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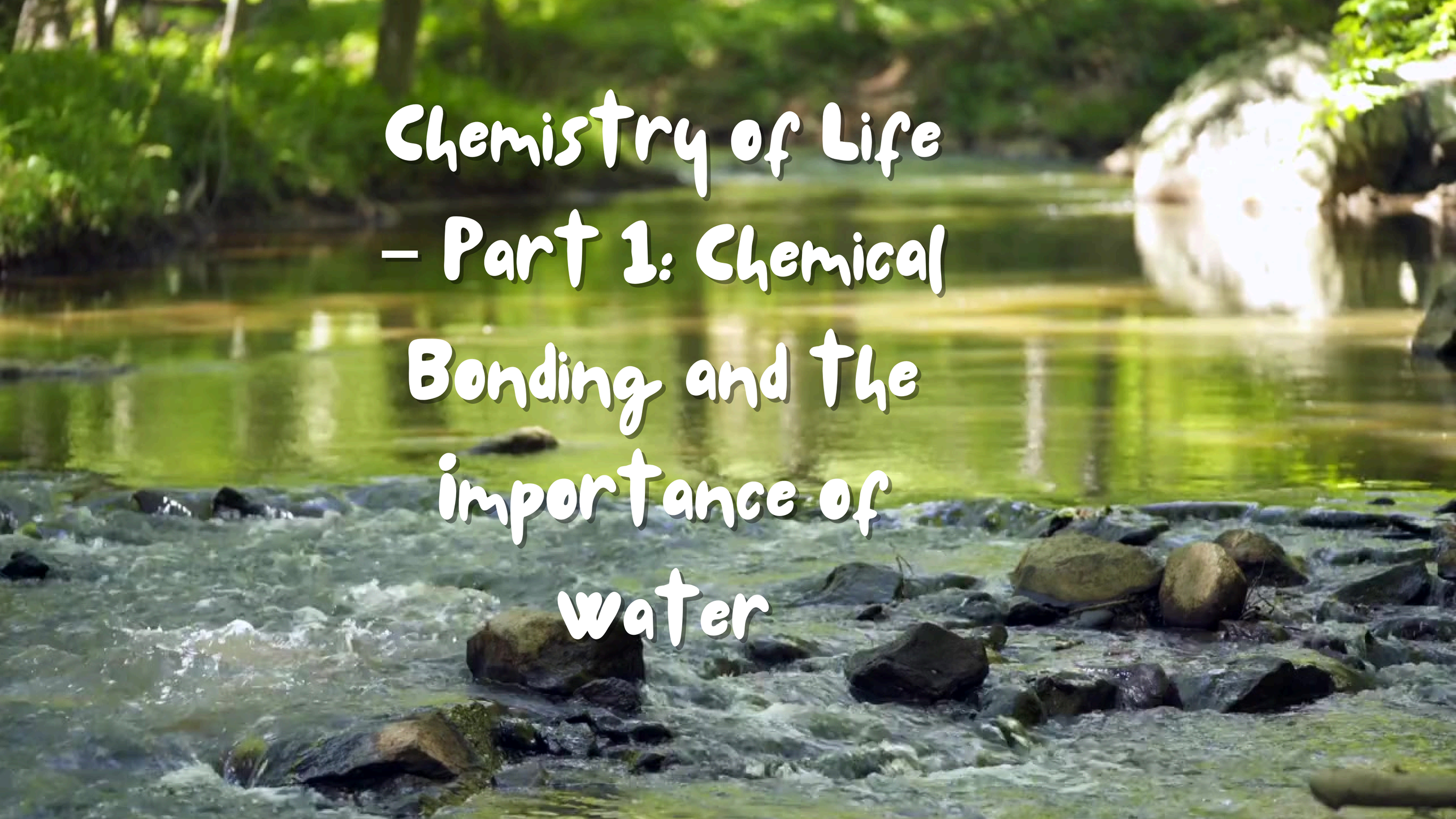
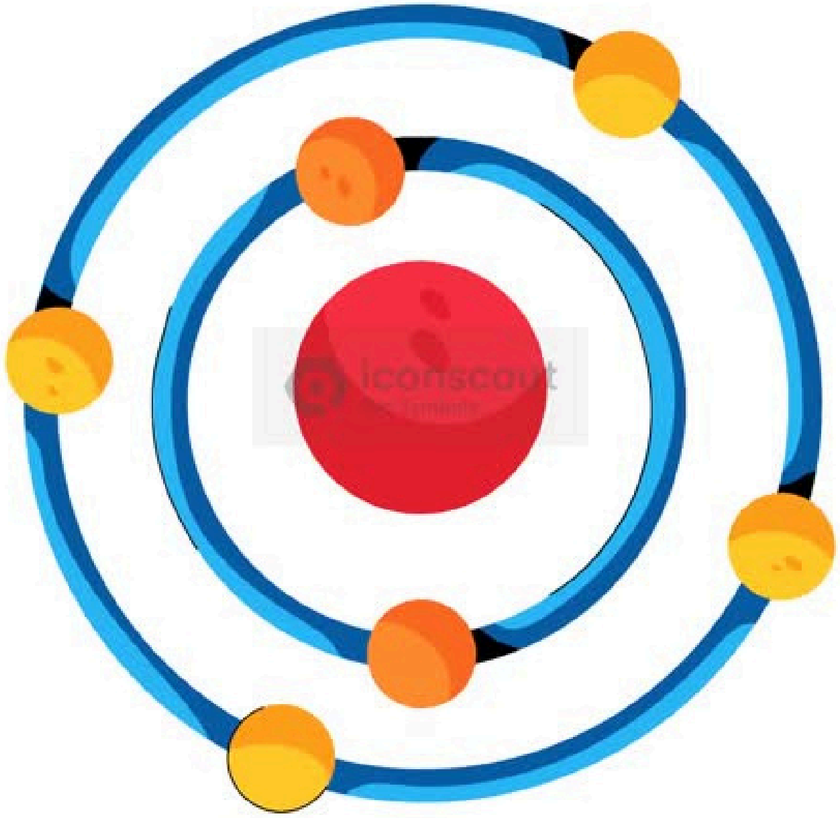

Chemistry of Life
– Part 1: Chemical
Bonding and the
importance of
water

Why Chemistry Matters in Biology:

- **All living things, from dragonflies to plants and cows, are made of chemical substances.**
- **Understanding chemical bonds helps us understand how molecules function in cells and organisms.**
- **Example: To understand water's properties, you must understand chemical bonding and dipoles.**



The Atom – Basic Unit of Matter

Nucleus:

Contains positive protons and neutral neutrons

Electron shells surround the nucleus with negative electrons

A full outer shell is a stable, non-reactive atom

Most atoms do not have a full outer shell

➡ they react to become stable

How Atoms Achieve Stability:

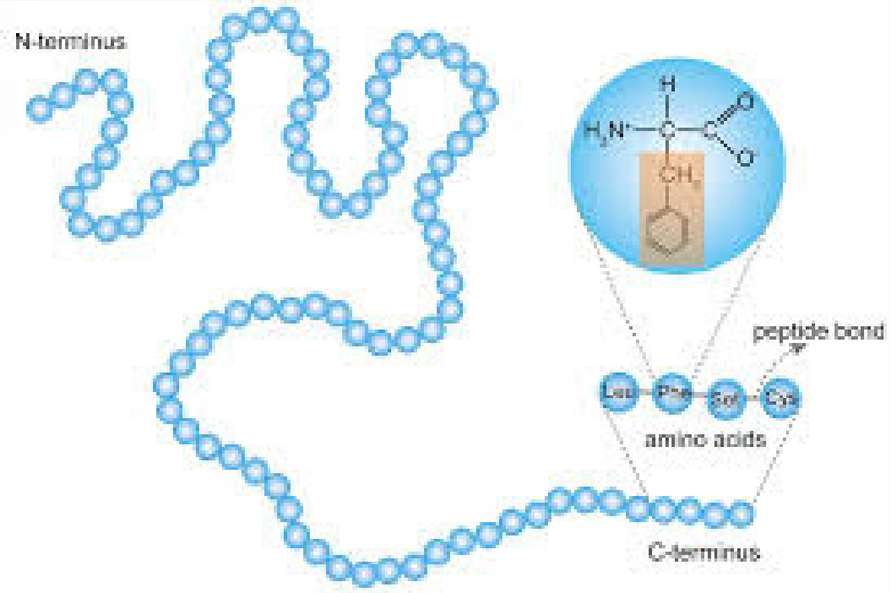
- **Atoms can gain, lose, or share electrons to complete their outer shells via:**

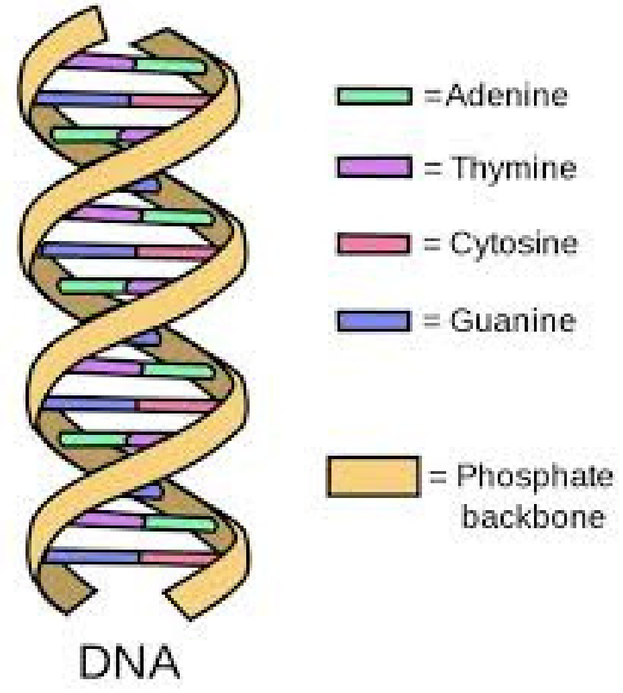
Bond Type	Description	Example
Ionic Bond	**Electrons are transferred from one atom to another**	**Sodium (Na^+) + Chloride (Cl^-) = NaCl**
Covalent Bond	**Electrons are shared between atoms**	**H_2O – Water molecule**

Biological Importance

Chemical bonding determines molecule structure, solubility, and function

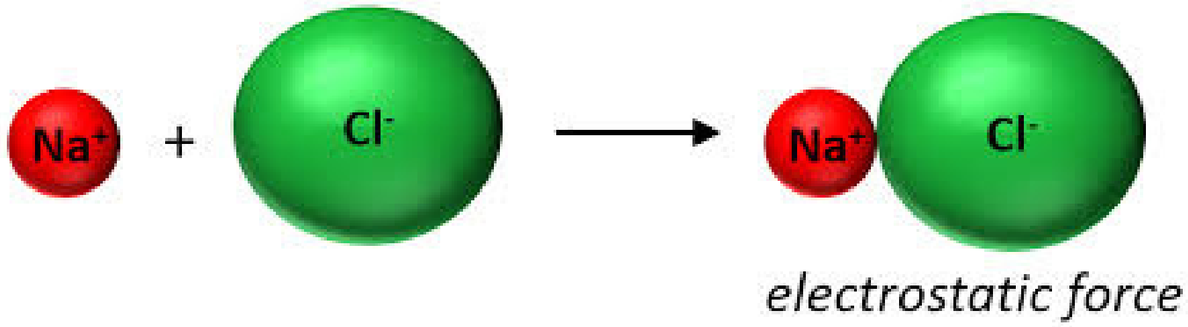
Critical for understanding biological molecules like water, DNA, and proteins



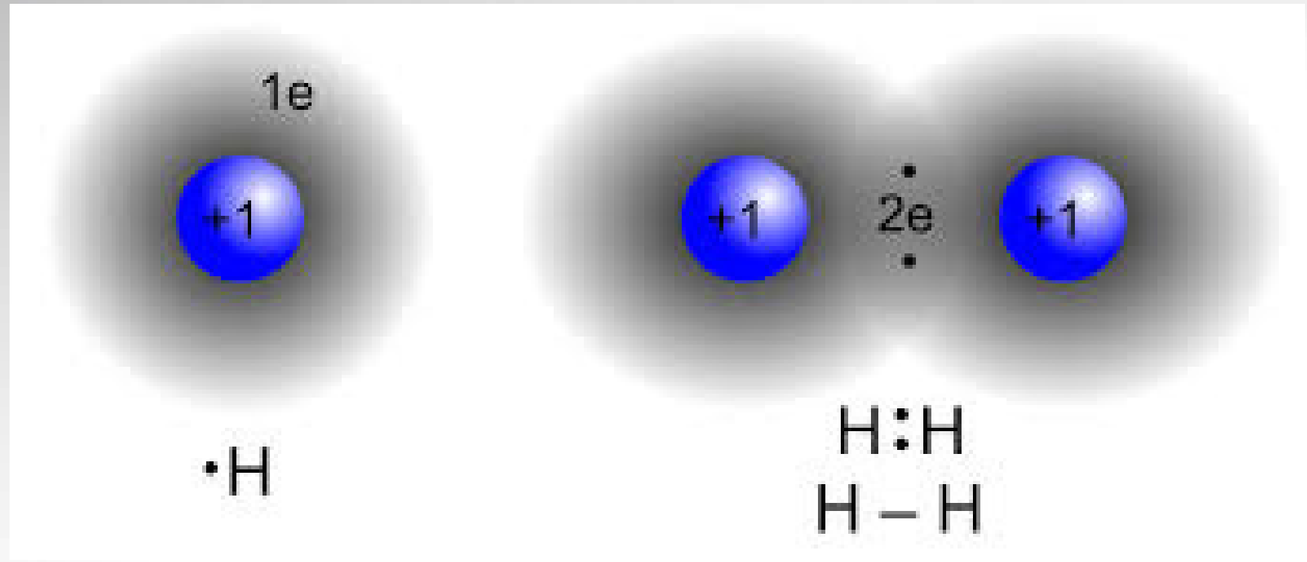


Ionic Bonding

- Involves transfer of electrons
- One atom gains electrons → becomes an anion (negatively charged)
- One atom loses electrons → becomes a cation (positively charged)
- Held together by strong electrostatic attraction between opposite charges
- Example: $Na^+ + Cl^- \rightarrow NaCl$ (table salt)
- 🧲 Ionic Bond = Strong attraction between oppositely charged ions



Covalent Bonding



- Involves sharing of electrons between atoms
- Covalent bonds are very strong
- Molecules formed are usually neutral
- Electrons are not evenly shared
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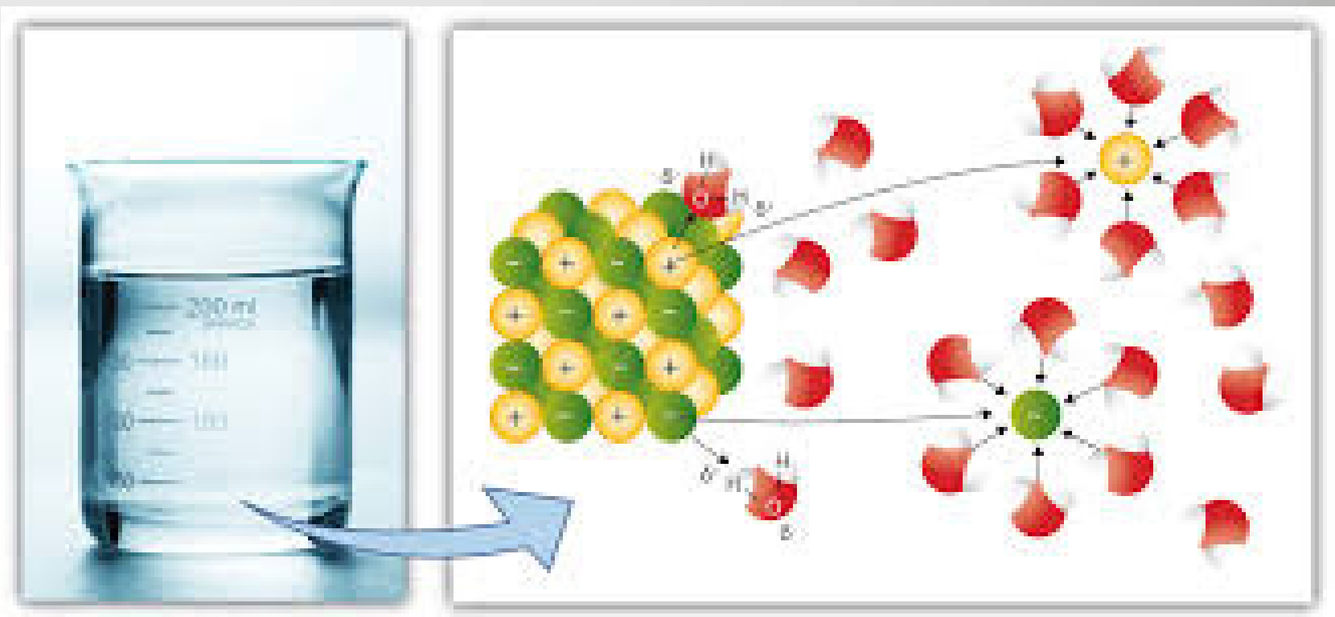
- **Polar Covalent Bonds**
- One part of the molecule becomes slightly negative (δ^-)
- Other part becomes slightly positive (δ^+)
- This creates a dipole
- 💧 **Example: Water (H_2O)**
- Oxygen pulls electrons closer → δ^-
- Hydrogen becomes δ^+
- Result: polar molecule

The Importance of Inorganic Ions in Living Organisms



- **Dissociation in Water**
- **Ionic substances dissolve and separate into ions in water**
- **Cells are 60–70% water, so most ionic substances exist as ions in living organisms**
- **These ions play critical roles in both cellular function and the body systems of organisms**

Important Anions (–ve ions)

Ion	Role
Nitrate (NO_3^-)	Needed by plants to make DNA, amino acids, and proteins from photosynthesis products
Phosphate (PO_4^{3-})	Used in ATP, DNA, and RNA formation in all organisms
Chloride (Cl^-)	Helps in nerve impulses, sweating, and secretory systems in animals
Hydrogen carbonate (HCO_3^-)	Acts as a buffer to maintain blood pH

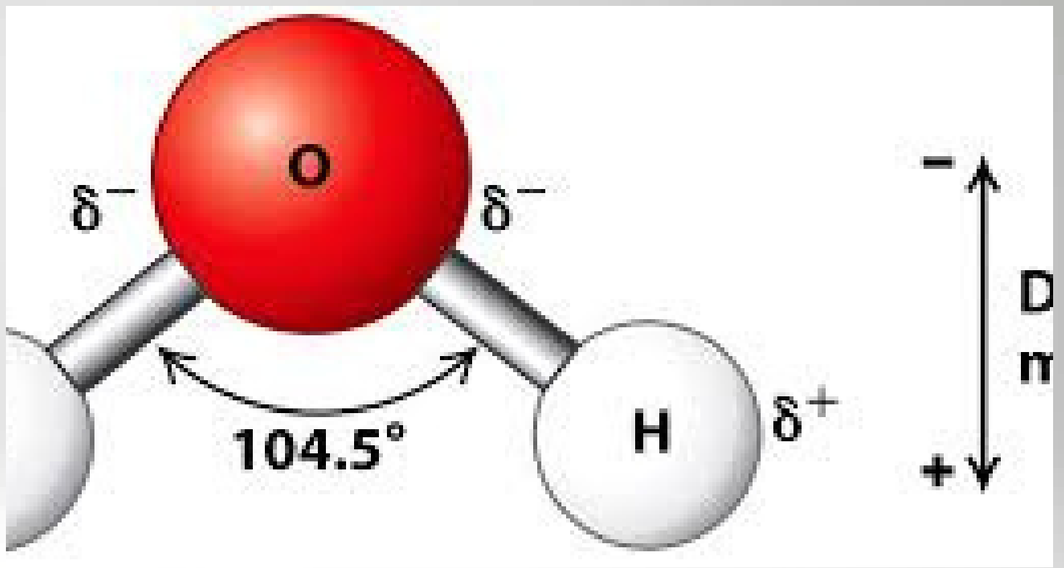
Important Cations (+ve ions)

Ion	Role
Sodium (Na^+)	Involved in nerve impulses, sweating, and secretions in animals
Calcium (Ca^{2+})	Forms calcium pectate in plant cell walls; important for bones and muscle contraction in animals
Hydrogen (H^+)	Crucial in respiration, photosynthesis, active transport, and pH balance
Magnesium (Mg^{2+})	Essential for chlorophyll production in plants

The Chemistry of Water

- **Why Water is Essential for Life?**
- **All cellular reactions occur in water**
  - **Transports substances throughout the body**
  - **A reactant in photosynthesis – vital for almost all life**
  - **Major habitat supporting more life than any other environment**

Structure of the Water Molecule



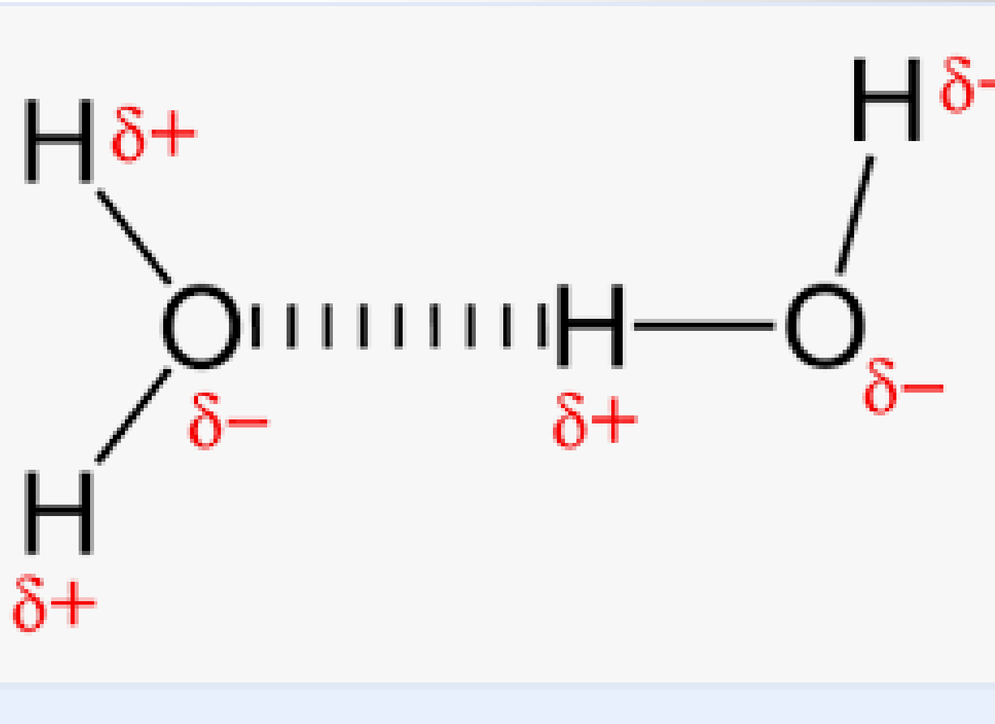
- **Formula: H_2O**
- **2 hydrogen atoms covalently bonded to 1 oxygen atom**
- **Polar molecule:**
- **Electrons are pulled closer to oxygen**
- **Creates slight charges:**
  - **Oxygen → δ^-**
  - **Hydrogen → δ^+**

Hydrogen Bonding in Water

Weak electrostatic attraction between δ^- oxygen and δ^+ hydrogen of different water molecules

Many hydrogen bonds ➡️ strong cohesion

Leads to higher melting & boiling points than similar molecules

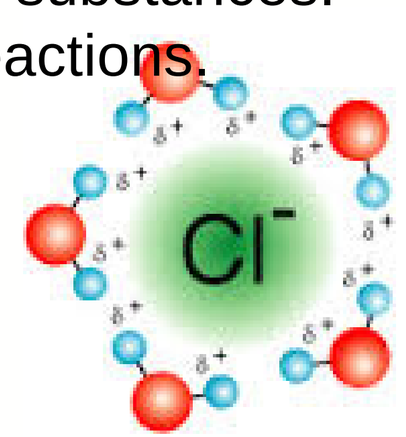


Properties of Water and Their Biological Importance

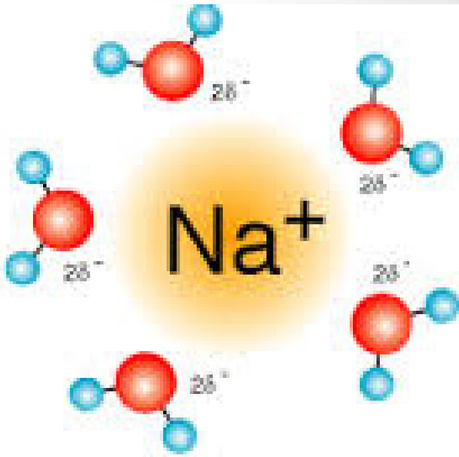
01. **Polarity**

Water is a polar molecule—oxygen is slightly negative (δ–), and hydrogen is slightly positive (δ+).

- Importance:
  - Enables water to dissolve ionic and polar substances.
  - Acts as a medium for biochemical reactions.



Slightly positive hydrogen are attracted to chlorine anions



Slightly negative oxygen are attracted to sodium cations

2. Hydrogen Bonding

Weak bonds form between the slightly positive hydrogen atom of one water molecule and the slightly negative oxygen of another.

Importance:
Provides high cohesion and surface tension (e.g., water droplets) water skaters can live on the surface of water

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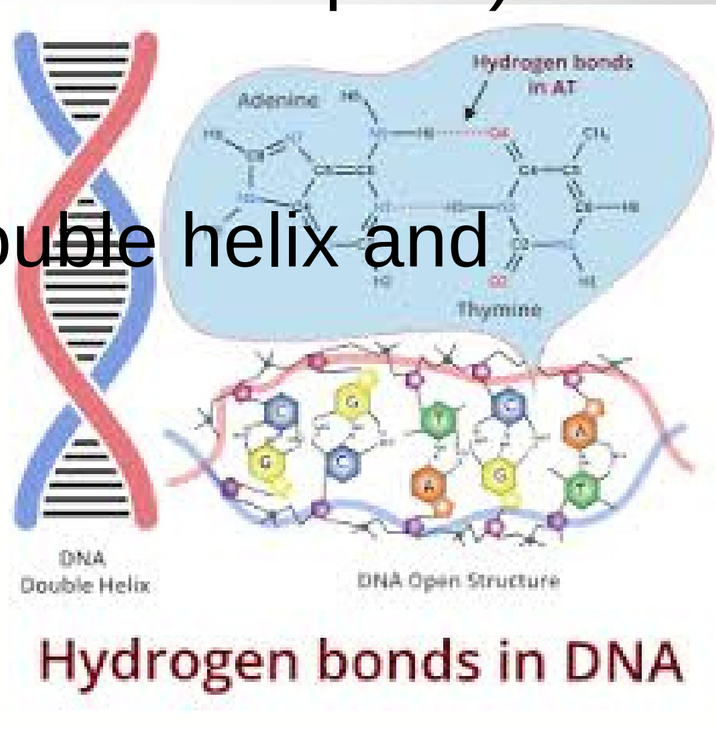
Stabilizes large biological molecules (e.g., DNA double helix and proteins).



3. Solvent

Water can dissolve many substances due to its polarity.

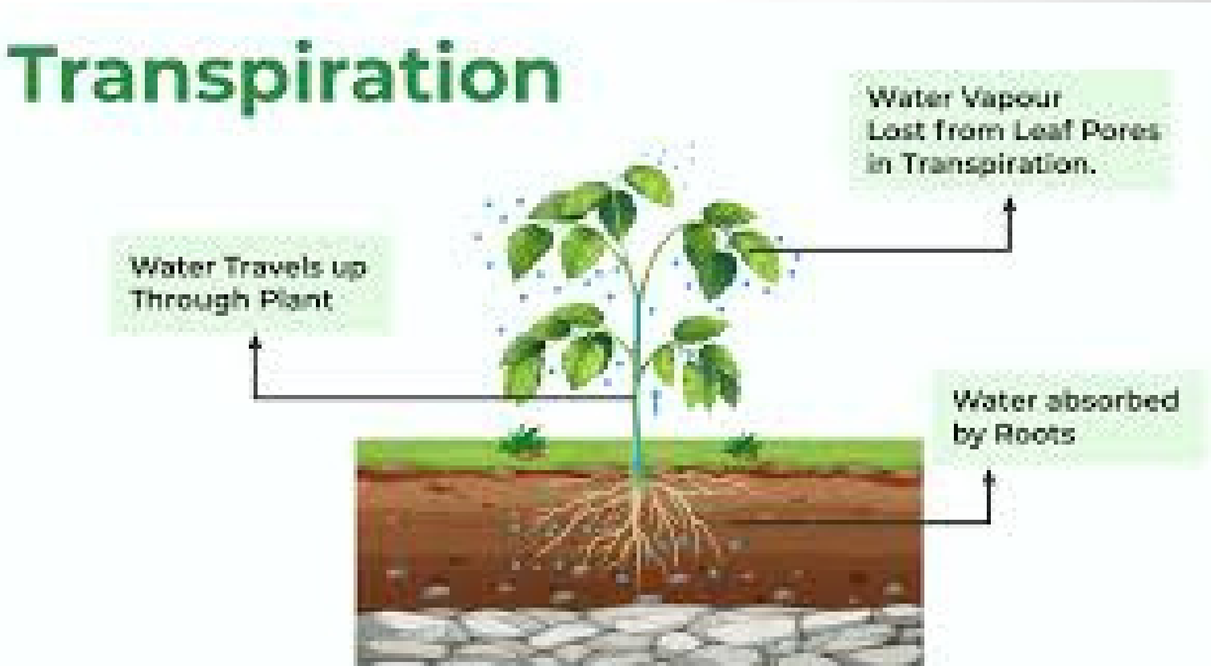
- Importance:
  - Facilitates transport of substances in blood and plant sap.
  - Enables metabolic reactions
  - (e.g., respiration, photosynthesis) to occur in solution.

4. High Specific Heat Capacity

- Water has a high specific heat capacity.
- It can absorb or release large amounts of heat with only a small change in temperature.
- Acts as a thermal buffer.
- Helps maintain stable internal temperatures in organisms.
- Stabilizes aquatic environments during environmental temperature changes.

5. High Latent Heat of Vaporization

- Water needs a large amount of heat energy to evaporate.
- This property is known as high latent heat of vaporization.
- Organisms can lose excess heat with minimal water loss.
- Helps to cool the body surface.
- Prevents overheating.
- Examples:
- Sweating in humans
- Transpiration in plants
    -



6. Cohesion and Adhesion

- Cohesion is the attraction between water molecules due to hydrogen bonding.
- Adhesion is the attraction between water molecules and other surfaces (like cell walls).
- These two properties allow water to function as a transport medium in plants.
- Cohesion helps pull water and dissolved minerals upward through xylem against gravity.
- Adhesion helps water stick to the walls of xylem vessels, aiding upward movement.
- Water also has a high surface tension due to cohesion.
- This causes surface water molecules to be strongly attracted to those below, forming a thin film at the surface.

7. Density and Ice Formation

- Usually, decreasing temperature increases the density of substances.
- Water reaches its maximum density at 4 °C.
- Below 4 °C, water starts to freeze, forming a crystalline lattice (ice).
- This structure makes ice less dense than liquid water.
- Ice floats on water because of its lower density.
- This floating ice acts as an insulating layer.
- Helps aquatic organisms survive under frozen surfaces during winter, especially in polar regions.

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