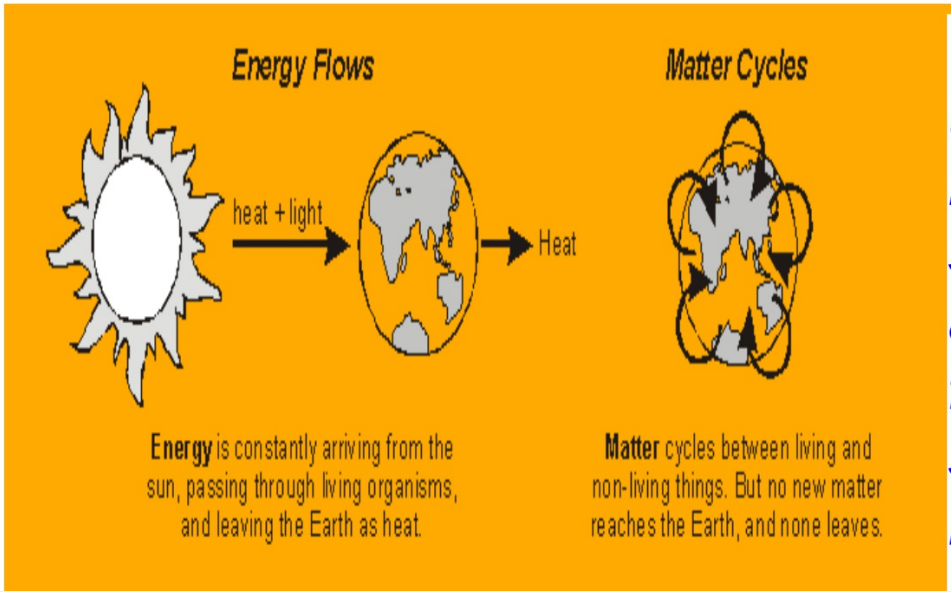
# CHAPTER 2

## Science, Matter, Energy, and Systems

MILLER/SPOOLMAN

LIVING IN THE ENVIRONMEN

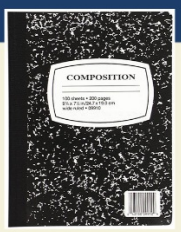



***"Science is bu up of facts, as house is built stones; but an accumulation facts is no mo science than a heap of stone house"***

# Core Case Study: Hubbard Br Experimental Forest in New Ham

- compared the loss of water and nutrients from an uncut forest (control site) with one that had been stripped (experimental site)

- Stripped site:
  - 30-40% more runoff
  - more dissolved nutrients
  - more soil erosion




What are the effects of deforestation on the los and soil nutrients?

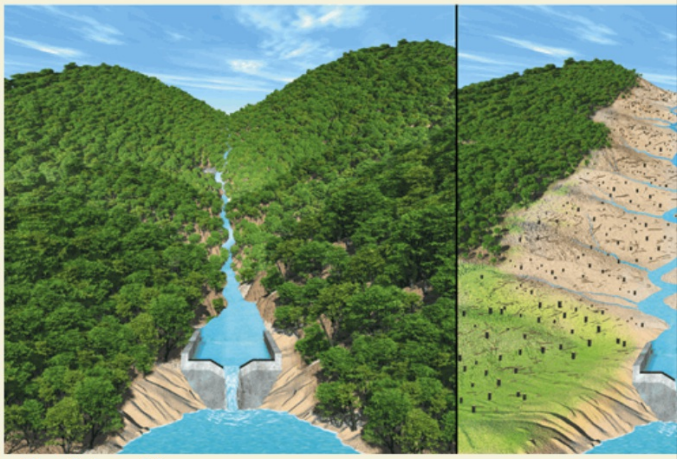


Fig. 2-1, p. 31

# 2-1 What Do Scientists Do?

- ***Concept 2-1*** *Scientists collect data and develop theories, models, and laws about how nature works.*

# Loss of $NO_3^-$ from a Deforested Watershed

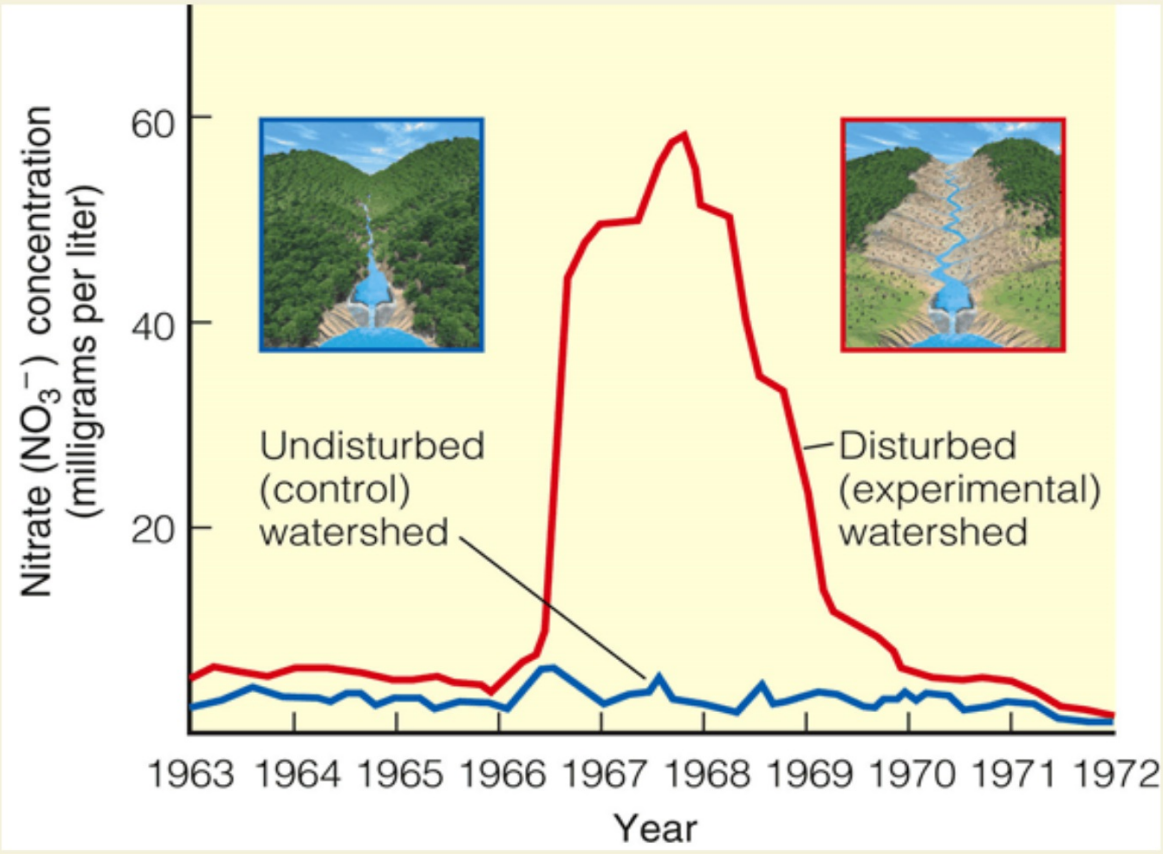



Fig. 2-6, p. 40

# The Scientific Process

- Identify a problem
- Find out what is known about the problem
- Ask a question to be investigated
- Gather **data** through **experiments**
- Propose a **scientific hypothesis**
- **Make testable predictions**
- Keep testing and making observations
- Accept or reject the hypothesis

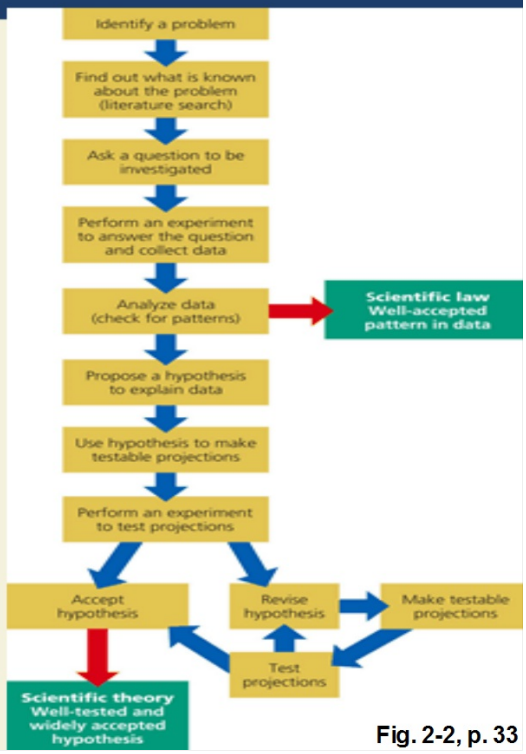



Fig. 2-2, p. 33

# Testing a Hypothesis

**Observation:** Nothing happens when I try to turn on my flashlight.

**Question:** Why didn't the light come on?

**Hypothesis:** Maybe the batteries are dead.

**Test hypothesis with an experiment:** Put in new batteries and try to turn on the flashlight.

**Result:** Flashlight still does not work.

**New hypothesis:** Maybe the bulb is burned out.

**Experiment:** Put in a new bulb.

**Result:** Flashlight works.

**Conclusion:** New hypothesis is verified.

Fig. 2-3, p. 33

# Experimental Design Diagram

## Read the scenario and complete the experimental design diagram.

lab assignment was to determine embers of a species are affected by ecific competition; competition by ers within the same species. She ung bean seeds and planted them ll pots. She put the same amount of each pot. In the first five plots she d one seed. In the second five pots anted 10 seeds and in the third five he planted 20 seeds. She placed n a well lighted area and watered her whenever the soil was dry. During a eriod of two weeks, she recorded the of each bean every two days. From e was able to determine the average

*Directions: Fill out the experimental design diagram for the seed germination e will not begin the experiment until it has been approved by the teacher.*

| | | | |
|---|---|---|---|
| **Title:** | | | |
| **Problem Statement:** | | | |
| **Hypothesis:** | | | |
| **Independent (Manipulated) Variable:** | | | |
| **Number of Tests** | | | |
| **Number of Trials per Test:** | | | |
| **Dependent (Responding) Variable:** | | | |
| **Control Test:** | | | |
| **Variables Held Constant:** | | | |

# Characteristics of Science…and Scientists

- Curiosity
- Skepticism
- Reproducibility
- **Peer review**
- Openness to new ideas
- Critical thinking
- Creativity

# VIDEO:  Earth as Our Easter Island


# Science Focus: Easter Island: Revisions to a Popular Environmental Story

Fig. 2-A, p. 35

**Does the new doubt about the original East Island hypothesis mean that we should not concerned about using resources unsustai on the island in space that we call earth? Explain.**

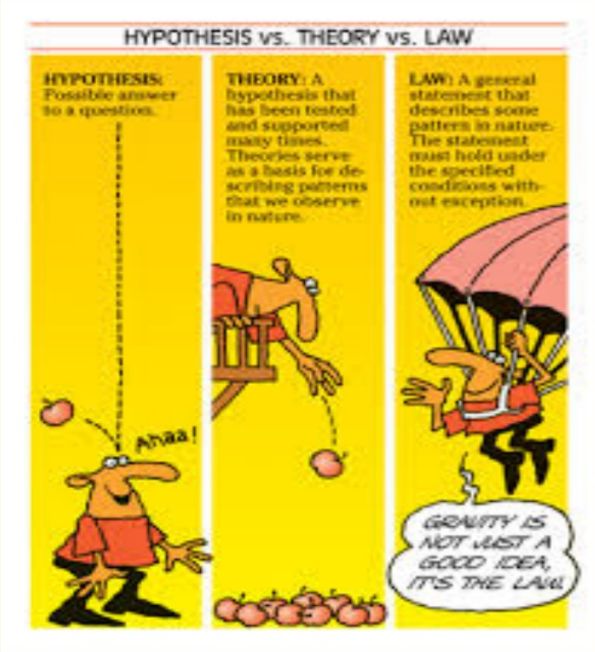
- Some revisions to a popular environmental story
- Polynesians arrived about 800 years ago
- Population may have reached 3000
- Used trees in an unsustainable manner, **but** rats may have multiplied and eaten the seeds of the trees

# Scientific Theories and Laws Are the Most Important Results of Science

## Scientific theory

- Widely tested
- Supported by extensive evidence
- Accepted by most scientists in a particular area

## Scientific law, law of nature



# Science Focus: Statistics and Probability

## Statistics

- Collect, organize, and interpret numerical data

## Probability

- The chance that something will happen or be valid
- Need large enough sample size

**Read the Science Focus on page 37 a following:**

- **What does it mean when an interna the world's climate experts say tha least 90% chance (probability of 0. activities, primarily the burning of the resulting carbon dioxide emiss an important cause of the observe warming during the past 35 years?**
- **Why is it that we would probably n 100% chance?**

# 2-2 What Is Matter?

- ***Concept 2-2*** *Matter consists of elements and compounds, which are in turn made up of atoms, ions, or molecules.*

# Matter Consists of Elements and Compounds

## Matter

- Has mass and takes up space

## Elements

- Unique properties
- Cannot be broken down chemically into other substances

## Compounds

- Two or more different elements bonded together in fixed proportions

# Examples of Chemical Elements

**Table 2-1** Chemical Elements Used in This Book

| Element | Symbol |
|---|---|
| Arsenic | As |
| Bromine | Br |
| Calcium | Ca |
| Carbon | C |
| Chlorine | Cl |
| Fluorine | F |
| Gold | Au |
| Lead | Pb |
| Lithium | Li |
| Mercury | Hg |
| Nitrogen | N |
| Phosphorus | P |
| Sodium | Na |
| Sulfur | S |
| Uranium | U |

Table 2-1, p. 38


Fig. 2-4a, p. 38

# What are atoms?

## Atomic theory

- All elements are made of atoms

## Subatomic particles

- **Protons** with positive charge and **neutrons** with no charge in **nucleus**
- Negatively charged **electrons** orbit the nucleus

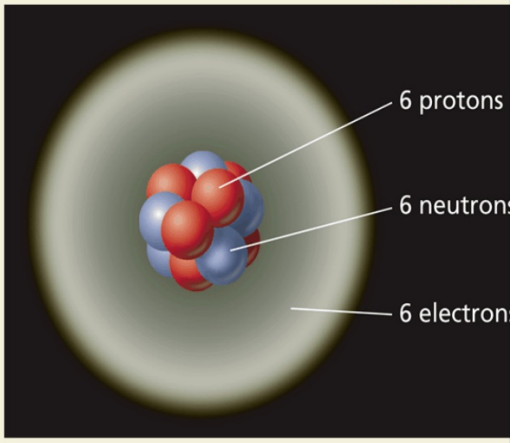
## Atomic number

- Number of protons in nucleus

## Mass number

- Number of protons plus neutrons

Fig. 2-5, p. 39




Model of a Carbon-12 Ato

# Istopes and Ions

**Table 2-2** Chemical Ions Used in This Book

| Positive Ion | Symbol | Components |
|---|---|---|
| hydrogen ion | $H^+$ | One H atom, one positive charge |
| sodium ion | $Na^+$ | One Na atom, one positive charge |
| calcium ion | $Ca^{2+}$ | One Ca atom, two positive charges |
| aluminum ion | $Al^{3+}$ | One Al atom, three positive charges |
| ammonium ion | $NH_4^+$ | One N atom, four H atoms, one positive charge |
| **Negative Ion** | **Symbol** | **Components** |
| chloride ion | $Cl^-$ | One chlorine atom, one negative charge |
| hydroxide ion | $OH^-$ | One oxygen atom, one hydrogen atom, one negative charge |
| nitrate ion | $NO_3^-$ | One nitrogen atom, three oxygen atoms, one negative charge |
| carbonate ion | $CO_3^{2-}$ | One carbon atom, three oxygen atoms, two negative charges |
| sulfate ion | $SO_4^{2-}$ | One sulfur atom, four oxygen atoms, two negative charges |
| phosphate ion | $PO_4^{3-}$ | One phosphorus atom, four oxygen atoms, three negative charges |

**Table 2-2, p. 40**

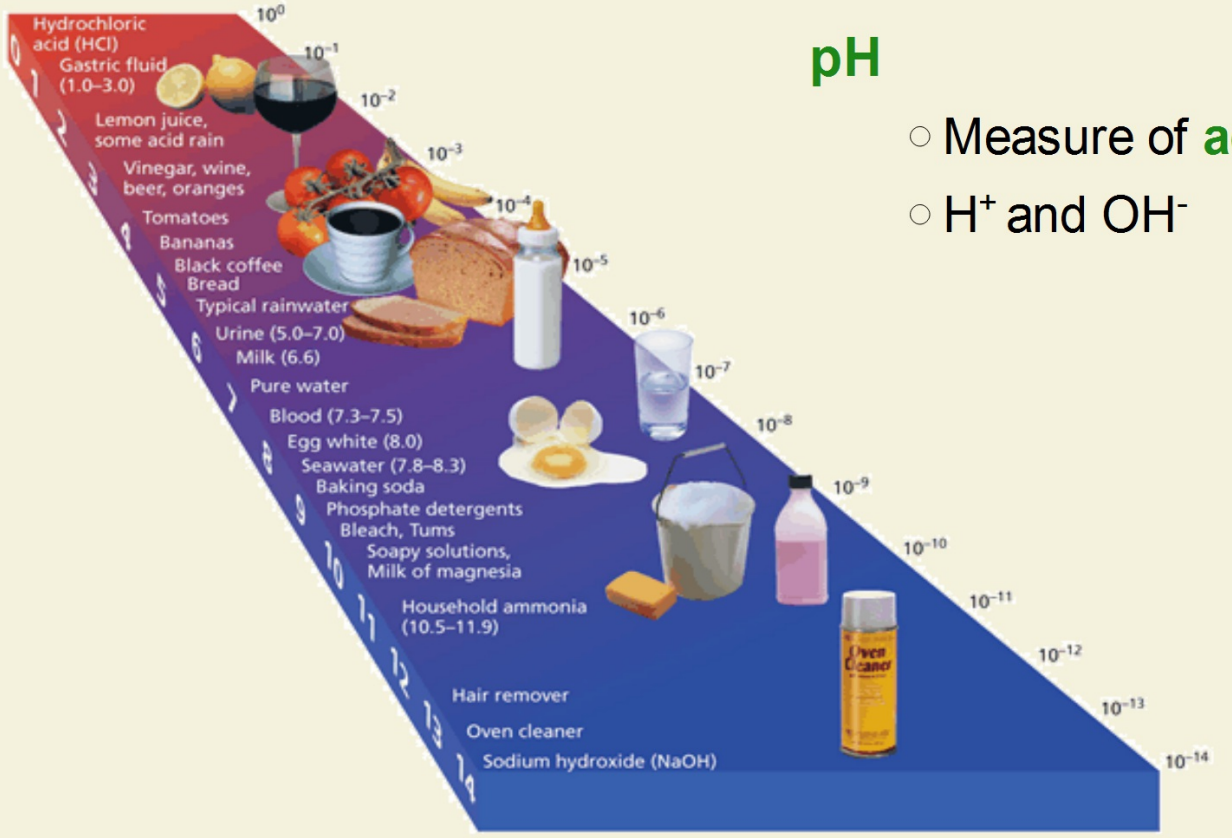
## Isotopes

- Same element, different number of protons

## Ions

- Gain or lose electrons
- Form ionic compounds

# pH Scale




## pH

- Measure of aci
- $H^+$ and $OH^-$

Supplement 5, Figure 4

# Molecules and Compoun

## Molecule

- Two or more atoms of the same or different elements held together by chemical bonds

## Compounds

## Chemical formula

**Table 2-3** Compounds U

| Compound |
| --- |
| sodium chloride |
| sodium hydroxide |
| carbon monoxide |
| oxygen |
| nitrogen |
| chlorine |
| carbon dioxide |
| nitric oxide |
| nitrogen dioxide |
| nitrous oxide |
| nitric acid |
| methane |
| glucose |
| water |
| hydrogen sulfide |
| sulfur dioxide |
| sulfuric acid |
| ammonia |
| calcium carbonate |

# Organic Compounds Are the Chemicals of Life

## Organic compounds

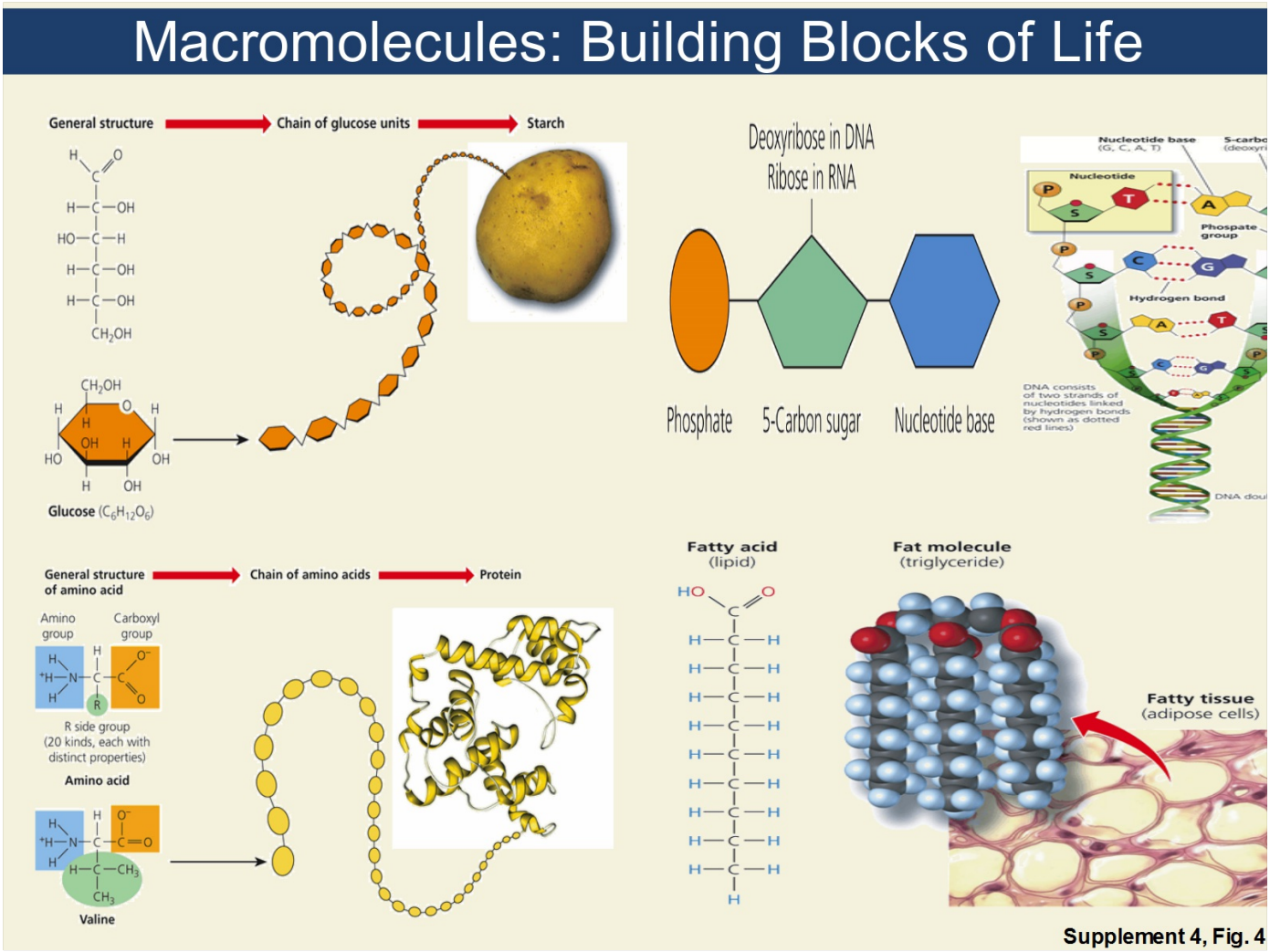
- Hydrocarbons and chlorinated hydrocarbons
- Simple carbohydrates
- Macromolecules: complex organic molecules
  - Complex carbohydrates
  - Proteins
  - Nucleic acids
  - Lipids

**TABLE 3.1** Inorganic Versus Organic Molecules

| *Inorganic Molecules* | *Organic Molecules* |
|---|---|
| Usually contain positive and negative ions | Always contain carbon and hydrogen |
| Usually ionic bonding | Always covalent bonding |
| Always contain a small number of atoms | Often quite large, with many atoms |
| Often associated withnonliving matter | Usually associated with living organisms |

## Inorganic compounds

# Macromolecules: Building Blocks of Life




**Supplement 4, Fig. 4**

# Matter Comes to Life through Genes, Chromosomes, and Cells

**Cells:** fundamental units of life; all organisms are composed of one or more cells

**Genes**

- Sequences of nucleotides within DNA
- Instructions for proteins
- Create inheritable **traits**

**Chromosomes**: composed of many genes

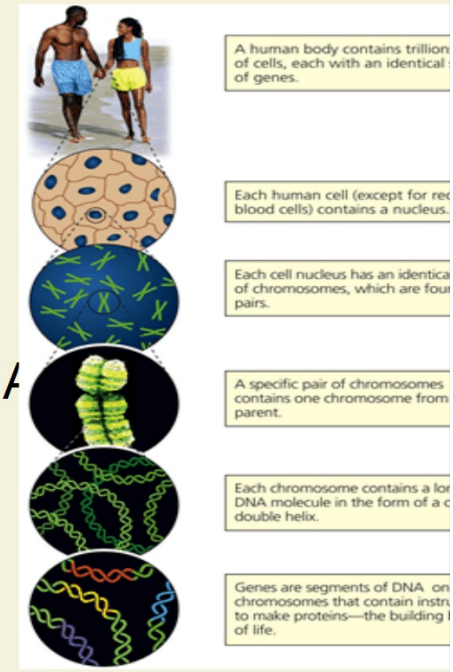



Fig. 2-7, p. 42

# Some Forms of Matter Are More Useful than Others

## High-quality matter

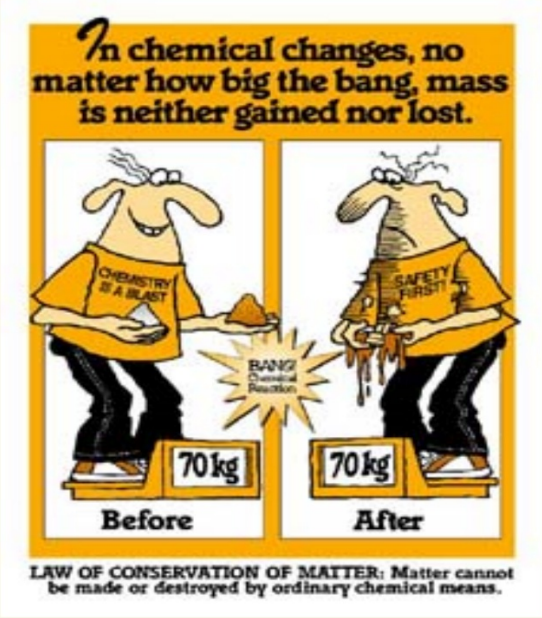
- Highly concentrated
- Near earth's surface
- High potential as a resource

## Low-quality matter

- Not highly concentrated
- Deep underground or widely dispersed
- Low potential as a resource


Fig. 2-8, p. 42

# 2-3 What Happens When Matter Undergoes Change?




***Concept 2-3***

*Whenever matter undergoes a physical or chemical change, no atoms are created or destroyed (the law of conservation of matter).*

# Physical vs. Chemical Changes

## Physical change

- No change in chemical composition

## Chemical change, chemical reaction

- Change in chemical composition
- Reactants and products

# Types of Nuclear Changes

## Nuclear change

- Natural radioactive decay
  - Radioisotopes: unstable
- Nuclear fission
- Nuclear fusion

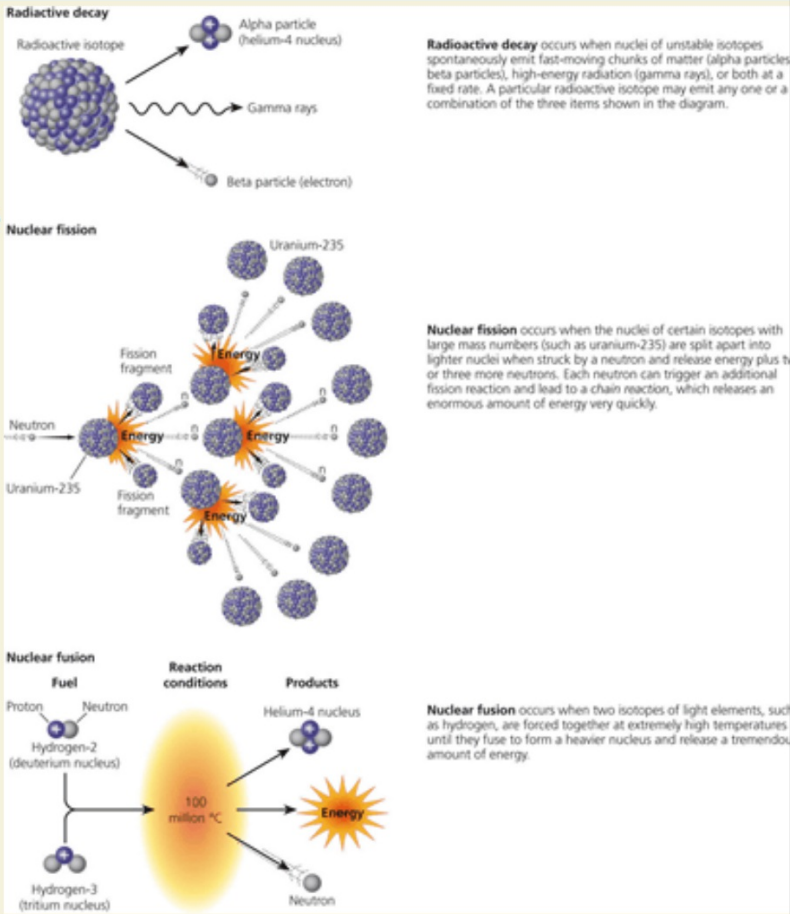


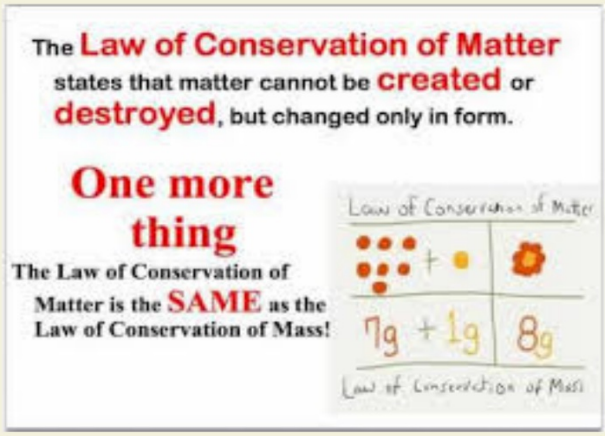

Fig. 2-9, p. 43

# We Cannot Create or Destroy Matter

## Law of conservation of matter

- Whenever matter undergoes a physical or chemical change, no atoms are created or destroyed

**Can you really through something away?**

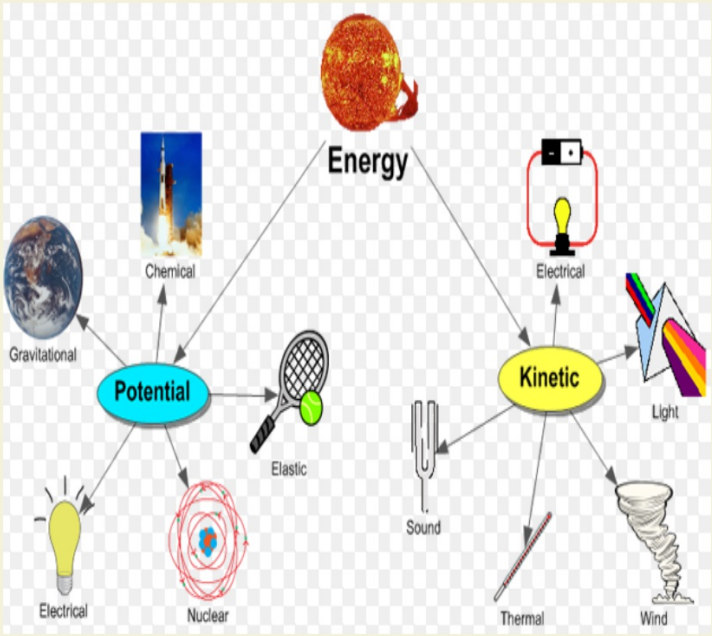


# *2-4 What is Energy and What Happens When It Undergoes Change?*

- ***Concept 2-4A*** *When energy is converted from one form to another in a physical or chemical change, no energy is created or destroyed (first law of thermodynamics).*

- ***Concept 2-4B*** *Whenever energy is changed from one form to another in a physical or chemical change, we end up with lower-quality or less usable energy than we started with (second law of thermodynamics).*

# Kinetic vs. Potential Energy




**Kinetic energy**

- Flowing water
- Wind
- **Heat**
- Transferred by radiation, conduction, or convection
- **Electromagnetic radiation**

**Potential energy**

- Stored energy
- Can be changed into kinetic energy

# Wind's Kinetic Energy Moves This Turbine

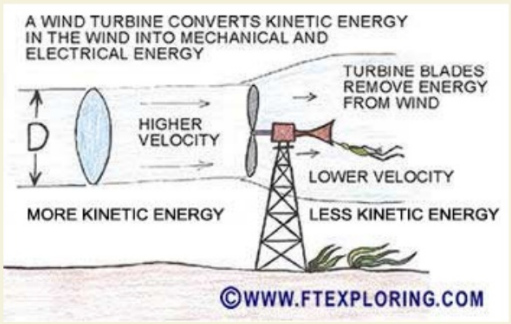



**Fig. 2-10, p. 44**

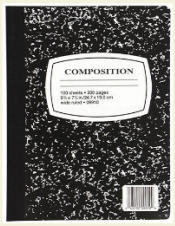
# Energy Comes in Many Forms

Sun provides 99% of earth's energy

- Warms earth to comfortable temperature
- Plant photosynthesis
- Winds
- Hydropower
- Biomass

# Fossil fuels


**Fossil fuels**: oil, coal, natural gas




**What are fossil fuels and what 3 fossil fuels do we use to supplement energy from the sun?**

Fig. 2-14a, p. 46

# Some Types of Energy Are More Useful Than Others

**High-quality energy**

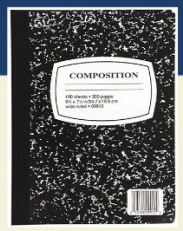
- High capacity to do work
- Concentrated
- High-temperature heat
- Strong winds
- Fossil fuels

**Low-quality energy**

- Low capacity to do work
- Dispersed


Fig. 2-15, p. 47

# Energy Changes Are Governed by Two Scientific Laws



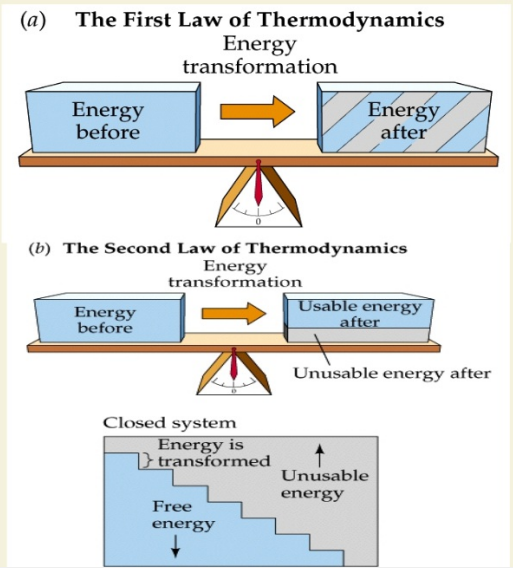

**Explain the 1st and 2nd law of thermodynamics.**

## First Law of Thermodynamics

- **Law of conservation of energy**
- Energy is neither created nor destroyed in physical and chemical changes

## Second Law of Thermodynamics

- Energy always goes from a more useful to a less useful form when it changes from one form to another
- Light bulbs and combustion engines are very inefficient: produce wasted heat



# Energy-Wasting Technologies

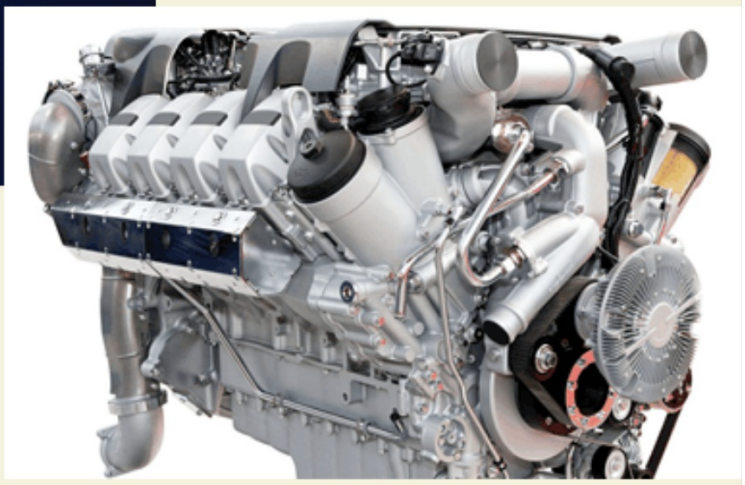


Fig. 2-16a, p. 48

# 2-5 What Are Systems and How Do They Respond to Change?

- ***Concept 2-5*** *Systems have inputs, flows, and outputs of matter and energy, and feedback can affect their behavior.*

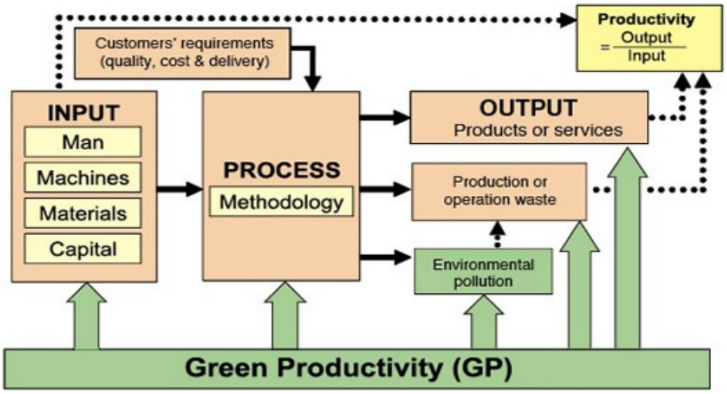



Figure 1. GP addresses all elements of a business system and helps improve productivity.
*Source:* Teian Consulting International, Singapore.

# Systems Have Inputs, Flows, and Outputs

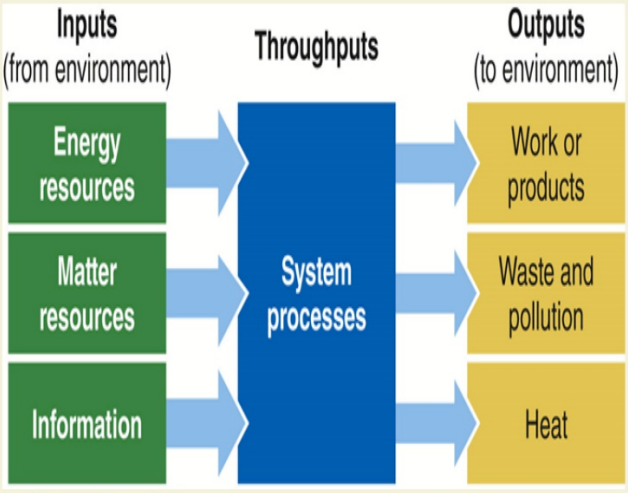



Fig. 2-17, p. 48

**System**

- Set of components that interact in a regular way
- Human body, earth, the economy

**Inputs** from the environment

**Flows, throughputs** of matter and energy

**Outputs** to the environment

# Systems Respond to Change through Feedback Loops

**Positive feedback loop**

- Causes system to change further in the same direction
- Can cause major environmental problems

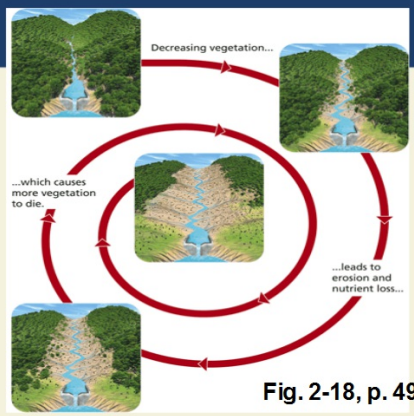



Fig. 2-18, p. 49

**Negative, or corrective, feedback loop**

- Causes system to change in opposite direction

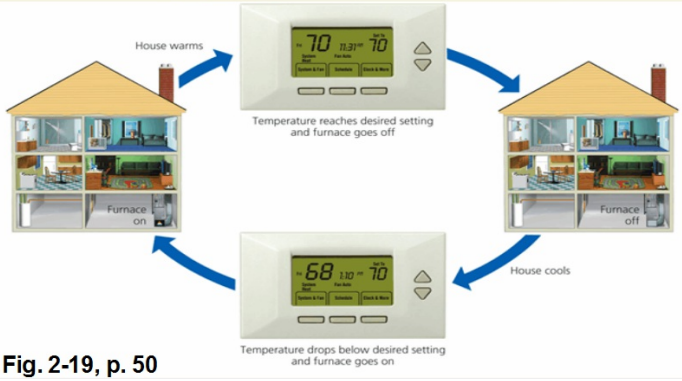
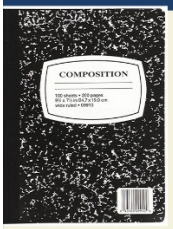



Fig. 2-19, p. 50

# VIDEO: Feedback Loops




**Answer the following:**

1. **What is the difference between a positive and negative feedack loop?**

2. **One of the more prevalent feedback loops discussed today is one in relation to melting polar ice caps due to climate change. Is this a positive or negative feedback loop? Explain your answer.**

# Time Delays Can Allow a System to Reach a Tipping Point

- Time delays vary
  - Between the input of a feedback stimulus and the response to it

- **Tipping point,** threshold level
  - Causes a shift in the behavior of a system
  - Melting of polar ice
  - Population growth

# System Effects Can Be Amplified through Synergy

## Synergistic interaction, synergy

- Two or more processes combine in such a way that combined effect is greater than the two separate effects
  - Helpful: Studying with a partner
  - Harmful: e.g., Smoking and inhaling asbestos

# Three Big Ideas

There is no away.

You cannot get something for nothing.

You cannot break even.