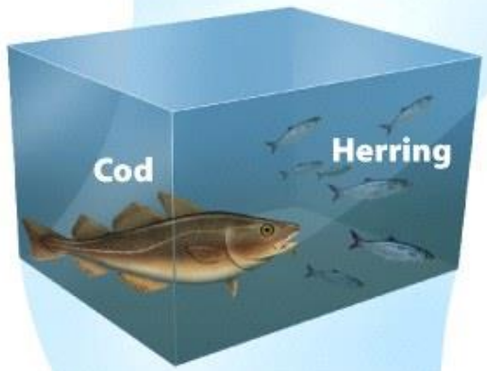
Chapter 2

Environmental Systems

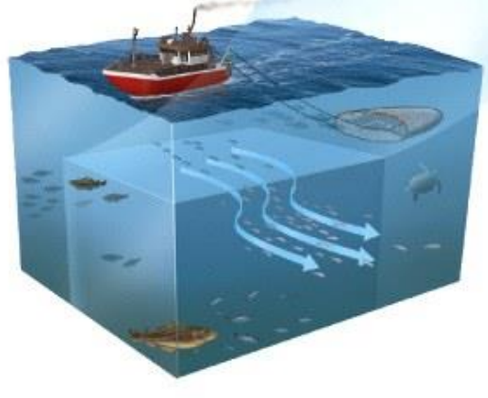
Earth is a single interconnected system

To a physiologist, a cod is a system.



To a marine biologist, the predator-prey relationship between two fish species forms a system.

For an oceanographer, the system might consist of ocean currents and their effects on fish populations.



A fisheries manager is interested in a larger system, consisting of fish populations as well as human activities and laws.

Figure 2.1
Environmental Science

All environmental systems consist of matter

- Matter- anything that occupies space and has mass.

- Mass- a measure of the amount of matter an object contains.

- Weight- the force that results from the action of gravity on mass.

Atoms and Molecules

- Atom- the smallest particle that can contain the chemical properties of an element.
- Element- a substance composed of atoms that cannot be broken down into smaller, simpler components. Elements can be solid, liquid or gas.
- Periodic Table- lists all the elements currently known.
- Molecules- particles containing more than one atom.

Atoms and Molecules

- Compounds- molecules that contain more than one element.
- Atomic Number- the number of protons in the nucleus of a particular element.
- Mass Number- the total number of protons and neutrons in an element.
- Isotopes- atoms of the same element that have different numbers of neutrons, and therefore different atomic masses.

Radioactivity

- Radioactive decay- the spontaneous release of material from the nucleus of an unstable isotope.
    - Radioactive decay changes the radioactive element into a different element. i.e. Uranium-235 decays to form Thorium-231.
- Uranium is called the parent and thorium the daughter.

Radioactivity

- Half-life- the time it takes for one-half of the original radioactive parent atoms to decay.
    - Some elements that undergo radioactive decay emit harmful radiation.
    - Knowledge of the half-life allows scientists to determine the length of time that a radioactive element may be dangerous.

Chemical bonds

- Covalent bonds- elements that form compounds by sharing electrons.

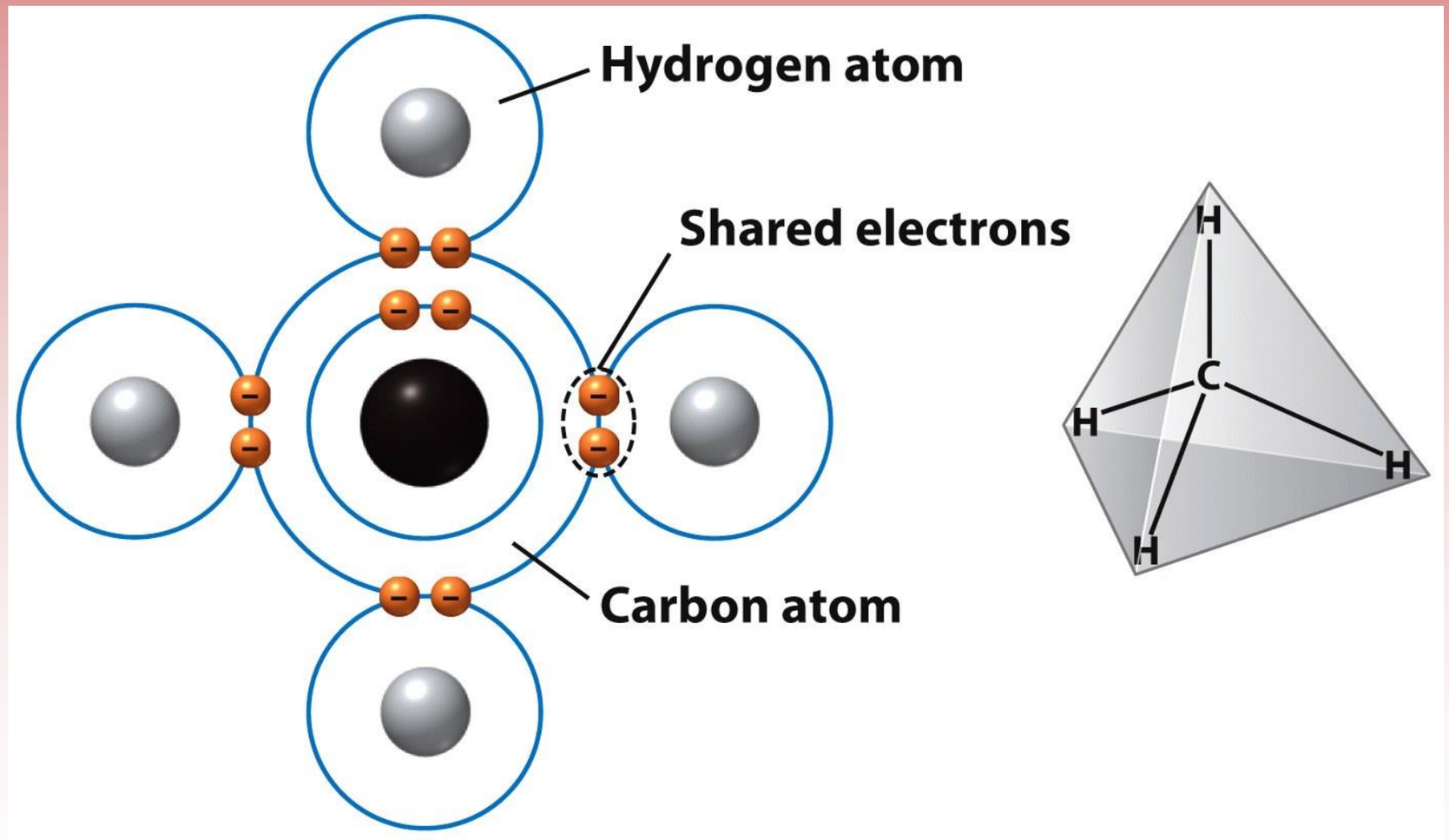


Figure 2.3
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Chemical bonds

- Ionic bonds- elements that form compounds by transferring electrons from one element to another.
    - When this transfer happens, one atom becomes electron deficient (positively charged) and one atom becomes electron rich (negatively charged)

Chemical bonds

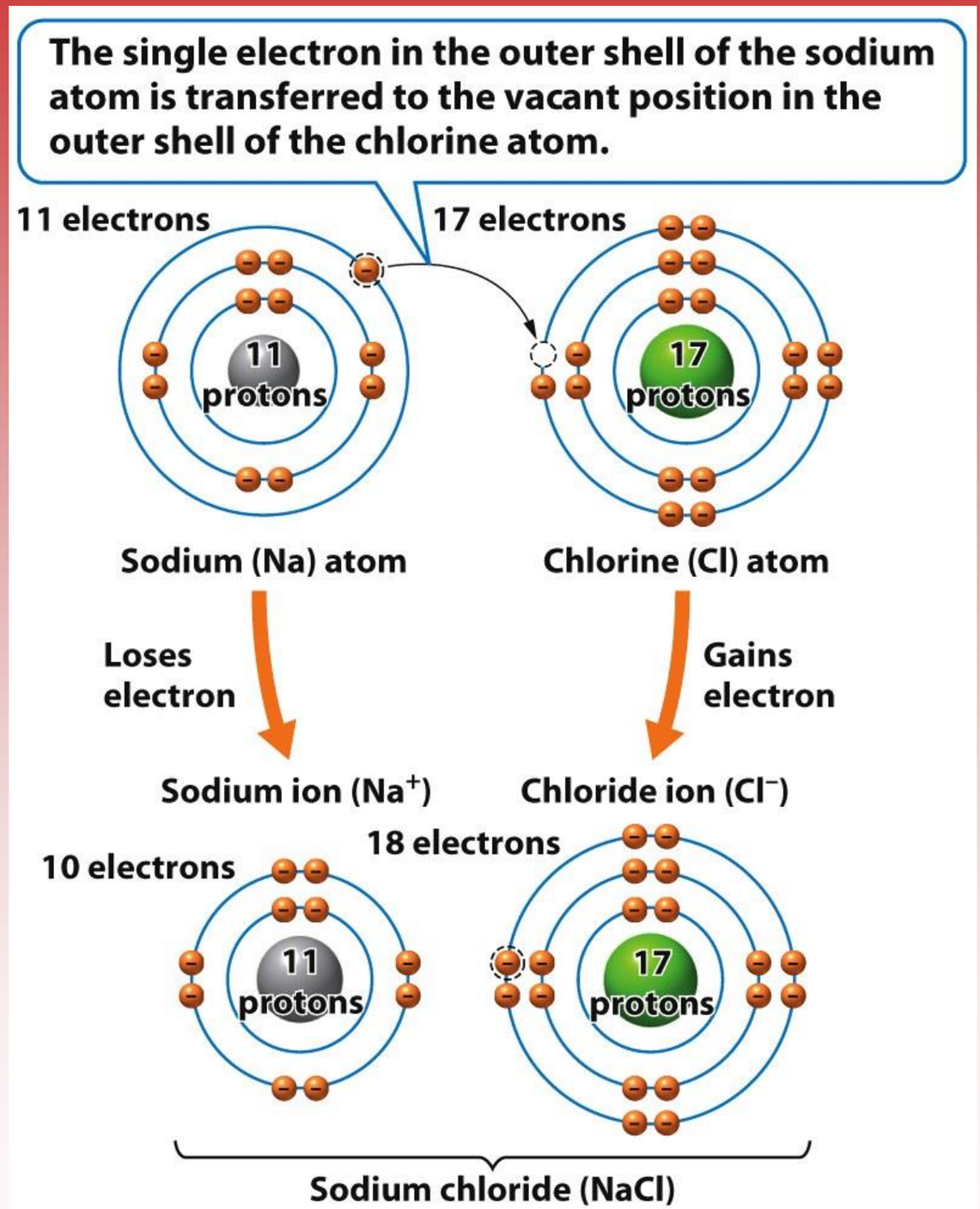

Figure 2.4
Environmental Science

Chemical bonds

- Hydrogen bonds- a weak chemical bond that forms when hydrogen atoms that are covalently bonded to one atom are attracted to another atom on another molecule.
    - Water is known as a polar molecule, one side is more positive and the other side is more negative.

Chemical bonds

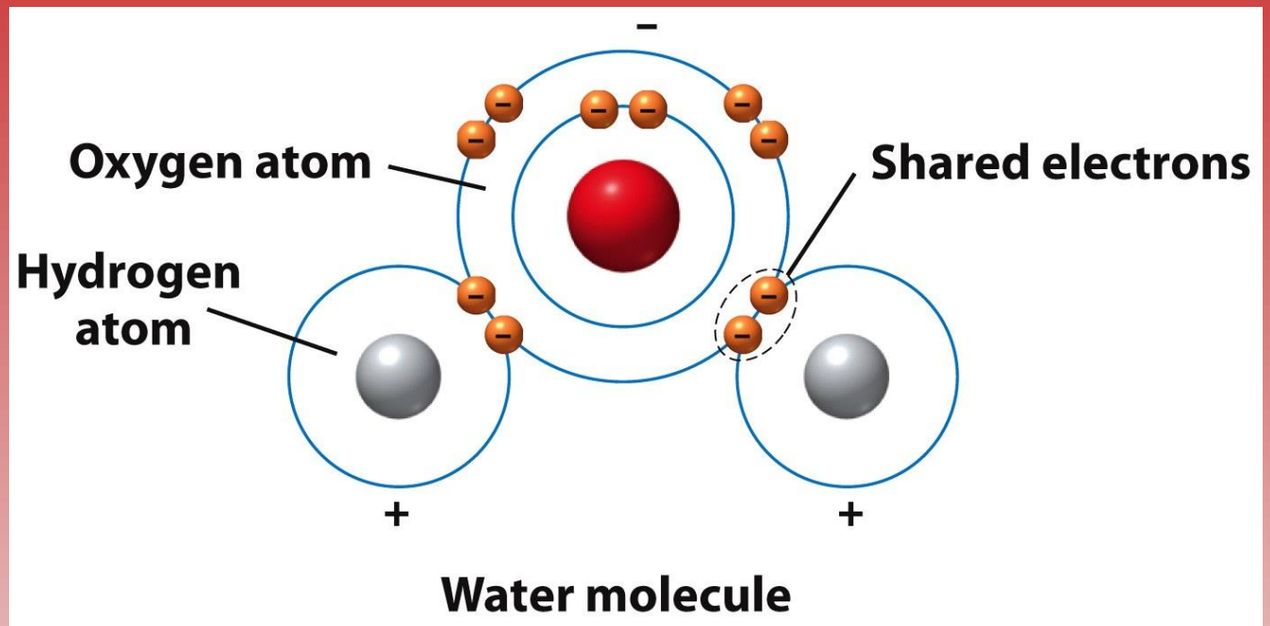

Figure 2.5a
Environmental Science

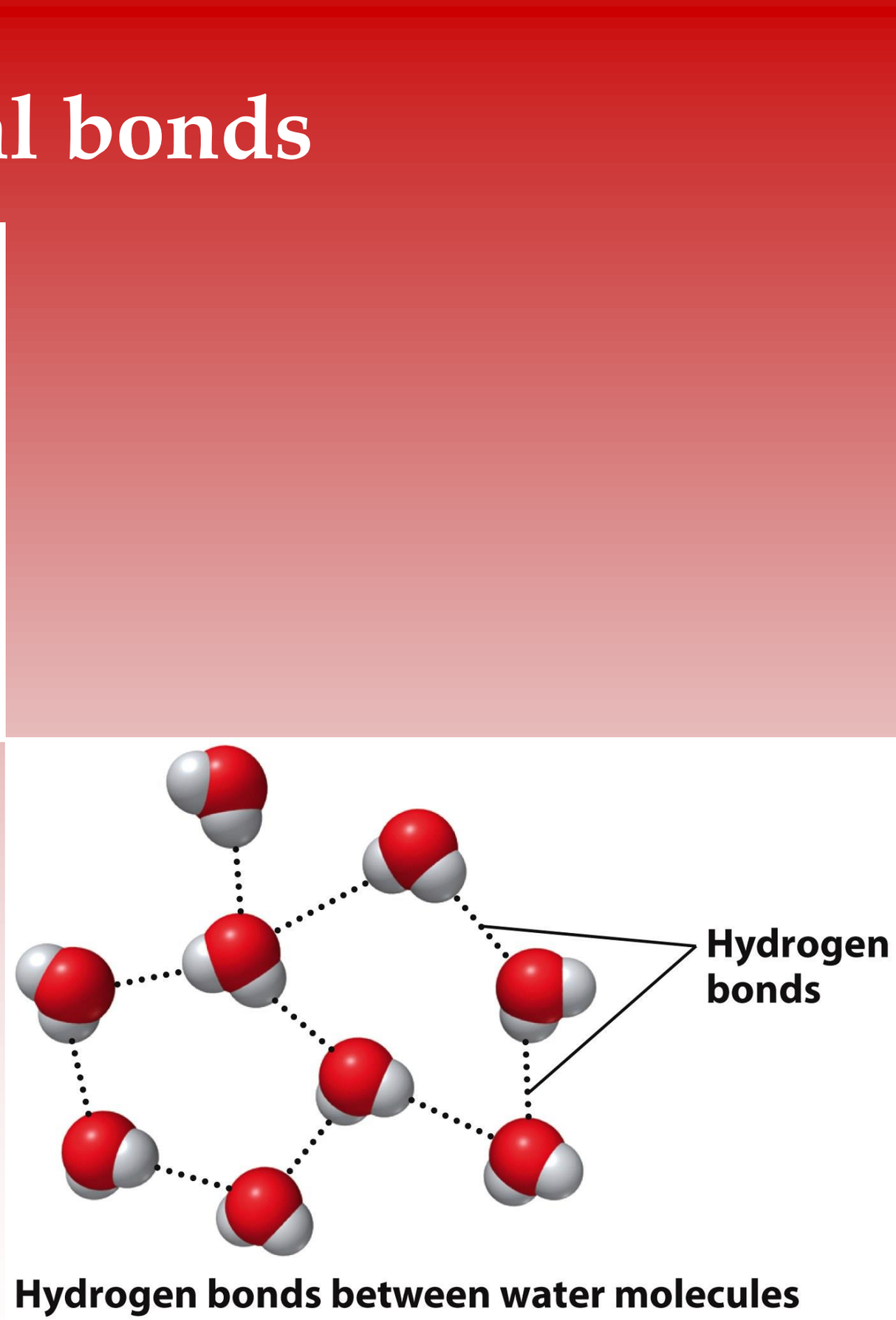

Figure 2.5b
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Properties of water

- Surface tension- the result from the cohesion of water molecules at the surface of a body of water.
- Capillary action- when adhesion of water molecules to a surface is stronger than cohesion between the molecules.

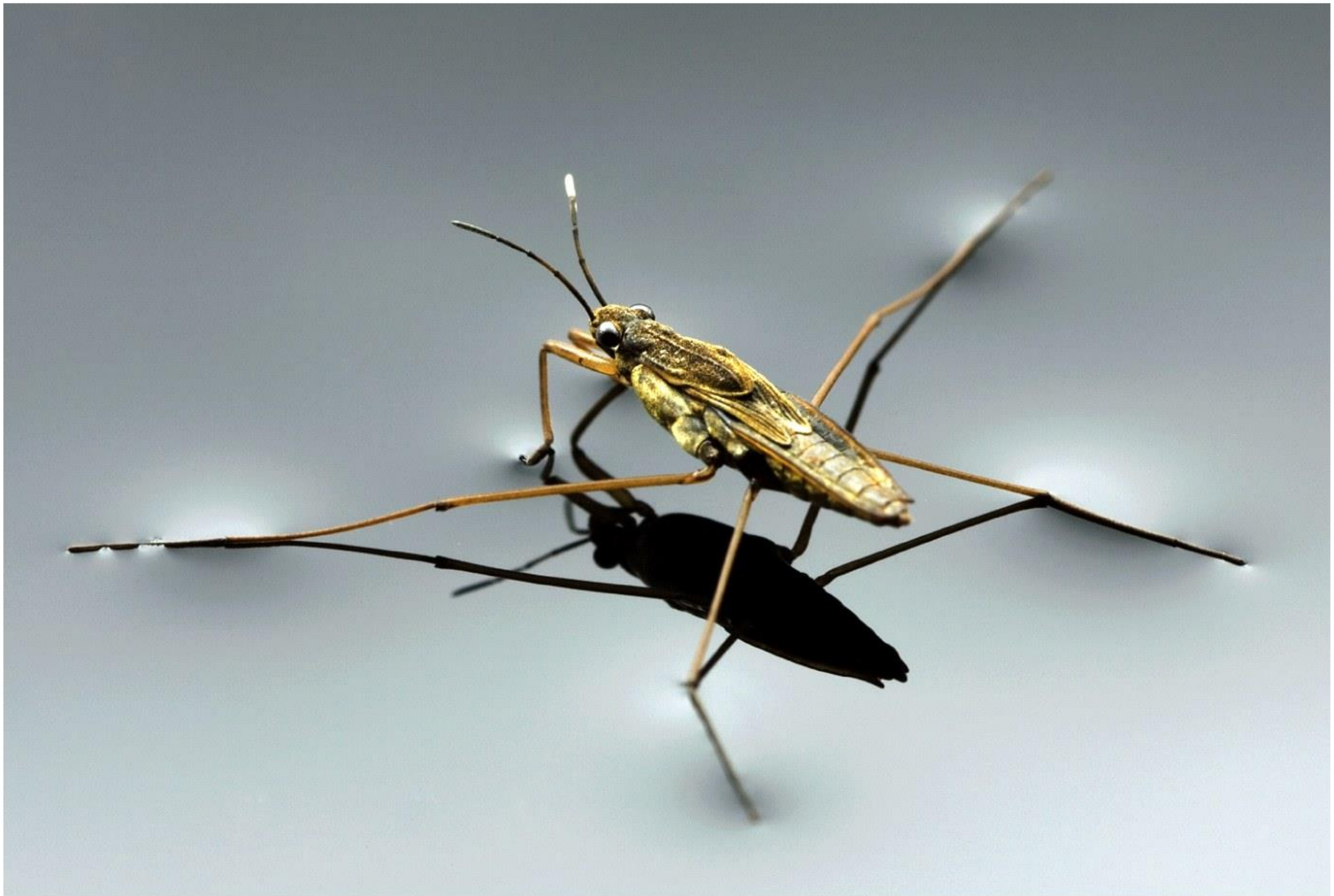

Figure 2.6
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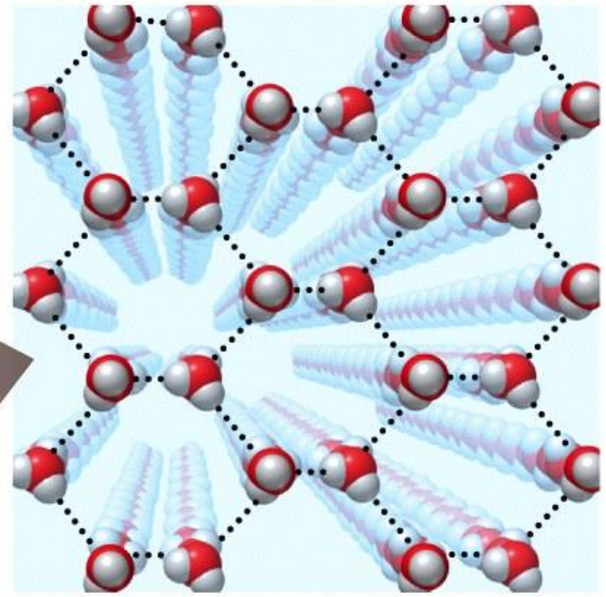
Properties of water

- Boiling and freezing- at Earth's surface, water boils at 100 degrees celsius and freezes at 0 degrees celsius.
- Water as a solvent- many substances dissolve well in water because their polar molecules bond easily with other polar molecules.

Properties of water



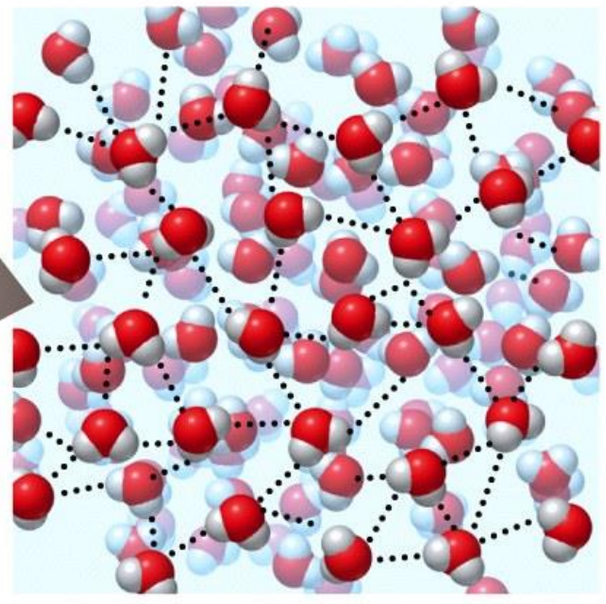


Figure 2.7
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acids, bases, and pH

- Acid- a substance that contributes hydrogen ions to a solution.
- Base- a substance that contributes hydroxide ions to a solution.

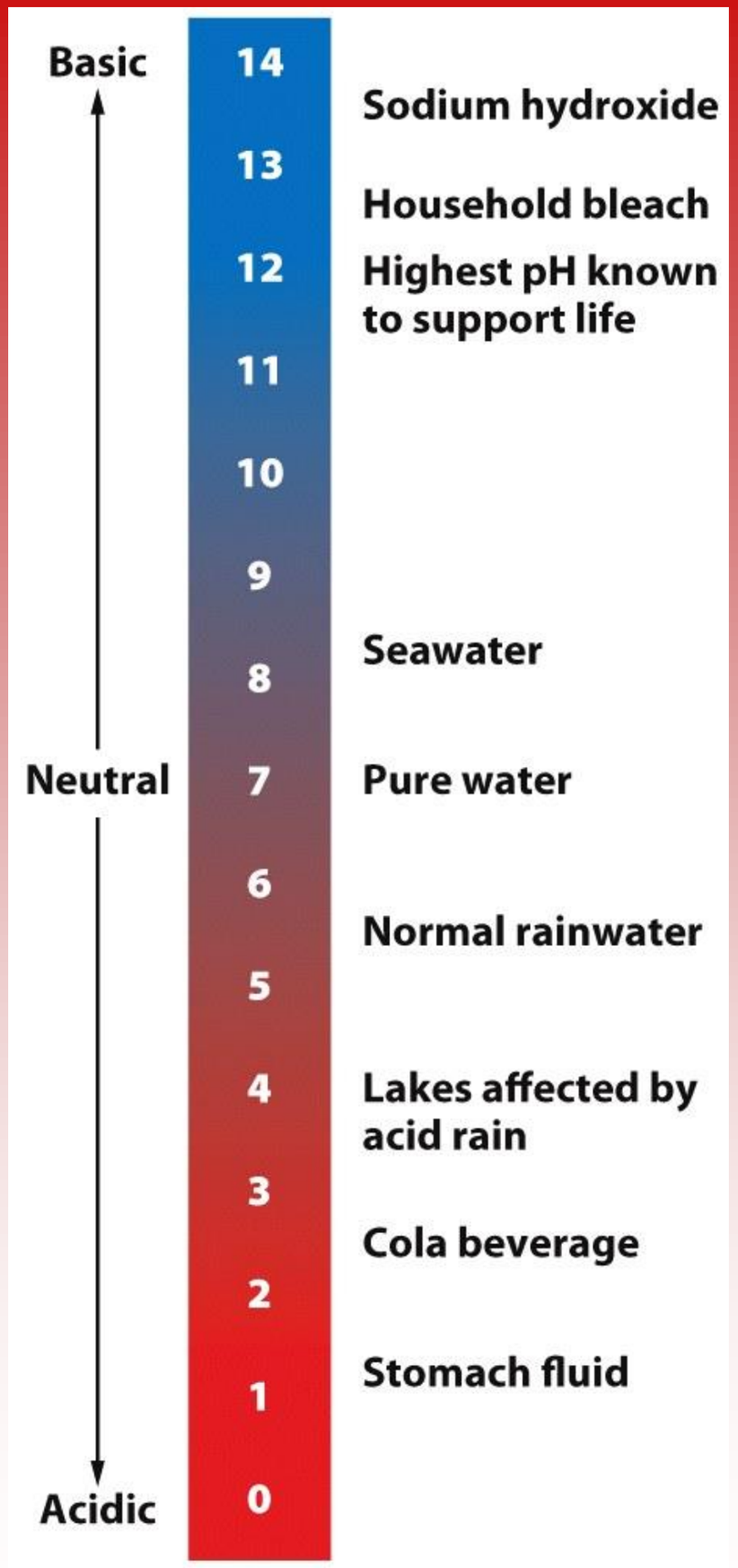

Figure 2.8
Environmental Science

acids, bases, and pH

- pH- a way to indicate the strength of acids and bases.
    - The pH scales ranges from 0 - 14.
    - A pH value of 7 is neutral
    - A pH above 7 is basic
    - A pH below 7 is acidic

acids, bases, and pH

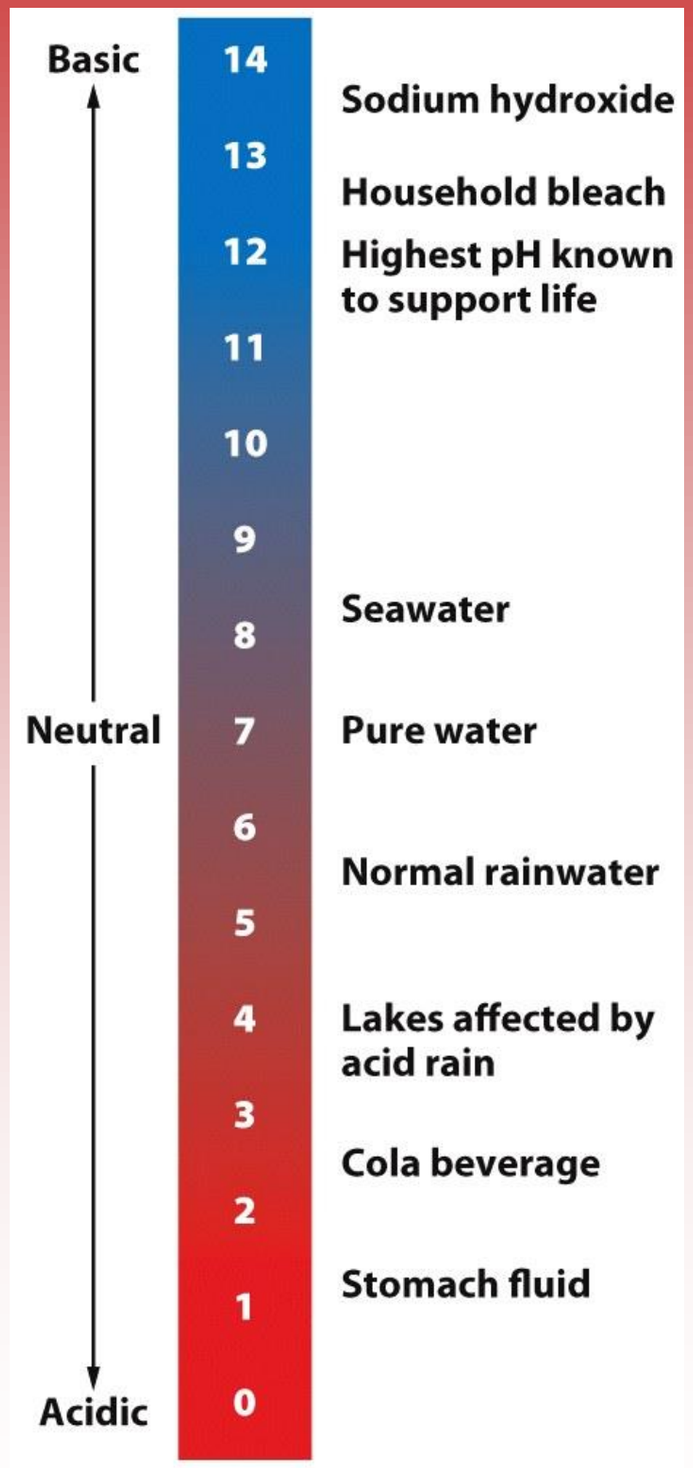

Figure 2.8
Environmental Science

Chemical reactions and the conservation of matter

- Chemical reaction- occurs when atoms separate from the molecules they are a part of or recombine with other molecules.
- Law of conservation of matter- matter cannot be created or destroyed; it can only change form.

Figure 2.9
Environmental Science

Biological molecules and cells

- Inorganic compounds- compounds that do not contain carbon or do contain carbon, but only carbon bound to elements other than hydrogen.
    - ex. NH_3, NaCL, H_2O, and CO_2
- Organic compounds- compounds that have carbon-carbon and carbon-hydrogen bonds.

Biological molecules and cells

- Carbohydrates- compounds composed of carbon, hydrogen,and oxygen atoms. Ex. C6H12O6
- Proteins- made up of long chains of nitrogen-containing organic molecules called amino acids.
- Nucleic Acids- organic compounds found in all living cells.
    - DNA
    - RNA
- Lipids- smaller biological molecules that do not mix with water. Ex. fats, waxes and steroids.

Biological molecules and cells

- Cells- the smallest structural and functional component of organisms.
    - single cells- Ex. bacteria and some algae
    - multicellular- Ex. bring shrimp

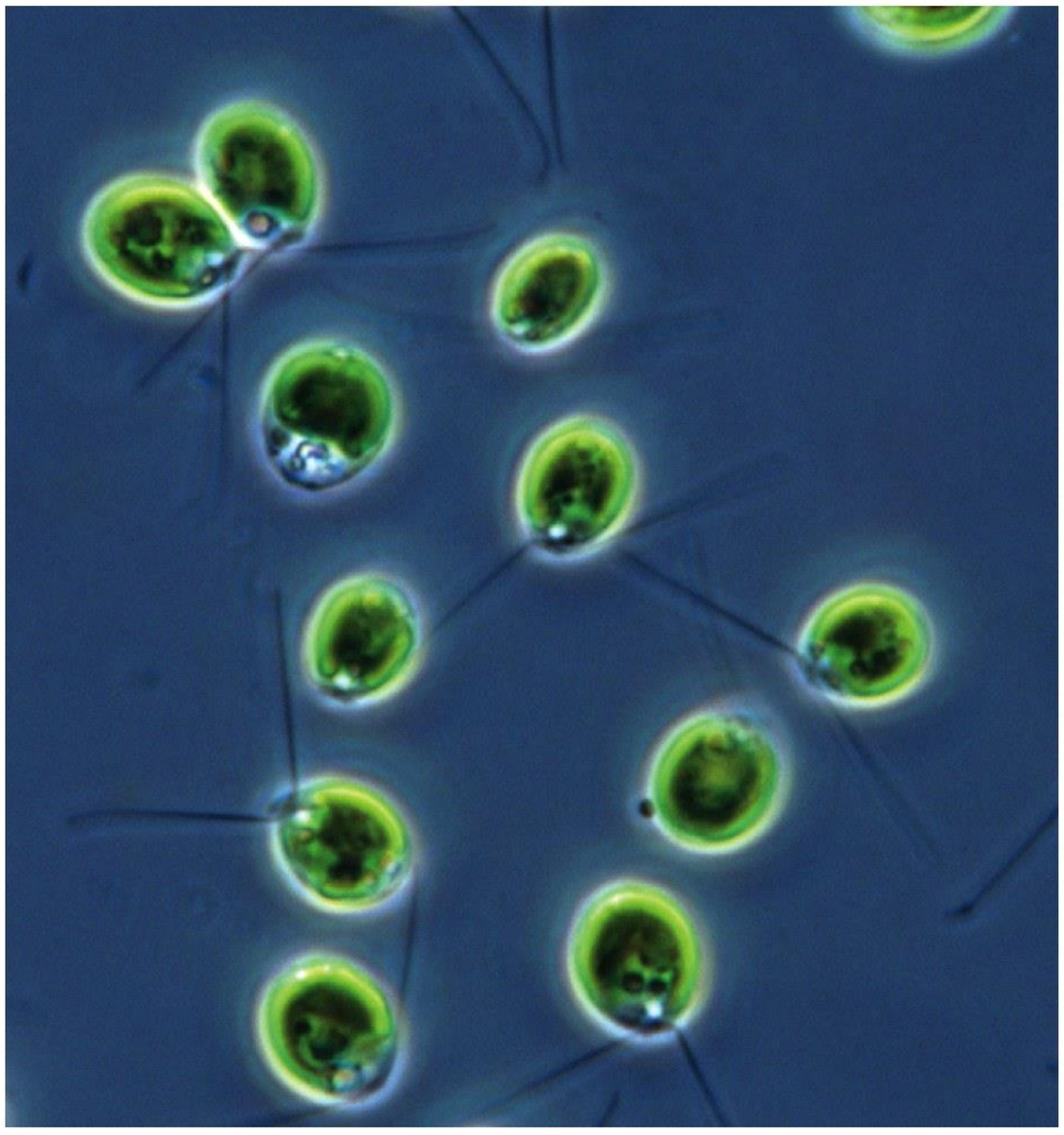

Figure 2.10a
Environmental Science

Figure 2.10b
Environmental Science

Energy is a fundamental component of environmental systems

Forms of Energy

- Energy- the ability to do work.
- Power- the rate at which work is done.
  - energy = power X time

TABLE 2.1 Common units of energy and their conversion into joules

Unit	Definition	Relationship to joules	Common uses
calorie	Amount of energy it takes to heat 1 gram of water 1°C	1 calorie = 4.184 J	Energy expenditure and transfer in ecosystems; human food consumption
Calorie	Food calorie; always shown with a capital C	1 Calorie = 1,000 calories = 1 kilocalorie (kcal)	Food labels; human food consumption
British thermal unit (Btu)	Amount of energy it takes to heat 1 pound of water 1°F	1 Btu = 1,055 J	Energy transfer in air conditioners and home and water heaters
kilowatt-hour (kWh)	Amount of energy expended by using 1 kilowatt of electricity for 1 hour	1 kWh = 3,600,000 J = 3.6 megajoules (MJ)	Energy use by electrical appliances, often given in kWh per year

Table 2.1
Environmental Science

Forms of Energy

- Kinetic energy- energy of motion.
- Potential energy- energy that is stored.
- Chemical energy- potential stored in chemical bonds.
- Temperature- the measure of the average kinetic energy of a substance.

Figure 2.12
Environmental Science

First law of thermodynamics

- Energy is neither created or destroyed.
- You can't get something from nothing.

Figure 2.13
Environmental Science

Second law of thermodynamics

- **When energy is transformed, the quantity of energy remains the same, but its ability to do work diminishes.**

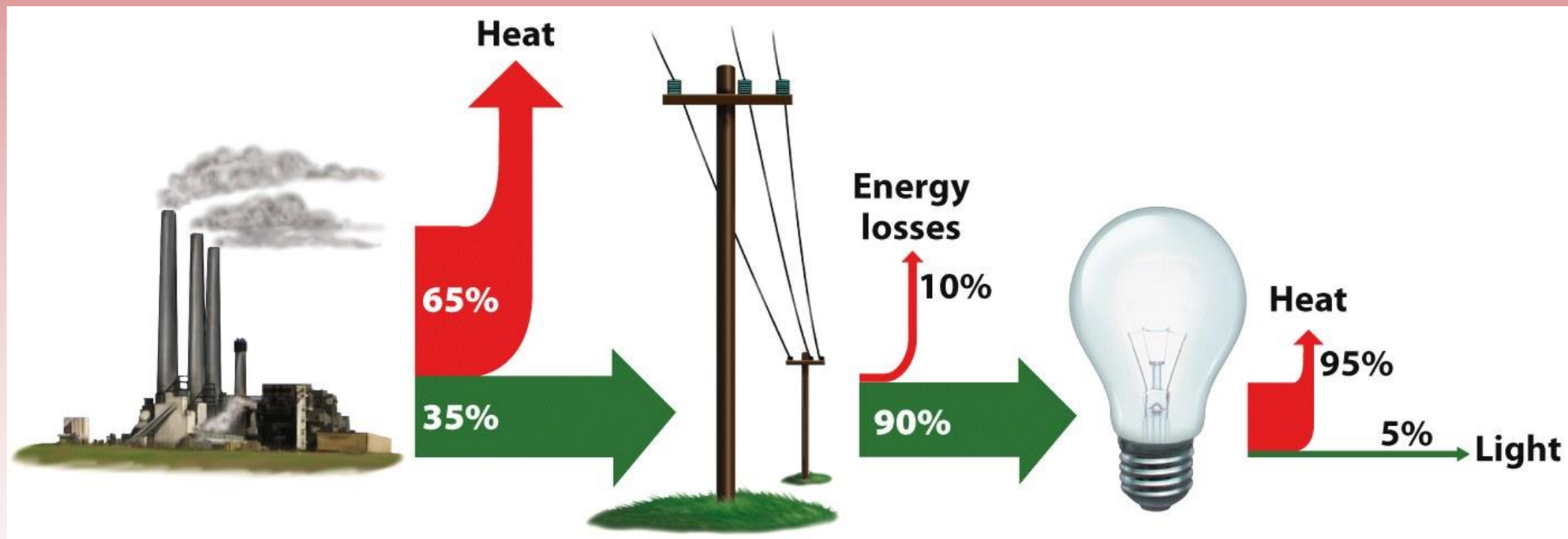

Figure 2.15
Environmental Science

Figure 2.15

Second law of thermodynamics

- Energy Efficiency- the ratio of the amount of work that is done to the total amount of energy that is introduced into the system.

(a) Traditional fireplace

(b) Modern woodstove

Figure 2.14
Environmental Science

Figure 2.14

Second law of thermodynamics

- Energy quality- the ease with which an energy source can be used for work.
- Entropy- all systems move toward randomness rather than toward order.
- This randomness is always increasing in a system, unless new energy from the outside of the system is added to create order.

Energy conversions underlie all ecological processes

Figure 2.17a
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Figure 2.17b
Environmental Science

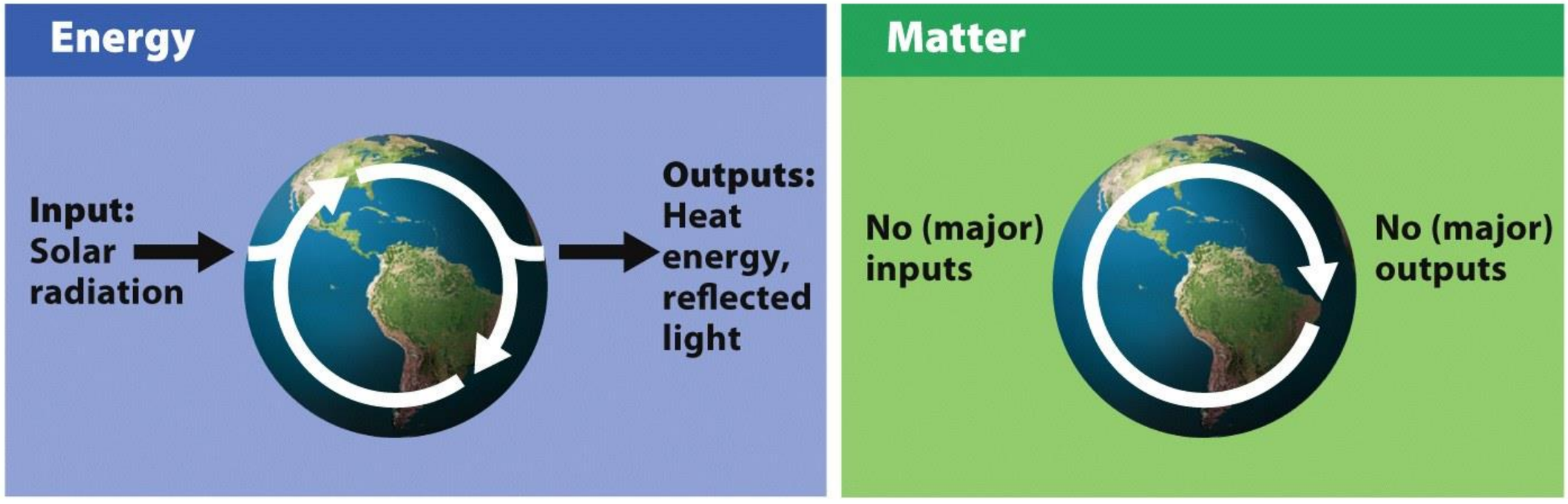
Figure 2.17c
Environmental Science

Figure 2.17d
Environmental Science

System analysis shows how matter and energy flow in the environment

- Open system- exchanges of matter or energy occur across system boundaries.

- Closed system- matter and energy exchanges across system boundaries do not occur.



(a) Open system

(b) Closed system

Figure 2.18
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steady states

- Steady state- in a system, when input equals output it is said to be in a steady state.

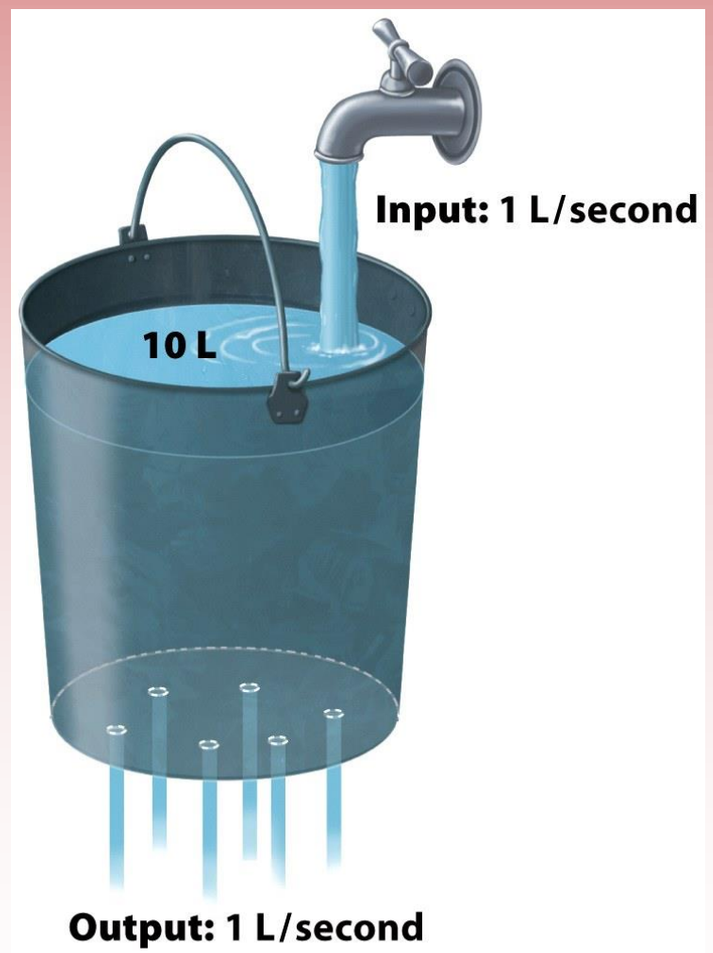

Figure 2.20
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steady states

- Negative feedback loops- when a system responds to change by returning to its original state, or at least by decreasing the rate at which the change is occurring.
- Positive feedback loops- when a system responds to change by increasing the rate at which the change is occurring.

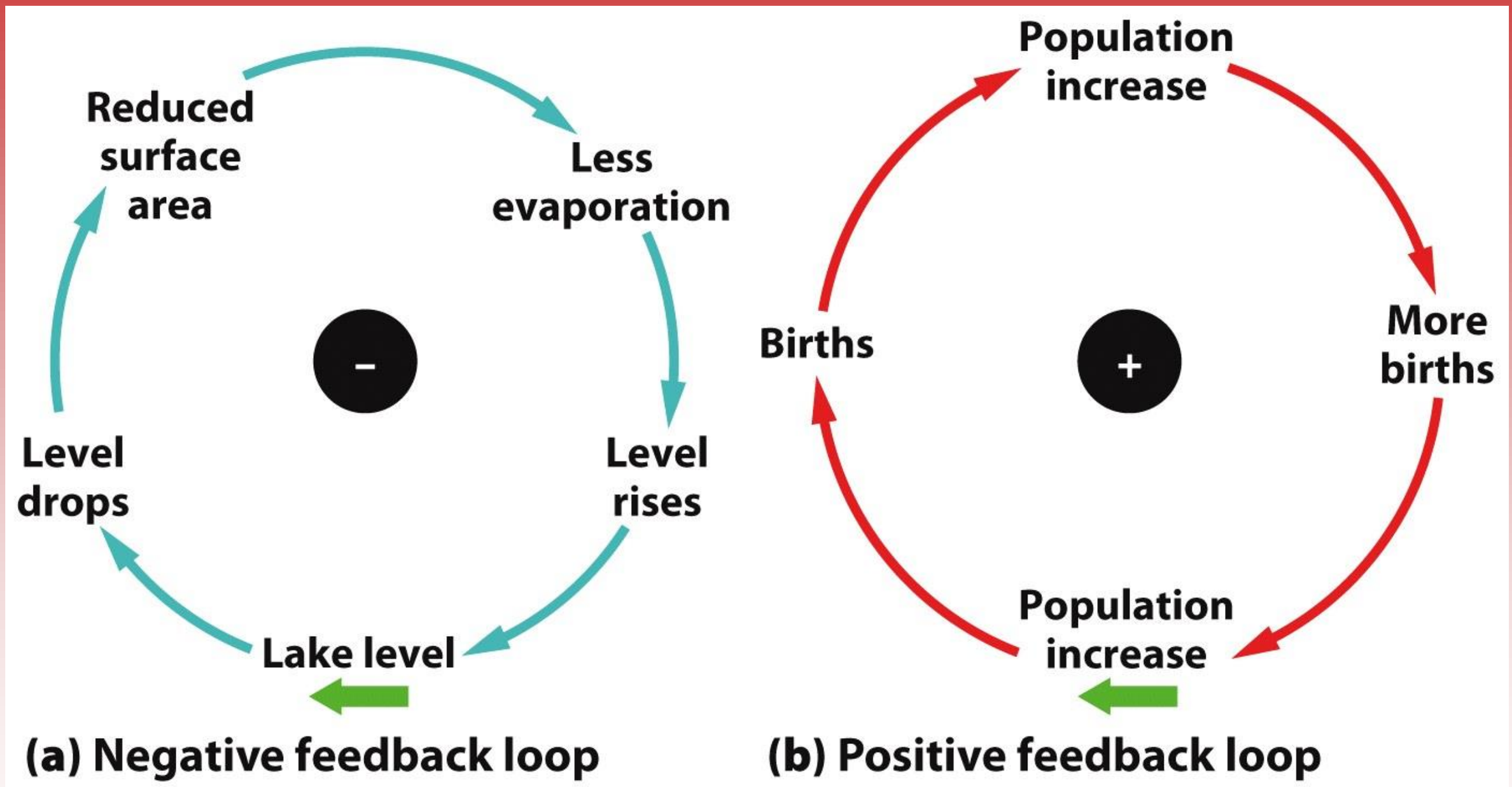

Figure 2.21
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