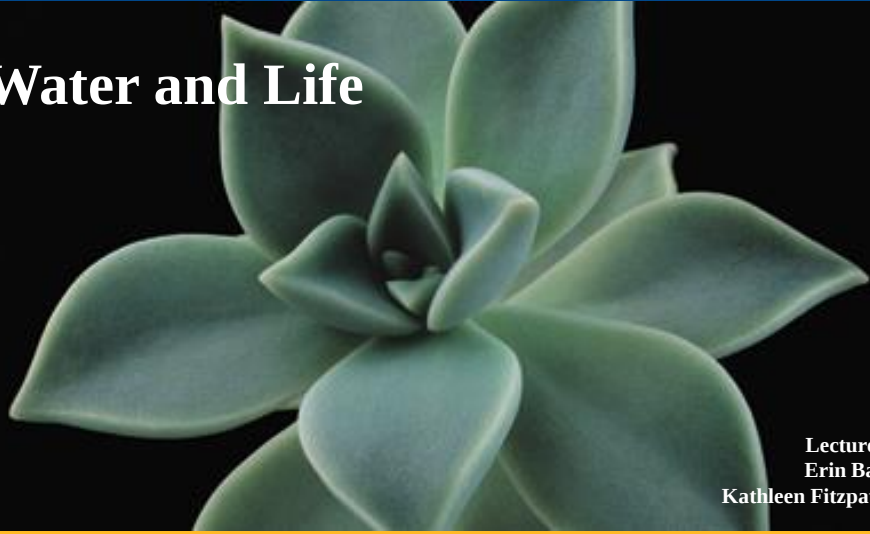


LECTURE PRESENTATIONS
For CAMPBELL BIOLOGY, NINTH EDITION
Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson

Chapter 3

Water and Life



Lectures by
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Overview: The Molecule That Supports All of Life

- Water is the **biological medium** on Earth
- All living organisms require water more than any other substance
- **Most cells are surrounded by water**, and **cells themselves are about 70–95% water**
- The abundance of water is the main reason the Earth is habitable

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Fig. 3-1



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Figure 3.1



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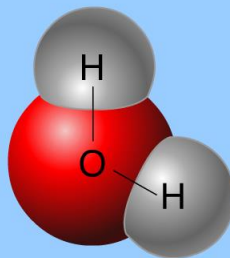
Concept 3.1: The **polarity** of water molecules results in hydrogen bonding

- The water molecule is a **polar molecule**: *The opposite ends have opposite charges*
- Polarity allows water molecules to form **hydrogen bonds** with each other

PLAY

Animation: Water Structure

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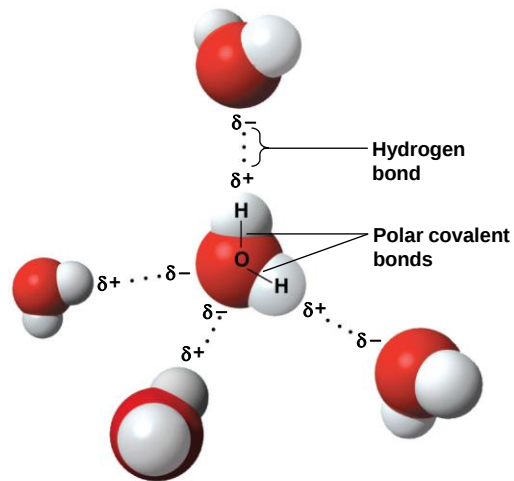


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Animation: Water Structure
Right-click slide/select "Play"

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Figure 3.2



Concept 3.2: **Four emergent properties** of water contribute to Earth's fitness for life

- Four of water's properties that facilitate an environment for life are:
 - **Cohesive behavior**
 - **Ability to moderate temperature**
 - **Expansion upon freezing**
 - **Versatility as a solvent**

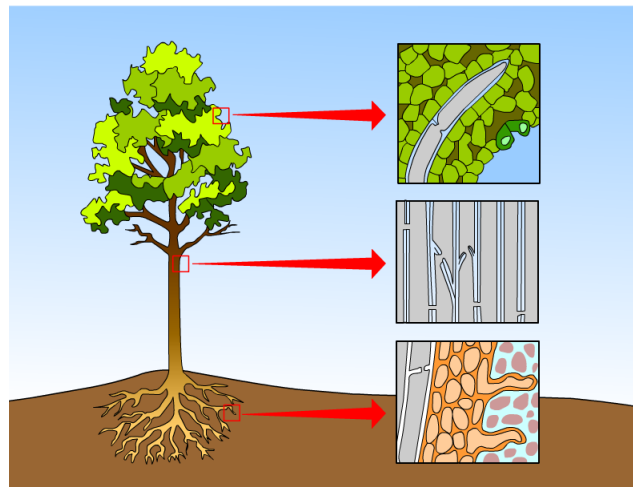
Cohesion

- Collectively, hydrogen bonds hold water molecules together, a phenomenon called **cohesion**
- Cohesion helps the transport of water against gravity in plants
- **Adhesion** is an attraction between different substances, for example, between water and plant cell walls

PLAY

Animation: Water Transport

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Animation: Water Transport
Right-click slide/select "Play"

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Water transport in plants.

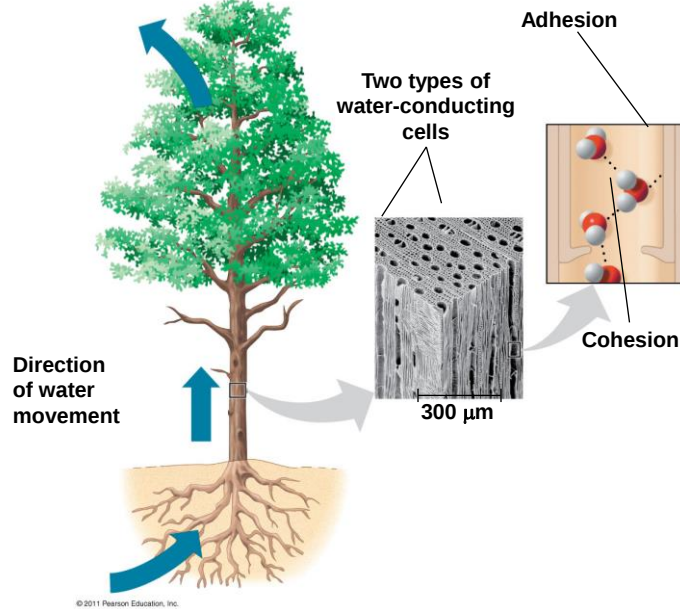
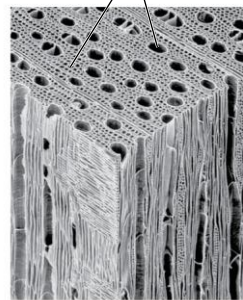


Figure 3.3a

**Two types of
water-conducting
cells**



$300\ \mu\text{m}$

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- **Surface tension** is a measure of how hard it is to break the surface of a liquid
- Surface tension is related to cohesion

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Walking on water



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Moderation of Temperature

- Water absorbs heat from warmer air and releases stored heat to cooler air
- Water can absorb or release a large amount of heat with only a slight change in its own temperature

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Heat and Temperature

- **Kinetic energy** is the energy of motion
- **Heat** is a measure of the *total amount* of kinetic energy due to molecular motion
- **Temperature** measures *the intensity* of heat due to the *average* kinetic energy of molecules

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-
- The **Celsius scale** is a measure of temperature using **Celsius degrees ($^{\circ}\text{C}$)**
 - A **calorie (cal)** is the amount of heat required to raise the temperature of 1 g of water by 1°C
 - The “calories” on food packages are actually **kilocalories (kcal)**, where $1\text{ kcal} = 1,000\text{ cal}$
 - The **joule (J)** is another unit of energy where $1\text{ J} = 0.239\text{ cal}$, or $1\text{ cal} = 4.184\text{ J}$
-

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Water's High Specific Heat

- The **specific heat** of a substance is the amount of heat that must be absorbed or lost for 1 g of that substance to change its temperature by 1°C
 - The **specific heat of water** is **$1\text{ cal/g}^{\circ}\text{C}$**
 - Water resists changing its temperature because of its high specific heat
-

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-
- Water's high specific heat can be traced to hydrogen bonding
 - Heat is absorbed when hydrogen bonds break
 - Heat is released when hydrogen bonds form
 - The high specific heat of water **minimizes temperature fluctuations** to within limits that permit life

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Evaporative Cooling

- **Evaporation** is transformation of a substance from liquid to gas
- **Heat of vaporization** is the heat a liquid must absorb for 1 g to be converted to gas
- As a liquid evaporates, its remaining surface cools, a process called **evaporative cooling**
- Evaporative cooling of water helps stabilize temperatures in organisms and bodies of water

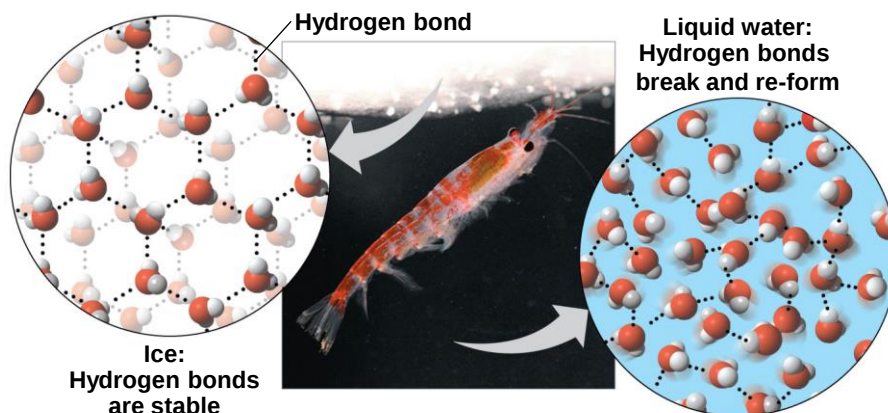
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Insulation of Bodies of Water by Floating Ice

- Ice floats in liquid water because hydrogen bonds in ice are more “ordered,” making ice less dense
- Water reaches its greatest density at 4° C
- If ice sank, all bodies of water would eventually freeze solid, making life impossible on Earth

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Figure 3.6



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Figure 3.6a



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Water: The Solvent of Life

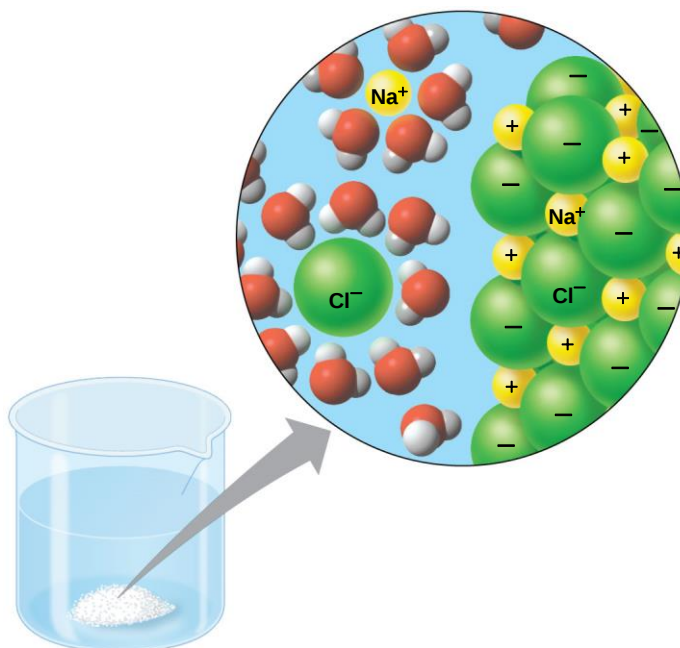
- A **solution** is a liquid that is a homogeneous mixture of substances
- A **solvent** is the dissolving agent of a solution
- The **solute** is the substance that is dissolved
- An **aqueous solution** is one in which water is the solvent

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- Water is a versatile solvent due to its polarity, which allows it to form hydrogen bonds easily
- When an ionic compound is dissolved in water, each ion is surrounded by a sphere of water molecules called **a hydration shell**

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Figure 3.7

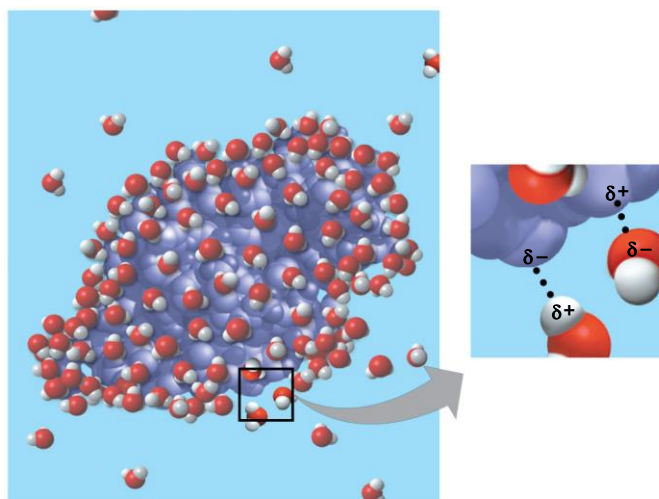


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- Water can also dissolve compounds made of **nonionic polar molecules**
- Even **large polar molecules** such as proteins **can dissolve in water** if they have ionic and polar regions

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Figure 3.8



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Hydrophilic and Hydrophobic Substances

- A **hydrophilic** substance is one that has an affinity for water
- A **hydrophobic** substance is one that does not have an affinity for water
- **Oil molecules** are **hydrophobic** because they have relatively nonpolar bonds
- A **colloid** is a stable suspension of fine particles in a liquid

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***Solute Concentration** in Aqueous Solutions*

- Most biochemical reactions occur in water
- Chemical reactions **depend on collisions** of molecules and therefore on **the concentration of solutes in an aqueous solution**

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- **Molecular mass** *is the sum of all masses of all atoms in a molecule*
- Numbers of molecules are usually measured in **moles**, where **1 mole (mol) = 6.02×10^{23} molecules**
- **Avogadro's number** and the unit **dalton** were defined such that **6.02×10^{23} daltons = 1 g**
- **Molarity (M)** *is the number of moles of solute per liter of solution*

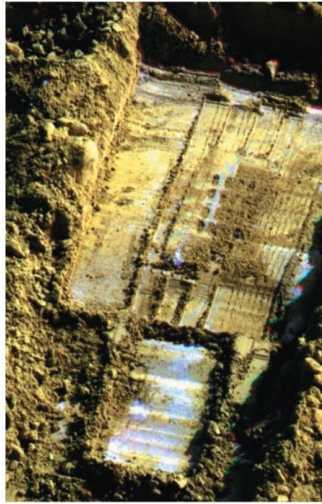
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Possible Evolution of Life on Other Planets with Water

- The **remarkable properties of water** support life on Earth in many ways
- Astrobiologists seeking life on other planets are concentrating their search on planets with water
- To date, more than **200 planets** have been found outside our solar system; **one or two of them contain water**
- In our solar system, **Mars** has been found to have water

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Subsurface ice and morning frost on Mars.



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Concept 3.3: **Acidic** and **basic** conditions affect living organisms

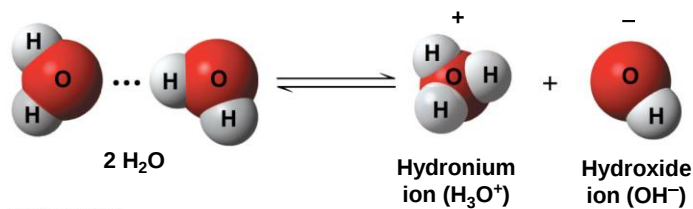
- A hydrogen atom in a hydrogen bond between two water molecules can shift from one to the other:
 - The hydrogen atom leaves its electron behind and is transferred as a **proton**, or **hydrogen ion (H^+)**
 - The molecule with the extra proton is now a **hydronium ion (H_3O^+)**, though it is often represented as **H^+**
 - The molecule that lost the proton is now a **hydroxide ion (OH^-)**

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- Water is in a state of dynamic equilibrium in which water molecules dissociate at the same rate at which they are being reformed

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Figure 3.UN02



- Though statistically rare, the dissociation of water molecules has a great effect on organisms
- Changes in concentrations of H^+ and OH^- can drastically affect the chemistry of a cell

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Effects of Changes in pH

- Concentrations of H^+ and OH^- are equal in pure water
- Adding certain solutes, called acids and bases, modifies the concentrations of H^+ and OH^-
- Biologists use something called the pH scale to describe whether a solution is acidic or basic (the opposite of acidic)

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Acids and Bases

- An **acid** is any substance that increases the H^+ concentration of a solution
- A **base** is any substance that reduces the H^+ concentration of a solution

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The pH Scale

- In any aqueous solution at $25^\circ C$ the product of H^+ and OH^- is constant and can be written as

$$[H^+][OH^-] = 10^{-14}$$
- The **pH** of a solution is defined by the **negative logarithm of H^+ concentration**, written as

$$pH = -\log [H^+]$$
- For a neutral aqueous solution

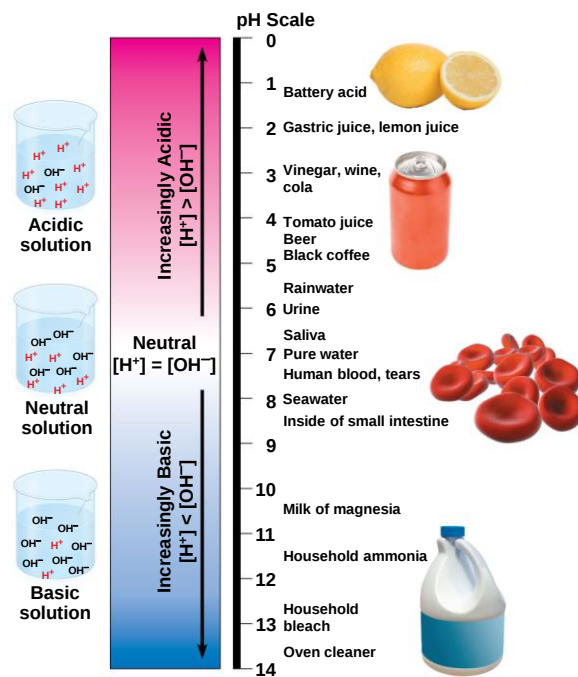
$$[H^+] \text{ is } 10^{-7} = -(-7) = 7$$

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- Acidic solutions have pH values less than 7
- Basic solutions have pH values greater than 7
- Most biological fluids have pH values in the range of **6 to 8**

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Figure 3.10



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Figure 3.10a



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Figure 3.10b



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Figure 3.10c



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Figure 3.10d



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Buffers

- The internal pH of most living cells must remain close to pH 7
- **Buffers** are substances that *minimize* changes in concentrations of H^+ and OH^- in a solution
- Most buffers consist of an **acid-base pair** that reversibly combines with H^+
- Buffers are made either of **weak acid + its conjugate base** or **weak base + its conjugate acid**

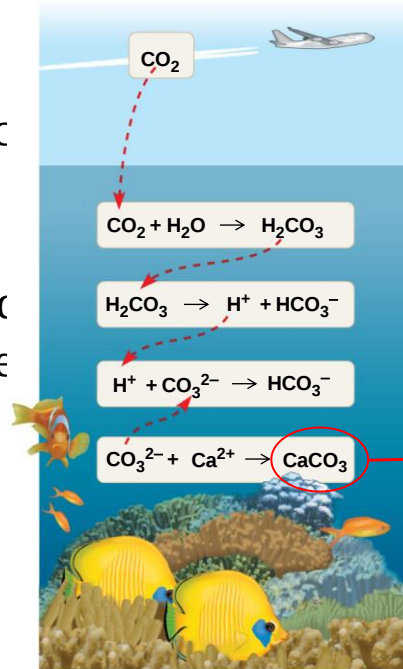
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Acidification: A Threat to Water Quality

- **Acid precipitation** refers to rain, snow, or fog with **a pH lower than 5.6**
- Acid precipitation is caused mainly by the mixing of different pollutants (**Sulfur oxides and nitric oxides**) with water in the air and can fall at some distance from the source of pollutants
- Acid precipitation **can damage life in lakes and streams**
- Effects of acid precipitation on **soil chemistry** are contributing to the decline of some forests

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Atmospheric CO_2 from human activities and its fate in the oceans.



Less carbonate ions are available for calcification by marine organisms like corals!!

- As seawater acidifies, **H^+ ions combine with carbonate ions to produce bicarbonate**
- Carbonate is required for **calcification** (production of calcium carbonate) by many **marine organism**, including **reef-building corals**

- The **burning of fossil fuels** is also a major source of sulfur oxides and nitrogen oxides
- These compounds react with water in the air to form strong acids that fall in rain or snow
- **Acid precipitation** is rain, fog, or snow with a pH **lower than 5.2**
- Acid precipitation damages life in lakes and streams and changes soil chemistry on land

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