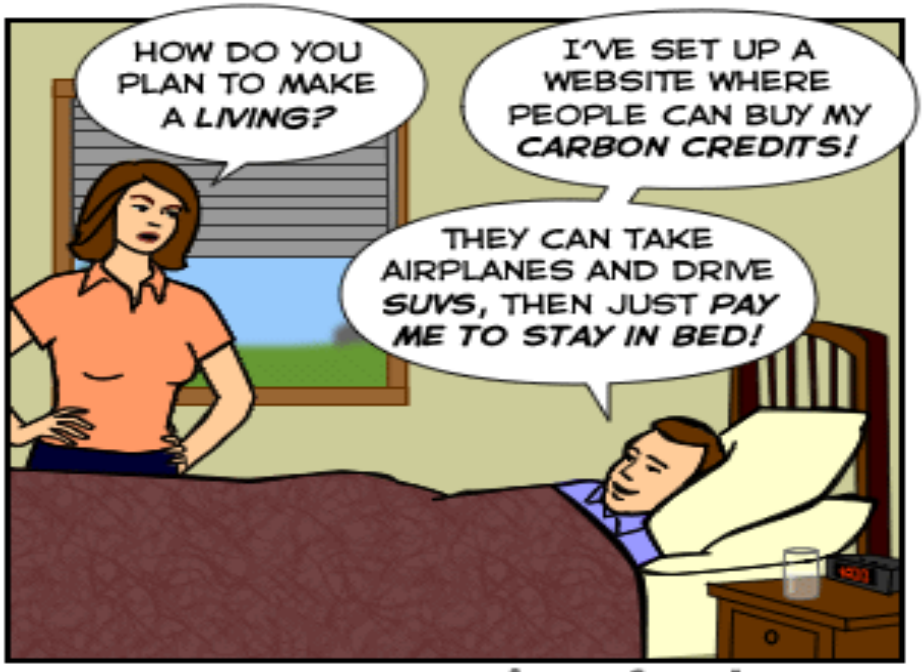
Using a cell phone

- A year's typical usage of just under 2 minutes per day
  - 47 kg (103 lbs) CO2e
- A year's usage of 1 hour per day
  - 1,250 kg (2,760 lbs) CO2e

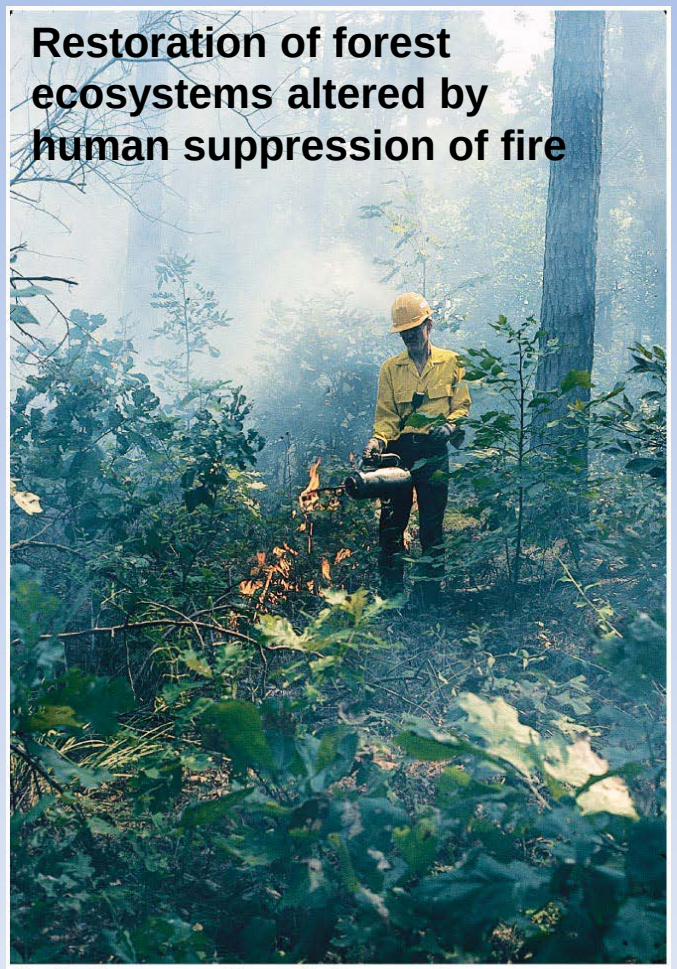
by Nitrozac & Snaggy







Policy decisions and management practices

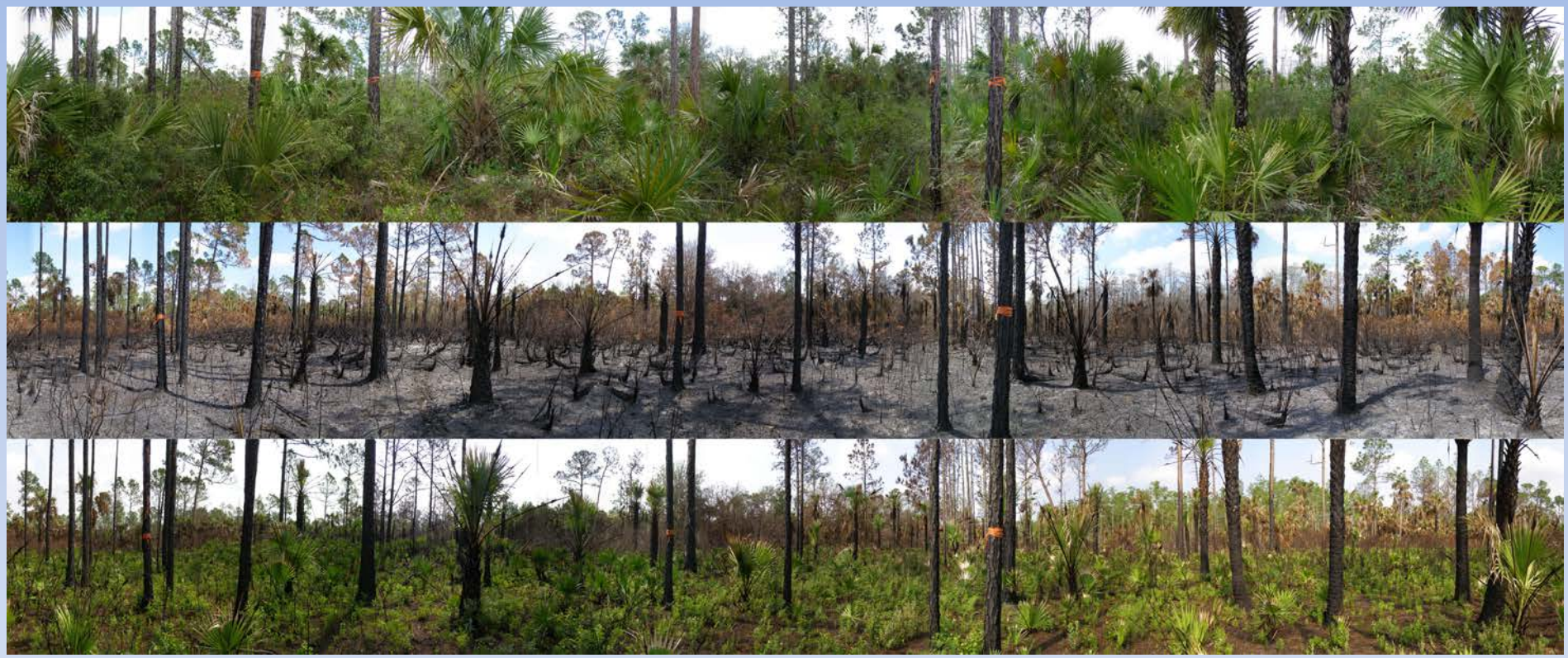


(a) Prescribed burning

Technology

(b) Methanol-powered fuel-cell car

Energy-efficient methanol-powered fuel cell car from DaimlerChrysler

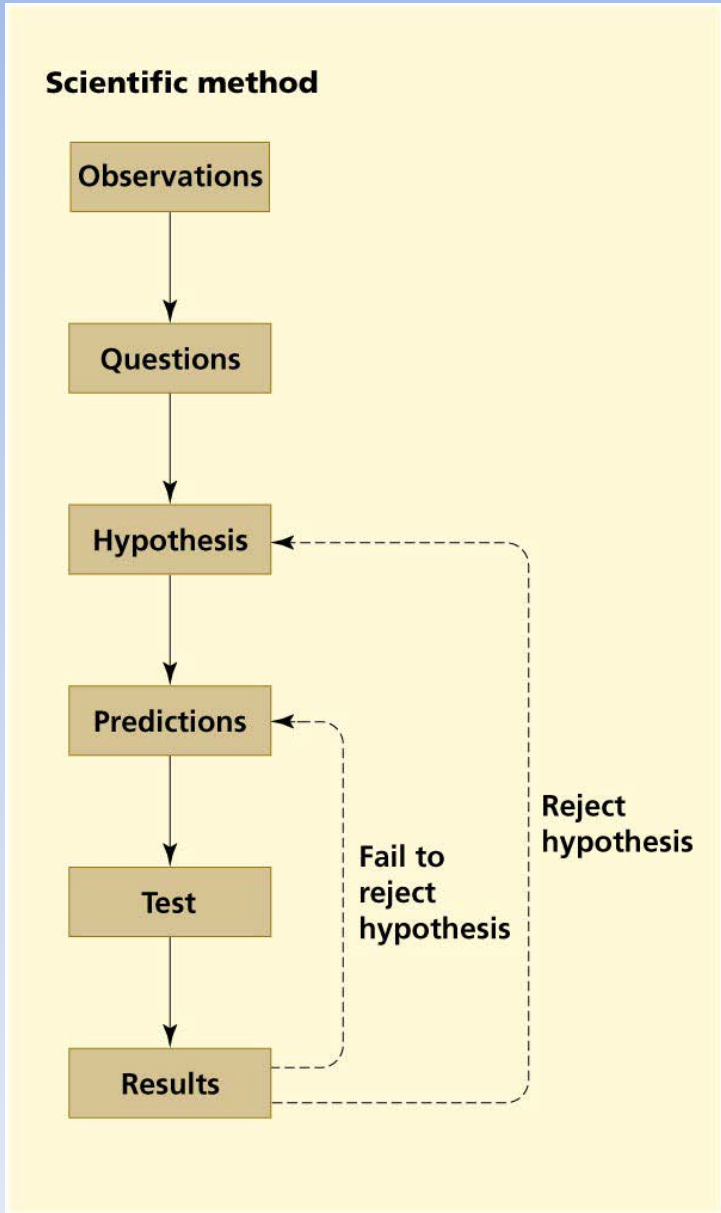


Will we develop in a sustainable way?

- ***This is the single most important question we face.***

The scientific method

- A technique for testing ideas
- A scientist makes an observation and asks questions of some phenomenon.
- The scientist formulates a hypothesis, a statement that attempts to answer the question.
- The hypothesis is used to generate predictions: specific statements that can be tested.
- The results support or reject the hypothesis.



Testing predictions

- **Experiment**: an activity that tests the validity of a hypothesis
- **Variables**: conditions that can be manipulated and/or measured
  - **Independent variable**: a condition that is manipulated
  - **Dependent variable**: a variable that is affected by the manipulation of the independent variable
- **Controlled experiment**: one in which all variables are controlled
  - **Control**: the unmanipulated point of comparison
  - **Treatment**: the manipulated point of comparison
- **Data**: information (more correctly facts) that is (are) generally quantitative (numerical)

Math Experiment

- You are given 2 global datasets in Excel format:
  - CO2 emissions (metric tons per capita) 1995 – 2010
  - Agricultural land (% of land area) from 1961 – 2012
- Ranked top 10 countries those produces higher amount of CO2 per capita
- Find 10 countries those increases agriculture land and 10 countries those decreases agriculture land
- Ranked top 10 countries those produces less amount of CO2 per capita.
- Is there any relation to GDP/capita with CO2 emission?