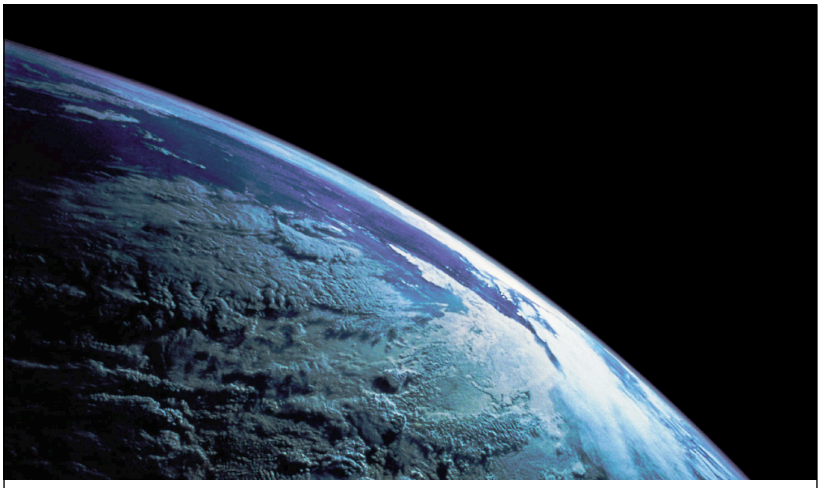


Chapter 2: Science, Matter, Energy, and Systems

APES 2013

1

Scientific Method

- Identify Problem
- Primary Research
- Ask Question
- Gather Data
- Hypothesis (testable)
- Keep testing and make observations
- Accept or Reject Hypothesis
- Share Results/Peer Review

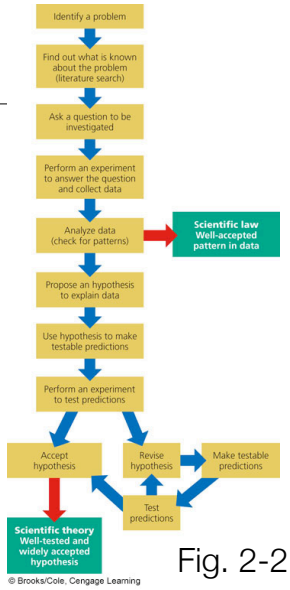
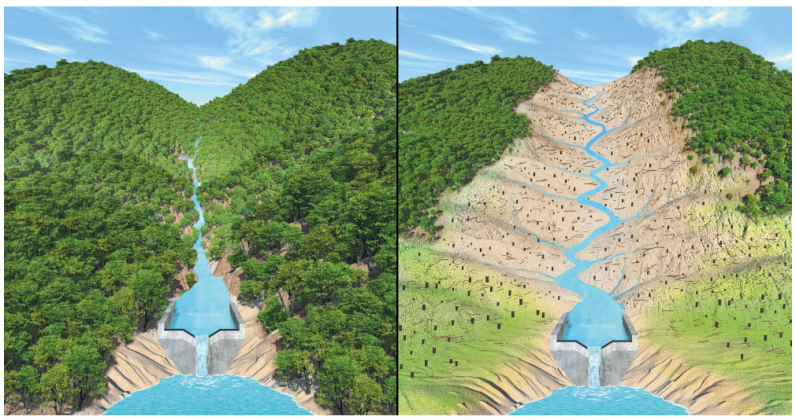


Fig. 2-2

2

Example: Deforestation effects on water and nutrient loss

Fig. 2-1



3

Revising a Hypothesis

- Easter Island was thought to have settlers 2,900 years ago and the maximum population was thought to be around 15,000 people.
- It was thought that the inhabitants overused resources (trees) until they were completely depleted.
- Newer models suggest that the first settlers did not appear until about 800 years ago and that their numbers never exceeded 3,000 individuals.
- It is still clear they deforested the island, but not why trees have still not grown back. It is now thought that rats brought along on ships multiplied on the island and ate the seeds, thus rendering the trees extinct on that island.

4

Scientific Reasoning

- Inductive Reasoning - using specific observations and measurements to arrive at a general conclusion or hypothesis
- Deductive Reasoning - using logic to arrive at a specific conclusion based on generalization.
- Overwhelming amount of observations and measurements that support a hypothesis causes it to become a theory.
- Scientific Law (Law of Nature) - well-tested and widely accepted explanation of what we find happening over and over again in the same way in nature
- Paradigm Shift - when new discoveries and new ideas can overthrow a well-accepted scientific theory or law

5

How can you tell if scientific findings are reliable?

- Ask yourself the following questions:
  - Was the experiment well designed? Did it involve enough testing? Did it involve a control group?
  - Have the data supporting the proposed hypotheses been verified? Have the results been reproduced by other scientists?
  - Do the conclusions and hypotheses follow logically from the data?
  - Are the investigators unbiased in their interpretations of the results? Are they free of hidden agenda? Were they funded by an unbiased source?
  - Have the conclusions been verified by impartial peer review?
  - Are the conclusions of the research widely accepted by other experts in this field?

6

Matter

- Matter - anything that has mass and takes up space
  - Matter is made up of elements
- Elements - a fundamental substance that has a unique set of properties and cannot be broken down into simpler substances by chemical means (ex. Gold or silver)
- Compounds - combinations of two or more elements held together in fixed proportions (ex. water or sodium chloride)

Table 2-1

Elements Important to the Study of Environmental Science

Element	Symbol	Element	Symbol
Hydrogen	H	Bromine	Br
Carbon	C	Sodium	Na
Oxygen	O	Calcium	Ca
Nitrogen	N	Lead	Pb
Phosphorus	P	Mercury	Hg
Sulfur	S	Arsenic	As
Chlorine	Cl	Uranium	U
Fluorine	F		

Atoms

- Atom - most basic building block of matter, made up of subatomic particles
  - Subatomic particles:
    - Protons - found in nucleus, positive charge
    - Neutrons - found in nucleus, neutral charge
    - Electrons - outside of nucleus, negative charge
- Atomic theory - idea that all elements are made up of atoms

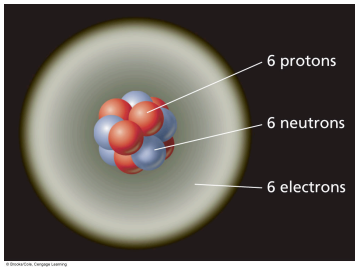


Fig. 2-3

Atoms (con.)

- Each elements has a unique atomic number (number of protons in the nucleus) (Ex. Carbon has 6 protons and its atomic number is 6)
- Atomic mass combines the protons, neutrons, and electrons (Ex. Carbon has 6 protons and 6 neutrons, so its mass number is around 12 because electrons have very, very small mass)
- Isotopes - forms of an element having the same atomic number, but different mass numbers (Ex. Carbon-14 has two extra neutrons)
- Ions - atom or small group of atoms with one or more positive or negative charges. Form from the gain or loss of electrons.
  - Cation = positive charge (Al^{3+})
  - Anion = negative charge (Cl^{-})

Table 2-2

Ions Important to the Study of Environmental Science

Positive Ion	Symbol	Negative Ion	Symbol
hydrogen ion	H^+	chloride ion	Cl^-
sodium ion	Na^+	hydroxide ion	OH^-
calcium ion	Ca^{2+}	nitrate ion	NO_3^-
aluminum ion	Al^{3+}	sulfate ion	SO_4^{2-}
ammonium ion	NH_4^+	phosphate ion	PO_4^{3-}

Acidity

- Acidity - determines how a substance dissolved in water will interact with its environment
- pH - measure of acidity based on the amount of H^+ (hydrogen ions) and OH^- (hydroxide ions)
  - Pure water has an equal number of H^+ and OH^- ions. It is called a neutral solution and has a pH of 7.
  - Acidic solutions are those with more hydrogen ions and a pH less than 7
  - Basic solutions are those with more hydroxide ions and a pH greater than 7

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Molecules

- Molecule - a combination of two or more atoms of the same or different elements held together by forces called chemical bonds
- Chemical formula - shows the number of each type of atom or ion in a compound
  - Ex. $NaCl$, H_2O, CH_4

Table 2-3

Compounds Important to the Study of Environmental Science

Compound	Formula	Compound	Formula
sodium chloride	$NaCl$	methane	CH_4
carbon monoxide	CO	glucose	$C_6H_{12}O_6$
carbon dioxide	CO_2	water	H_2O
nitric oxide	NO	hydrogen sulfide	H_2S
nitrogen dioxide	NO_2	sulfur dioxide	SO_2
nitrous oxide	N_2O	sulfuric acid	H_2SO_4
nitric acid	HNO_3	ammonia	NH_3

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Loss of NO_3^- from a Deforested Watershed

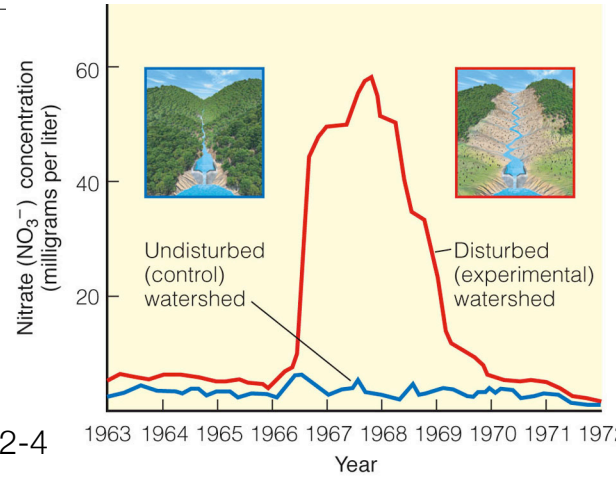

Fig. 2-4

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Organic Compounds

- Inorganic Compounds - all non-organic compounds
- Organic Compounds - contain at least two carbon atoms combined with atoms of one or more other elements (one exception is CH_4 - methane- is considered an organic compound)
- Types of Organic Compounds: (page 38)
  - Hydrocarbons, Chlorinated hydrocarbons, Simple carbohydrates
  - Macromolecules: Complex carbohydrates, Proteins, Nucleic acids, Lipids

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Basic Genetics

- Cells - fundamental structural units of life
- Genes - certain sequences of amino acids in DNA that code for specific proteins
- Each of these genes relates to a specific trait (characteristic) passed on from parent to offspring
- Thousands of genes make up the chromosome (a special DNA molecule held together with proteins)

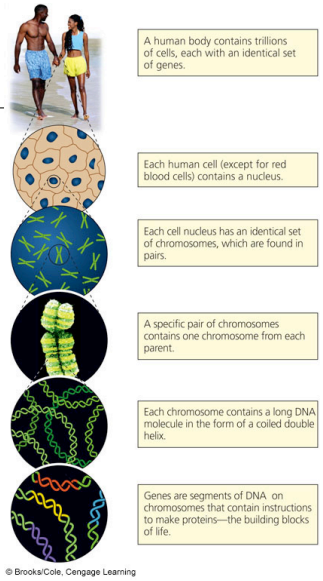

Fig. 2-5

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Fig. 2-6

Physical Forms of Matter

- Solid - most compact and orderly arrangement of atoms, ions, or molecules
- Liquid
- Gas - least compact and orderly arrangement
- Matter quality - measure of how useful a form of matter is to humans as a resource based on its availability and concentration
  - High quality matter is highly concentrated and typically found at the surface of the earth
  - Low quality matter is not highly concentrated and located deep underground or dispersed in the ocean or atmosphere

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Changes

- Physical Changes - chemical composition stays the same
  - Ex. solid water melts
- Chemical changes (chemical reactions) - change in the arrangement of atoms or ions within the molecules of the substances involved
  - Ex. Carbon + Oxygen --> Carbon dioxide + energy

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Nuclear Changes

- Natural radioactive decay - isotopes spontaneously emit fast moving subatomic particles, high-energy radiation (gamma rays), or both. The unstable isotopes are called radioisotopes
- Nuclear fission - nuclei of certain isotopes with larger mass number are split apart into lighter nuclei when struck by neutrons
  - Each fission releases two or three neutrons plus energy
  - This can produce a chain reaction which releases huge amounts of energy
- Nuclear fusion - two isotopes of light elements are forced together at extremely high temperatures until they fuse to form a heavier nucleus. An immense amount of energy is released in this process. This is what powers the sun and other stars.

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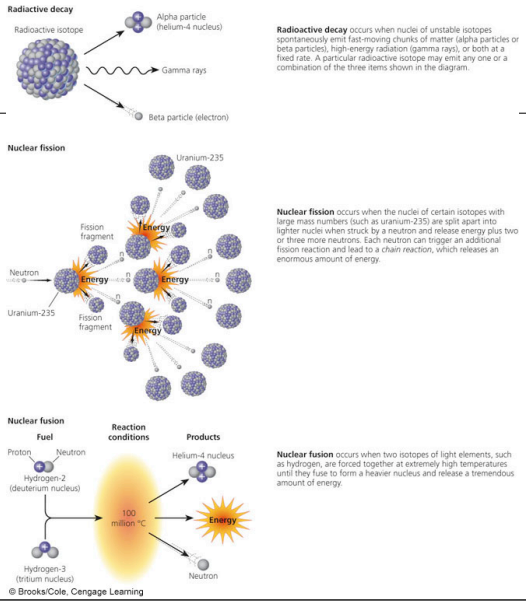

Fig. 2-7

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Law of Conservation of Matter

- Matter can not be created or destroyed
- It can only be converted from one form to another

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Energy

- Energy is the capacity to do work or transfer heat (work = force x distance)
- Kinetic energy - the energy of movement (has mass and velocity)
  - Heat is a type of kinetic energy that is transfered through radiation, conduction, or convection
  - Electromagnetic radiation is also a form of kinetic energy that travels in the form of a wave as a result of changes in electric and magnetic fields

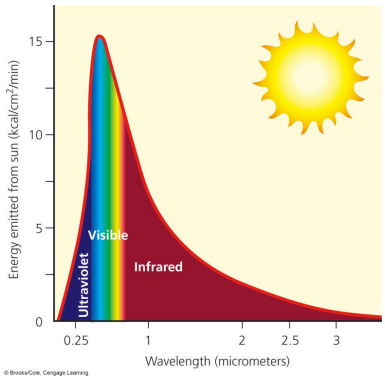

Fig. 2-8

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Energy (con.)

- Potential Energy - stored and potentially available for use
  - Ex. A book held in your hand, an unlit match
  - Potential energy can be changed into kinetic energy
    - Ex. Drop the book and its stored energy is released

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Energy Usefulness

- Energy quality is the measure of an energy source's capacity to do useful work
- High-quality energy - concentrated and has a high capacity to do useful work
  - Ex. nuclear fission , concentrated sunlight
- Low-quality energy - dispersed and has little capacity to do work
  - Ex. the heat dispersed over the entire ocean

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Energy Related Scientific Laws

- Law of Conservation of Energy (First Law of Thermodynamics) - when energy is converted form one form to another in a physical or chemical change, no energy is created or destroyed
- Second Law of Thermodynamics - when energy changes from one form or another, we always end up with lower-quality or less usable energy than started with (this usually takes the form of heat given off at a low temperature into the environment)
  - Ex. When driving a car, only 6% of the energy in the gasoline is used to propel the car. The other 94% is degraded to heat.
  - Ex. With an incandescent lightbulb, only 5% of the energy changes into useful light and 95% is transfered to heat.

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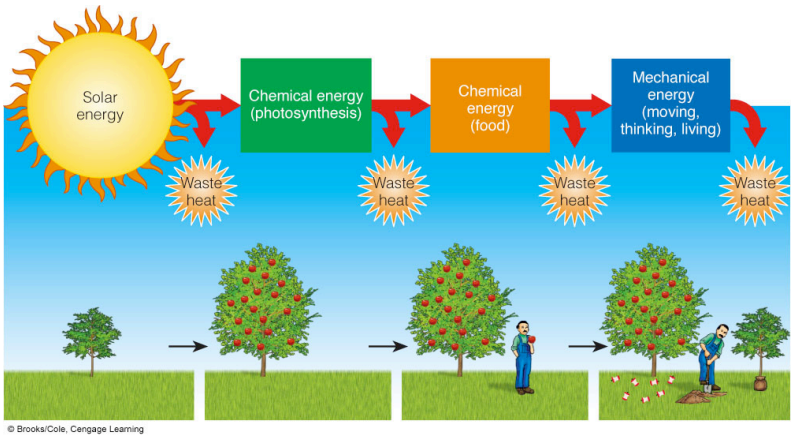

Fig. 2-9

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Energy Efficiency

- Energy efficiency (energy productivity) - measure of how much useful work is accomplished by a particular input of energy to the system
  - Estimated that only 16% of energy used in the United States performs useful work. The remaining 84% is unavoidably wasted because of the second law of thermodynamics (41%) or unnecessarily wasted (43%)

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Systems

- System - set of components that function or interact in some way
  - Ex. human body, a lake, forest, etc.
  - Most systems contain:
    - inputs
    - flows (throughputs)
    - outputs

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Feedback Loops

- Feedback - any process that increases (positive feedback) or decreases (negative feedback) a change to a system

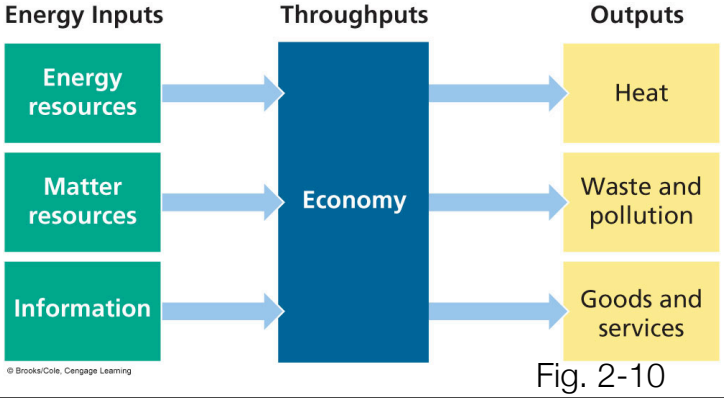

Fig. 2-10

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Feedback Loops

- Positive feedback loop - cases a system to change further in the same direction

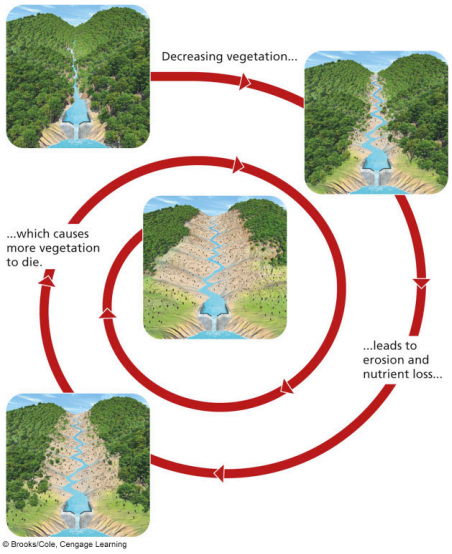

Fig. 2-11

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Feedback Loops

- Negative (corrective) feedback loop - causes a system to change in the opposite direction from which it is moving

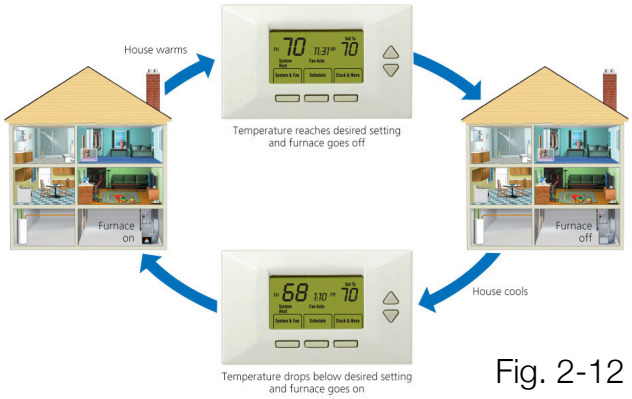

Fig. 2-12

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Time Delays and Synergy

- Time delays - time between the input of a feedback stimulus and the response to it
- Tipping point - a fundamental shift in the behavior of a system (point of no return)
- Synergistic interaction - when two or more processes interact so that the combined effect is greater than the sum of their separate effects.

30