ENVIRONMENT

THE SCIENCE BEHIND THE STORIES

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Ch 4

From Chemistry to Energy to Life

Part 1: Foundations of Environmental Science

PowerPoint® Slides prepared by
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Central Case: Bioremediation of the *Exxon Valdez* Oil Spill

- In 1989, 11 million gallons coated the Alaskan coastline
  - The largest spill in U.S. history
- Defiled the pristine environment
- Tourism plummeted and jobs were lost
- **Bioremediation**= pollution cleanup through enhanced natural biodegradation

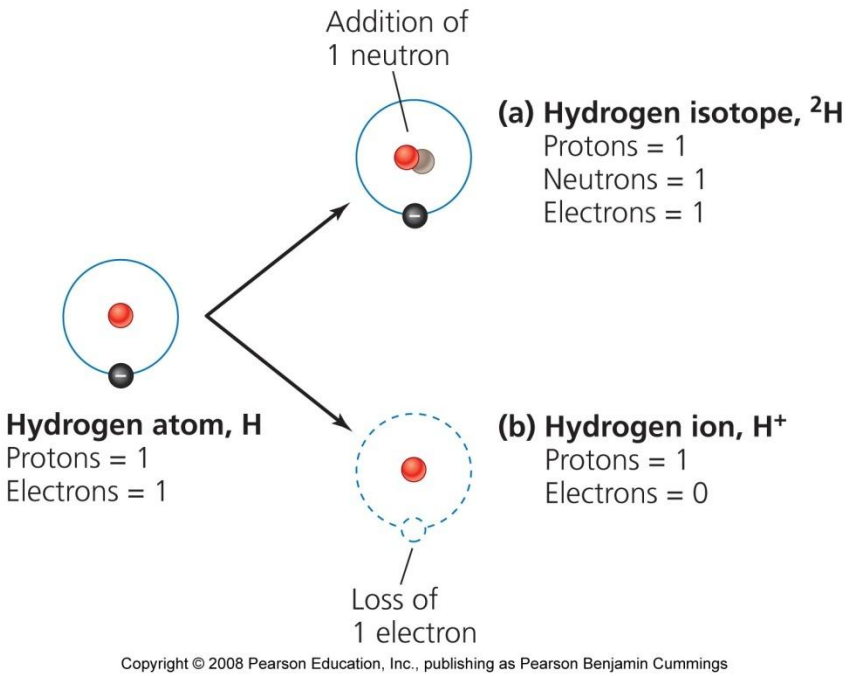
Chemistry is crucial for understanding:

- How gases contribute to global climate change
- How pollutants cause acid rain
- The effects on health of wildlife and people
- Water pollution
- Wastewater treatment
- Atmospheric ozone depletion
- Energy issues

Chemical building blocks

- **Matter** = all material in the universe that has mass and occupies space
  - The smallest unit of matter is atoms
  - Can be transformed from one type of substance into others
  - But it cannot be destroyed or created which is…
  - The **law of conservation of matter**
    - Helps us understand that the amount of matter stays constant
    - It is recycled in nutrient cycles and ecosystems

Chemical building blocks

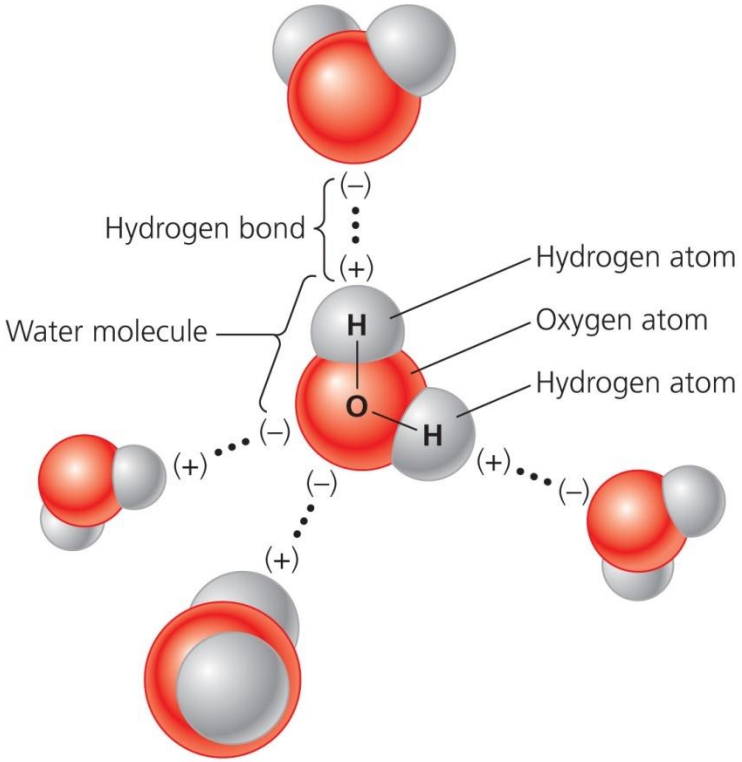


- **Isotopes** = atoms with differing numbers of neutrons
  - **Mass number** = the combined number of protons and neutrons
  - Isotopes of an element behave differently
  - Some isotopes are **radioactive** and decay until they become non-radioactive **stable isotopes**
    - Emit high-energy radiation

Radioactive decay

- **Half-life** = the amount of time it takes for one-half of the atoms to give off radiation and decay
  - Different radioscopes have different half-lives ranging from fractions of a second to billions of years
  - *Uranium-235, used in commercial nuclear power, has a half-life of 700 million years*
- Atoms may also gain or lose electrons to become **ions**, electrically charged atoms

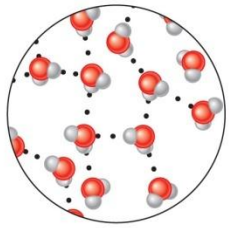
Water: the main reason life can exist

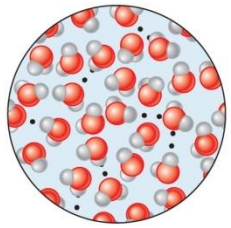


- **Hydrogen bond** = oxygen from one water molecule attracts hydrogen atoms of another
- Water's strong cohesion allows nutrients and waste to be transported
- Water absorbs heat with only small changes in its temperature, which stabilizes systems

Additional properties of water

- Less dense ice floats on liquid water
- Water dissolves other molecules

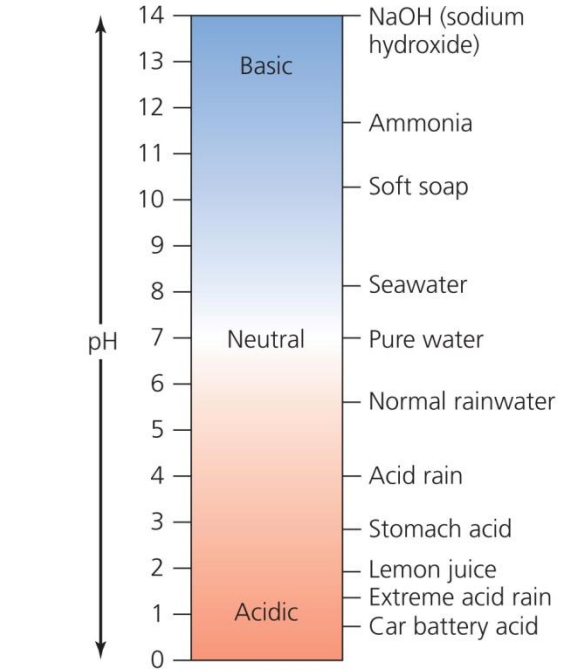




(a) Why ice floats on water

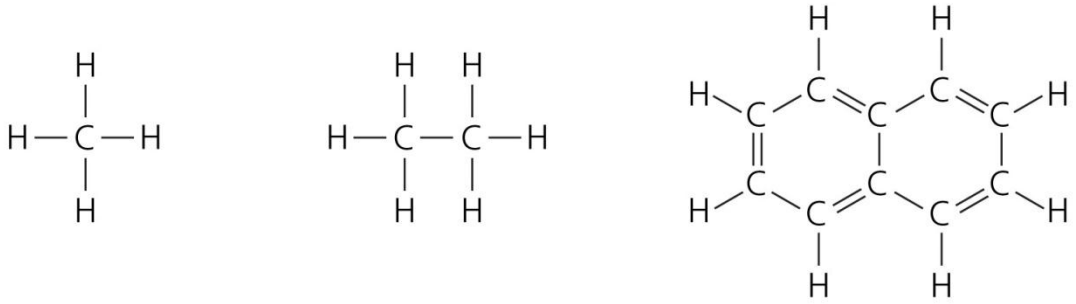
Hydrogen ions determine acidity

- The pH scale ranges from 0 to 14 and quantifies the acidity of solutions
  - **Acidic** solutions have a pH less than 7
  - **Basic** solutions have a pH greater than 7
  - **Neutral** solutions have a pH of 7
- A substance with pH of 6 contains 10 times as many hydrogen ions as a substance with pH of 7



Organic Compounds

- **Organic Compounds** = carbon atoms joined by covalent bonds and may include other elements
  - Such as nitrogen, oxygen, sulfur, and phosphorus
- **Hydrocarbons** = contain only carbon and hydrogen
  - The simplest hydrocarbon is methane
  - Hydrocarbons can be a gas, liquid or solid



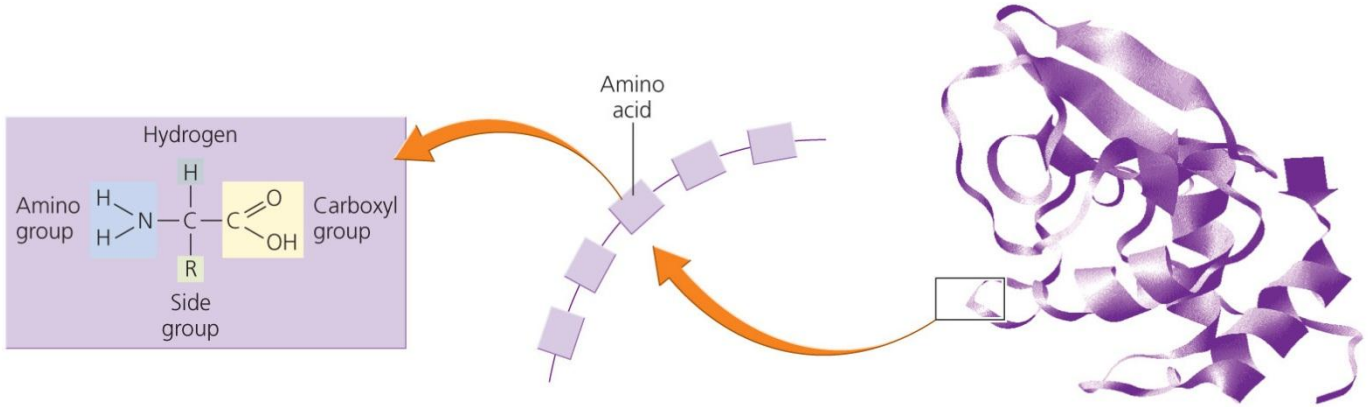
(a) Methane, CH_4 (b) Ethane, C_2H_6 (c) Naphthalene, $C_{10}H_8$ (a polycyclic aromatic hydrocarbon)

Macromolecules

- **Polymers =** long chains of repeated molecules
  - The building blocks of life
- **Macromolecules** = large-size molecules
  - Three types of polymers are essential to life
    - Proteins
    - Nucleic acids
    - Carbohydrates
  - Lipids (are not polymers, but are also essential)

Proteins

- Produce tissues, provide structural support, store and others transport energy
  - Animals use proteins to generate skin, hair, muscles, and tendons
  - Some function as components of the immune system
  - They can serve as **enzymes**, molecules that promote certain chemical reactions



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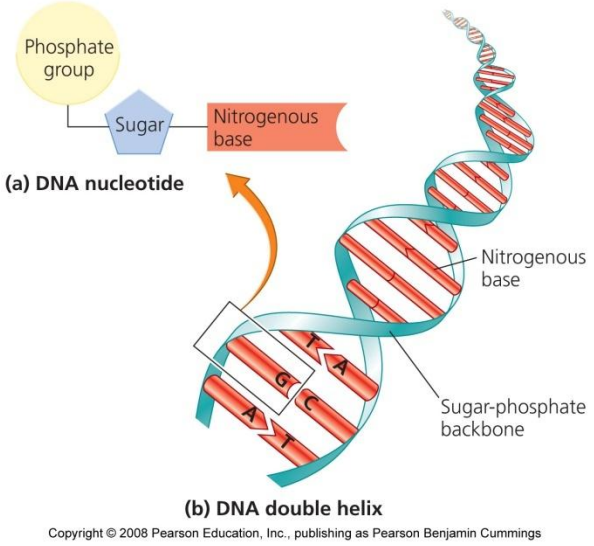
A special process involving proteins

- **Deoxyribonucleic acid (DNA)** and **Ribonucleic Acid (RNA)** carry the hereditary information of organisms
  - Long chains of nucleotides that contain
    - Sugar, phosphate, and a nitrogen base
- Information in DNA is rewritten to RNA
- RNA directs amino acid assembly into proteins
- **Genes** = regions of DNA that code for proteins that perform certain functions
- **Genome** = an organism's genes
  - Divided into chromosomes

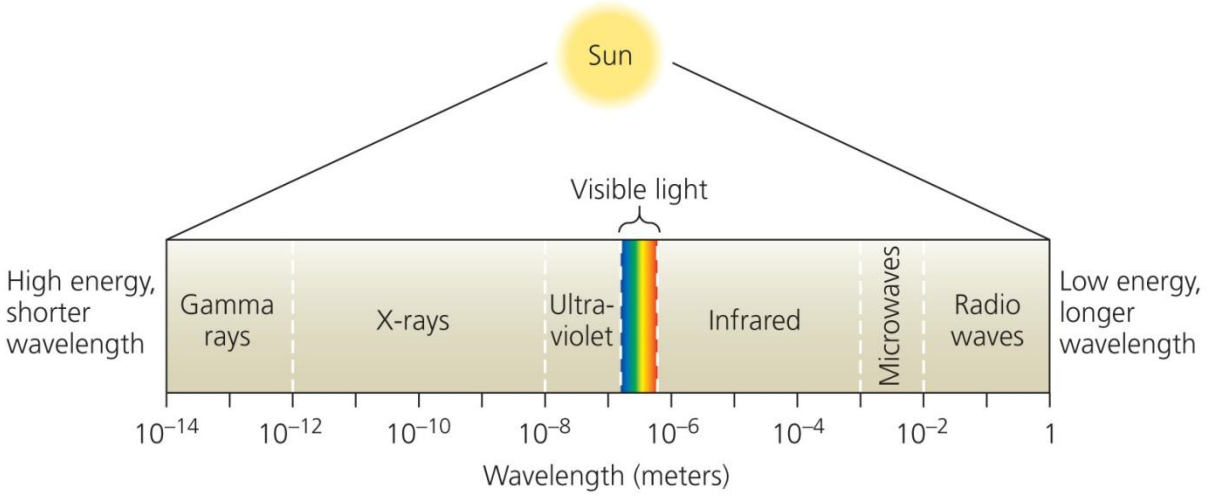


Carbohydrates and lipids

- **Carbohydrates =** consist of atoms of carbon, hydrogen, and oxygen
  - Sugars = simple carbohydrates
    - Glucose = provides energy for cells
  - Complex carbohydrates build structures and store energy
    - Starch = a complex carbohydrate
- **Lipids =** a chemically diverse group of compounds grouped together because they don't dissolve in water
  - For energy, cell membranes, structural support, and steroids

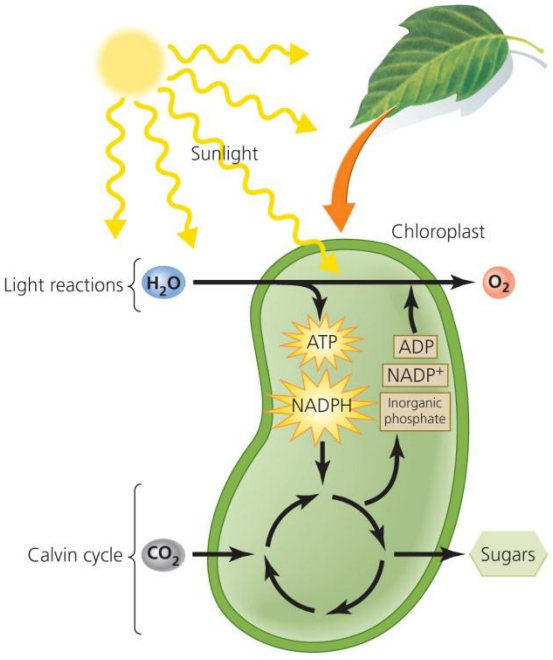
The sun's energy powers life

- The sun releases radiation from the electromagnetic spectrum
  - Some is visible light
- Solar energy drives weather and climate, and powers plant growth
- **Approximately 1% of light energy is converted into chemical energy during photosynthesis**



Photosynthesis

- **Autotrophs** (**primary producers**) = organisms such as green plants, algae and cyanobacteria produce their own food from the sun's energy
- **Photosynthesis** = the process of turning light energy from the sun into chemical energy
  - Carbon dioxide + water + sun's energy is converted into sugars and high-quality energy



Photosynthesis produces food

- **Chloroplasts** = organelles where photosynthesis occurs
  - Contain **chlorophyll** = a light-absorbing pigment
  - **Light reaction** = splits water by using solar energy
  - **Calvin cycle** = links carbon atoms from carbon dioxide into sugar (glucose)

$$6CO_2 + 6H_20 + \text{the sun's energy} \longrightarrow C_6H_{12}O_6 + 6O_2$$

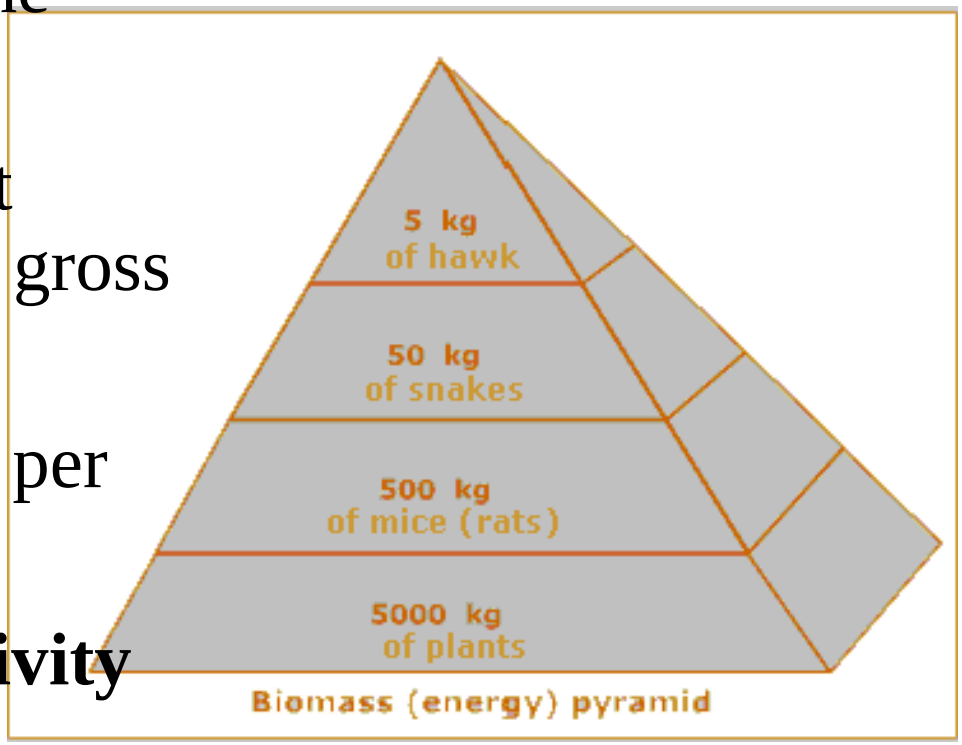
Cellular respiration releases chemical energy

- Organisms use chemical energy from photosynthesis
- Oxygen is used to convert glucose into water + carbon dioxide + energy
- Heterotrophs = organisms that gain energy by feeding on others
  - Animals, fungi, microbes

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_20 + \text{energy}$$

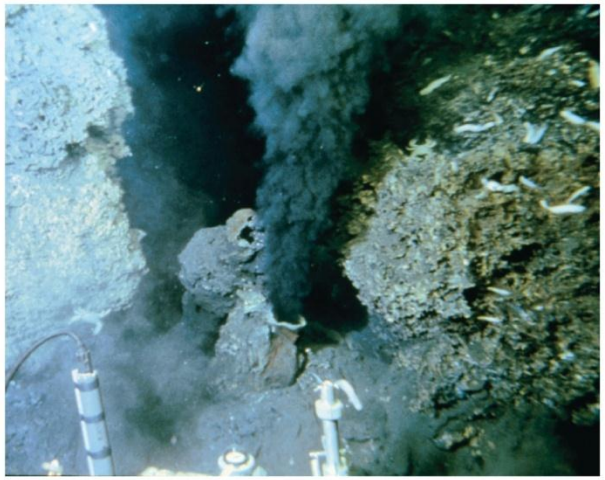
Primary Productivity

- The biomass of a given ecosystem is measured by the primary productivity.
  - It can be measured by net primary productivity and gross primary productivity
  - It is measured in calories per area
  - **Gross primary productivity (GPP) = Net primary productivity (NPP) + respiration**



Geothermal energy powers Earth's systems

- **Hydrothermal vents** = host entire communities that thrive in high temperature and pressure
  - Lack of sun prevents photosynthesis
  - **Chemosynthesis** = uses energy in hydrogen sulfide to produce sugar



(a) Hydrothermal vent

(b) Giant tubeworms

$$6CO_2 + 6H_20 + 3H_2S \longrightarrow C_6H_{12}O_6 + 3H_2SO_4$$