Earth System
and
APES Overview

The Earth System

(system = interacting components)

•• Simple Global System Perspective ••

<u>abiotic components</u>

geosphere
hydrosphere
atmosphere

- developed > 4 billion years ago
- interactions among spheres (matter cycling)
- energy input to drive matter cycling
- spheres evolved chemically and physically over time to become a life support system

<u>biotic component</u>

biosphere

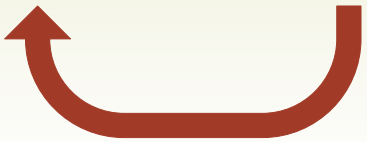
- biosphere affected by evolution and extinction events
- first cells ~ 3.5 billion years ago
- first complex organisms ~ 500 million years ago
- first humans ~ 200,000 years ago

The Earth System

•• More Complex System Perspective ••

Numerous and diverse ecosystems (subsystems in global system)
Many factors involved in cause →effect

- interactions can be "synergistic"
  cause x → effect x
  cause y → effect y
  but cause (x+y) → effect >>> (x+y)
- there may be a "time delay"
  cause → → → → effect
- there may be feedback mechanisms
  cause → effect 1 → effect 2



"positive feedback mechanism"
enhances previous effect
"negative feedback mechanism"
reduces previous effect

The Earth System

"MATTER" has mass and volume

Law of Conservation of Matter

- matter is not created or destroyed
- matter can change from one physical or chemical state to another

The Earth System

"ENERGY" is the ability to do work

Laws of Thermodynamics

1st Law

- energy is not created or destroyed
- energy can be converted from one form to another

2nd Law

- in every energy conversion, some portion of input energy is degraded to less useful energy (thermal energy)

The Earth System

"ENERGY" is the ability to do work

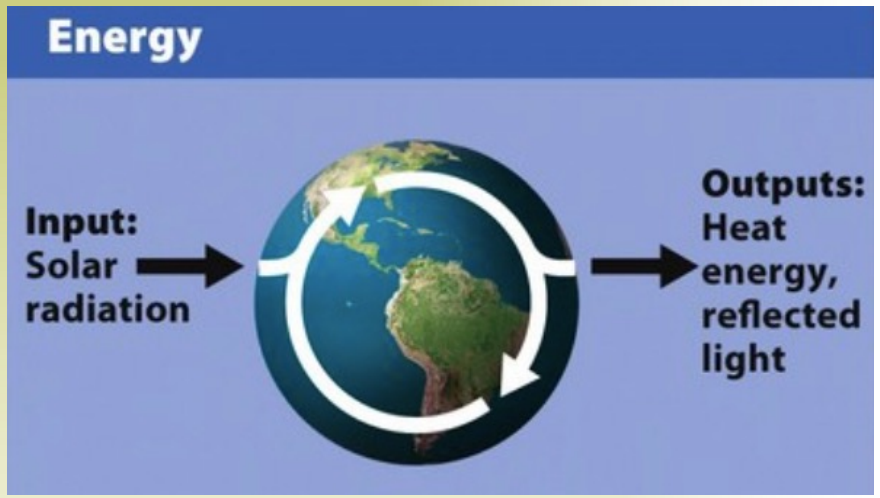
The 2nd Law of Thermodynamics indicates no process can be 100% efficient (convert all energy input to useful energy output).

Efficiency can be calculated: $\%\ \text{efficency} = \frac{\text{useful energy out}}{\text{energy in}} (100)$

Example: Light bulbs convert electricity to visible light energy. An incandescent (glowing filament) bulb emits 95 J of heat for every 100 J of electricity used. What is the efficiency of the bulb?

$$\%\ \text{eff} = \frac{\text{useful energy out}}{\text{energy in}} (100) = \frac{95\ \text{J}}{100\ \text{J}} (100) = 95\%\ \text{efficiency}$$

The Earth System



The present day Earth system is <u>CLOSED TO MATTER</u>

- NO significant input or output of matter
- all matter is cycled

(also means that nothing can actually be thrown away)

The present day Earth system is <u>OPEN TO ENERGY</u>

- YES significant input and output of energy
- energy flows through

The Earth System

Before humans:

•• "Balance of Nature" in matter cycling and energy flow ••

"natural capital"
- natural wealth (ex. air, water, soil) that supports/maintains system
- provides food, drink, habitat, protection ("ecosystem services")

"natural debits"
- depletes/degrades capital (ex. eating, food waste, bodily waste)

"natural income"
- replenishes capital (ex. plant regrowth, waste decomposition)

The Earth System

"Sustainability"

- biosphere surviving on the income that replenishes the debits, without decreasing the capital
- maintains "healthy ecosystems"

The Earth System

•• Humans affect the Balance of Nature ••

Use matter and energy as "natural resources"

- for much more than just food, water, protection
- both "renewable" and "nonrenewable" resources

income > debits means resources are replenished faster than they are used

debits > income means resources are used faster than they are replenished

Produce much more byproduct than biodegradable waste

- pollution and degradation of environment
- progressively more "unhealthy ecosystems"

The Earth System

Why do humans deplete resources/degrade environment?

Value economic growth

- increased population provides consumers
- increased consumption as a whole and per capita

The Earth System

Per capita consumption and waste globally unbalanced

- highest in "developed countries" (approx. 20% of pop.)
  - fully industrialized, high per capita GNP
  - U.S., Canada, E.U., Japan, Australia, New Zealand
- "developing countries"
  - some moderately developed, some undeveloped
  - includes two most populous countries:
    China (1.4 billion) and India (1.3 billion)
    together nearly 40 % of world population
    (U.S. is 3rd population 325 million ~ 5% of world)

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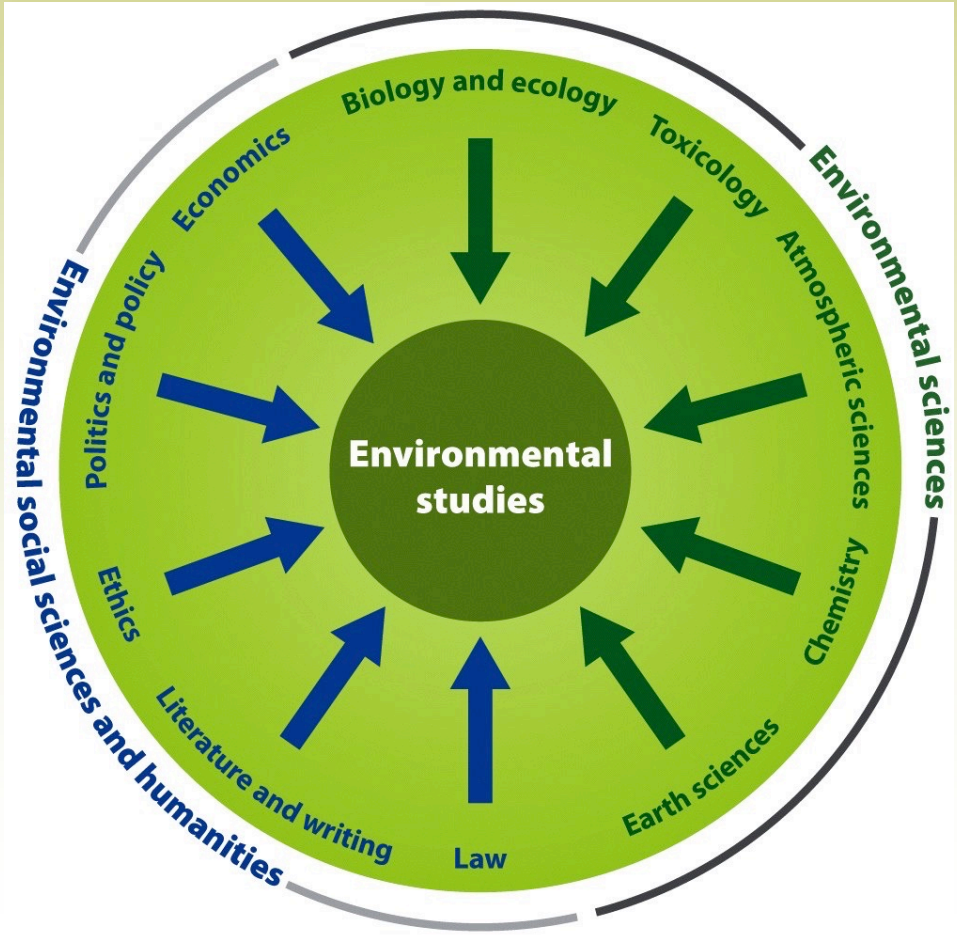
Environmental Science is now a major interdisciplinary field of study



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How to determine the "health" of ecosystems? Some common "Environmental Indicators":

Environmental indicator	Unit of measure	Chapter where indicator is discussed
Human population	Individuals	7
Ecological footprint	Hectares of land	1
Total food production	Metric tons of grain	11
Food production per unit area	Kilograms of grain per hectare of land	11
Per capita food production	Kilograms of grain per person	11
Carbon dioxide	Concentration in air (parts per million)	19
Average global surface temperature	Degrees centigrade	19
Sea level change	Millimeters	19
Annual precipitation	Millimeters	4
Species diversity	Number of species	5, 18
Fish consumption advisories	Present or absent; number of fish allowed per week	17
Water quality (toxic chemicals)	Concentration	14
Water quality (conventional pollutants)	Concentration; presence or absence of bacteria	14
Deposition rates of atmospheric compounds	Milligrams per square meter per year	15
Fish catch or harvest	Kilograms of fish per year or weight of fish per effort expended	11
Extinction rate	Number of species per year	5
Habitat loss rate	Hectares of land cleared or "lost" per year	18
Infant mortality rate	Number of deaths of infants under age 1 per 1,000 live births	7
Life expectancy	Average number of years a newborn infant can be expected to live under current conditions	7

APES Overview

•• Five key GLOBAL Environmental Indicators ••

Indicator	Recent trend	Outlook for the future	Overall impact on environmental quality
Biological diversity	Large number of extinctions, extinction rate increasing	Extinctions will continue	Negative
Food production	Per capita production possibly leveling off	Unclear	May affect the number of people Earth can support
Average global surface temperature and CO_2 concentration	CO_2 concentrations and temperatures increasing	Probably will continue to increase, at least in the short term	Effects are uncertain and varied but probably detrimental
Human population	Still increasing, but growth rate slowing	Population leveling off; resource consumption rates also a factor	Negative
Resource depletion	Many resources being depleted at rapid rate, but human ingenuity develops "new" resources, and efficiency of resource use is increasing in many cases	Unknown	Increased use of most resources has negative effects

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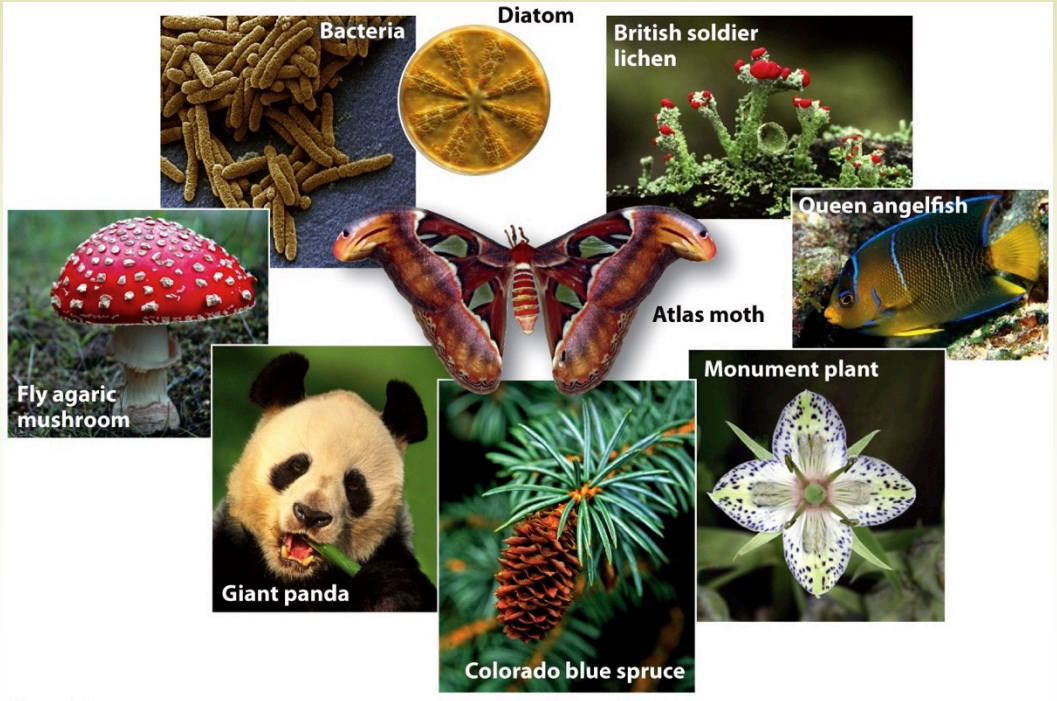
•• Five <u>key GLOBAL</u> Environmental Indicators ••

<u>Biodiversity</u>: total number of species

- affected by ecosystem diversity
- dependent on genetic diversity



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•• Five key GLOBAL Environmental Indicators ••

Biodiversity: current extinction rate up to 1000x natural rate

(a)

(b)

(c)

(d)

Humans have saved some species from the brink of extinction

a) American bison
b) peregrine falcon

Others species continue to decline toward extinction

c) snow leopard
d) West Indian manatee

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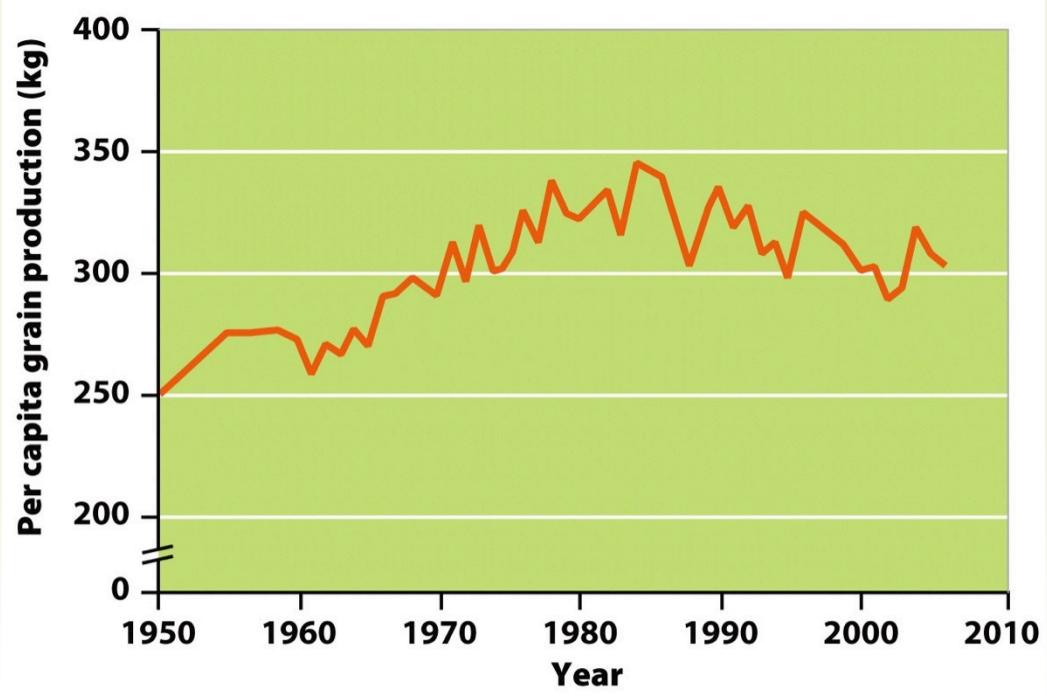
•• Five key GLOBAL Environmental Indicators ••

Food Production: "yield" = amount produced
increased through time until recently
not keeping up with population growth



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•• Five key GLOBAL Environmental Indicators ••

Food: meat production is source of major degradation

- U.S. 10 billion animals killed per year (world 65 billion)
- U.S. 70% of grain production is fed to livestock

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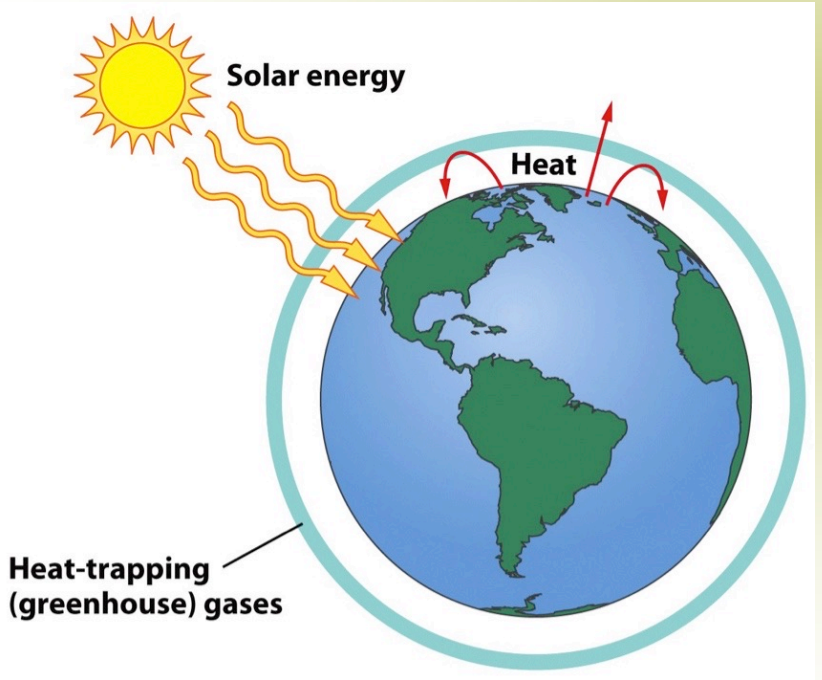
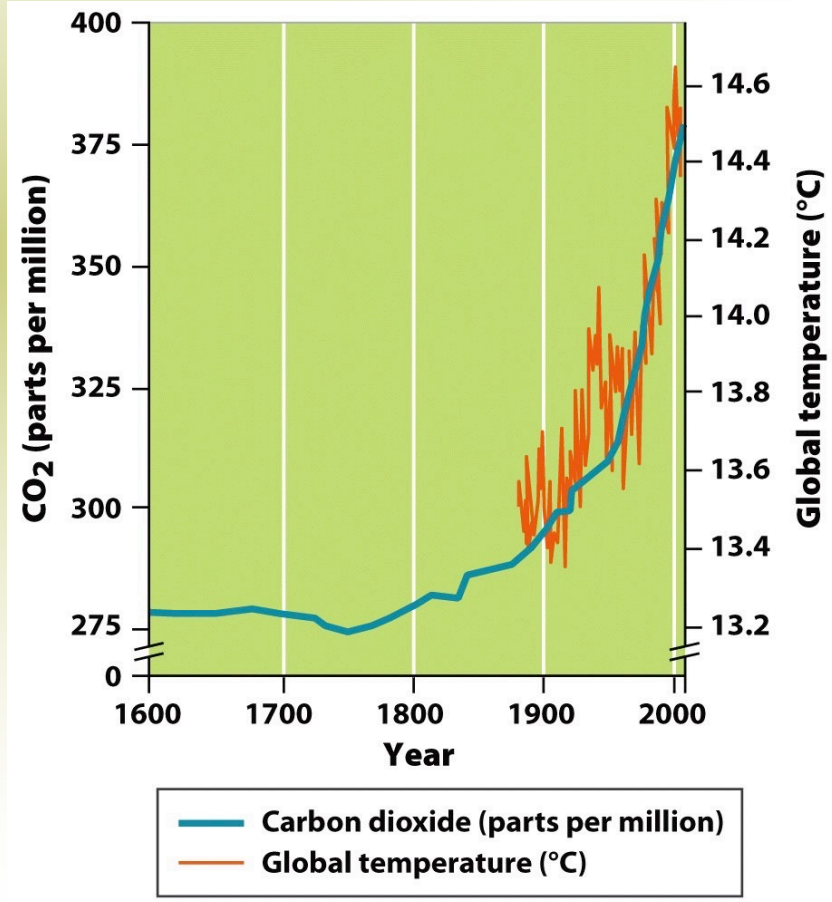
•• Five <u>key GLOBAL</u> Environmental Indicators ••

<u>Climate</u>: "anthropogenic" CO_2 causing global warming





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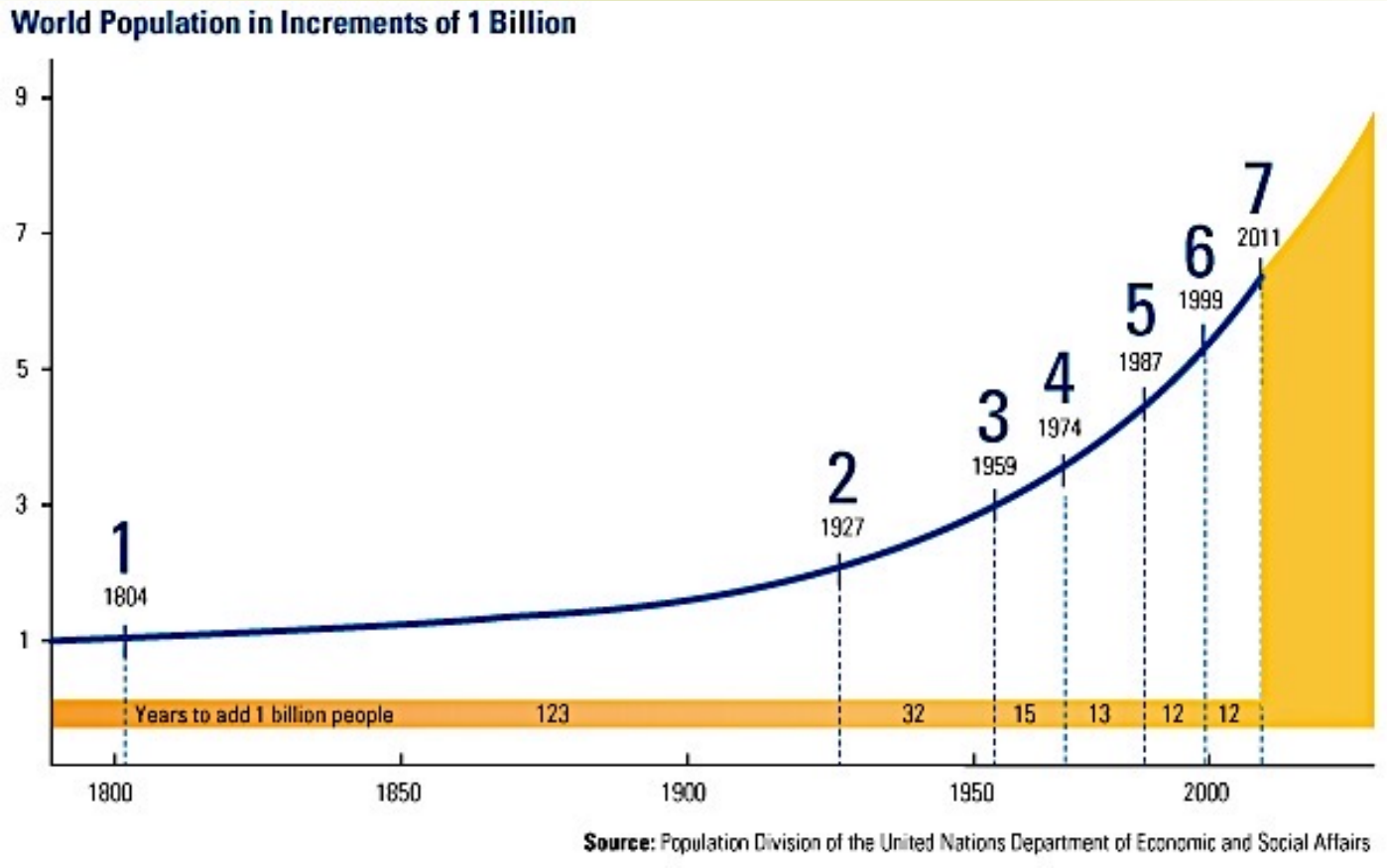
•• Five key GLOBAL Environmental Indicators ••

Population: over 7 billion humans, doubled since 1960s



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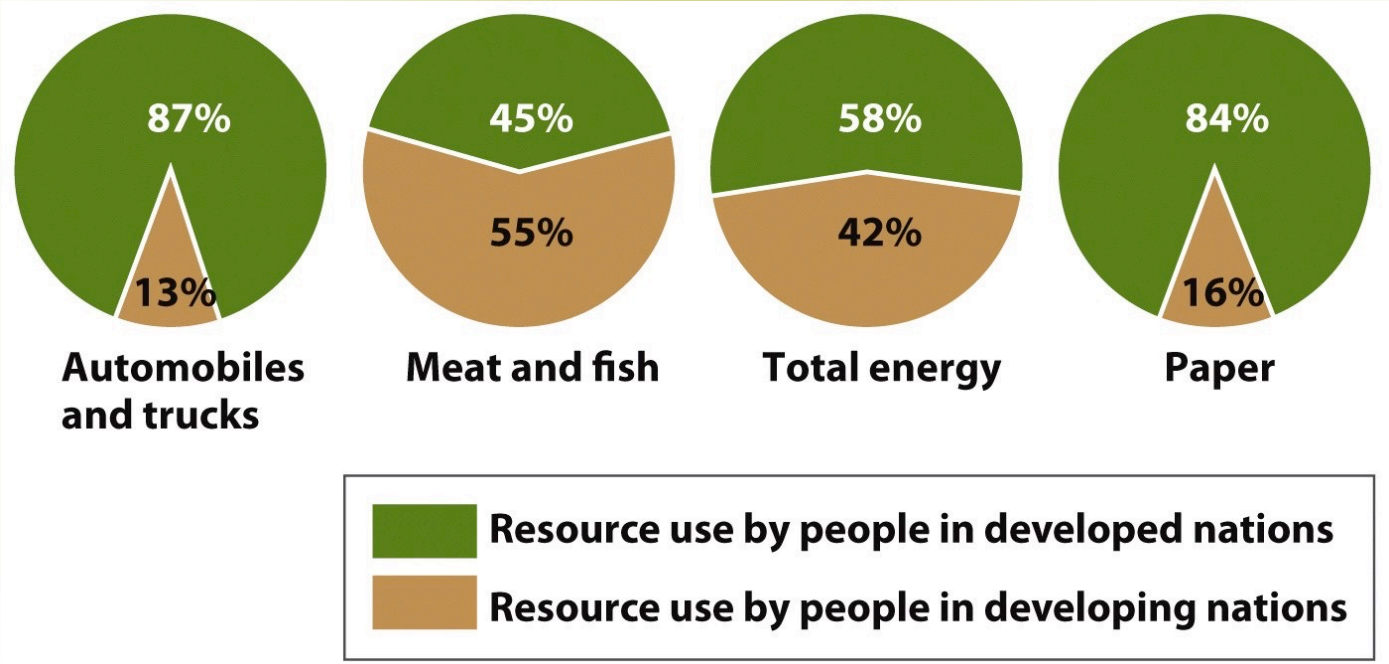
•• Five key GLOBAL Environmental Indicators ••

Resource Depletion: Finite resources have finite life

- 20% of population: most resource use, most waste
- add environmental damage from resource extraction



Earth System Practice!

Some questions are easy and some are "thinkers" based on your reading

1. Environmental indicators
   a. always tell us what is causing an environmental change
   b. are useful only when studying large-scale changes
   c. can be used to analyze the health of natural systems
   d. do not provide information regarding sustainability
   e. take into account only the biotic component of ecosystems

2. Human population today is closest to
   a. 3 billion b. 5 billion c. 6 billion d. 7 billion e. 12 billion

3. Economic development goes hand in hand with
   a. decreased use of nonrenewable resources
   b. increased consumption of resources
   c. smaller more efficient living styles
   d. better planting strategies for crops
   e. sustainable use of renewable resources

Earth System Practice! (cont.)

4. The populations of some endangered animal species have stabilized or increased in numbers after human intervention. An example of a species that is still endangered and needs further assistance to recover is the
   a. American bison
   b. snow leopard
   c. bald eagle
   d. American alligator
   e. peregrine falcon

5. The following are non-renewable resources except
   a. aluminum b. oil c. coal d. copper e. timber

6. The concentration of carbon dioxide in the atmosphere
   a. has not significantly changed in the past 200 years
   b. is increasing due to anthropogenic input
   c. is decreasing as deforestation increases
   d. has been decreasing since the 1800's
   e. cycles between 300 ppm and 400 ppm each decade

Earth System Practice! (cont.)

7. All of the following would be exclusively caused by anthropogenic activities except
   a. corn plants modified with a bacterial gene to resist herbicide spray
   b. forest fire spreading by winds
   c. forest clearing for crops
   d. atmospheric soot from burning gasoline
   e. mining uranium

8. Which statement regarding a global environmental indicator is not correct?
   a. atmospheric CO_2 has been increasing steadily since the Industrial Revolution
   b. world grain production has increased fairly steadily since 1950, but global production of grain per capita has decreased dramatically over the same period
   c. over the past 130 years, average global surface temperatures have shown an overall increase that seems likely to continue
   d. world population is expected to be between 8 billion and 10 billion by 2050
   e. some natural resources are in finite amounts and consumed during a one-time use, whereas other finite resources can be used multiple times through recycling

Earth System Practice! (cont.)

9. U.S. meat production has become industrialized in the U.S. and subsidized by the government in order to supply the largest purchasers of meat – the fast food industry. As a consequence, all of the following are true except
   a. each livestock species is bred to be the same size because the slaughter is mechanized
   b. In the U.S., more animals are killed each year than there are humans on the planet
   c. in the U.S., over 2/3 of grain production is fed to livestock
   d. meat production is the source of major environmental degradation
   e. antibiotics are no longer in livestock feed because most animals are free range now

10. Earth is essentially an open system for
    a. matter b. energy c. matter & energy d. neither matter nor energy

11. Of the following, which is not an ecosystem service provided by soil?
    a. soil bacteria decompose body waste and dead organisms
    b. soil acts as a water filter for rainwater as it seeps into the soil
    c. soil is the medium to support the base of the food chain
    d. soil is carried by runoff into streams in areas of deforestation
    e. soil provides habitat for worms, larvae, insects, and fungi

Earth System Practice! (cont.)

12. Consider a power plant that uses natural gas as a fuel to generate electricity. If there are 10,000 J of chemical energy contained in a specified amount of natural gas, then the amount of electricity that could be produced would be
    a. greater than 10,000 J because electricity has higher energy quality than natural gas
    b. can fluctuate to greater or less than 10,000 J depending on demand
    c. greater than 10,000 J because of the positive feedback loop of waste heat
    d. something less than 10,000 J, depending on the efficiency of the generator
    e. equal to 10,000 J because energy cannot be created or destroyed
13. An automobile with an internal combustion engine converts the potential energy of gasoline (40 MJ/kg) into the kinetic energy of the moving pistons. If the average internal combustion engine is 20 percent efficient and 4 kg of gasoline is combusted, how much potential energy is converted into energy to run the pistons?
    a. 160 MJ
    b. 32 MJ
    c. 8 MJ
    d. depends on the capacity of the gas tank
    e. depends on the size of the engine