1.3 Properties of water and their applications in biological system:

Water makes up 60-75% of human body weight. A loss of just 4% of total body water leads to dehydration, and a loss of 15% can be fatal. Likewise, a person could survive a month without food but wouldn't survive 3 days without water. This crucial dependence on water broadly governs all life forms. Clearly water is vital for survival, but what makes it so necessary?

The Molecular Make-up of Water

Many of water's roles in supporting life are due to its molecular structure and a few special properties. Water is a simple molecule composed of two small, positively charged hydrogen atoms and one large negatively charged oxygen atom. When the hydrogens bind to the oxygen, it creates an asymmetrical molecule with positive charge on one side and negative charge on the other side (Figure 1). This charge differential is called polarity and dictates how water interacts with other molecules.

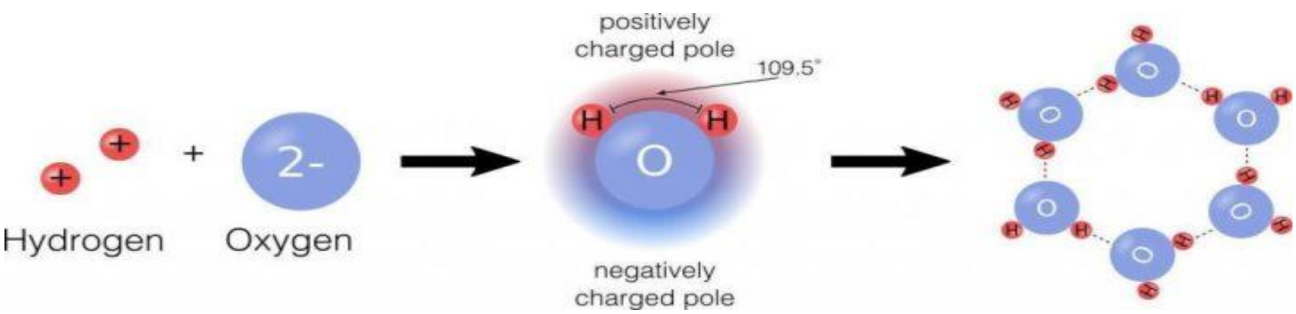

Figure 1: **Water Chemistry.** Water molecules are made of two hydrogens and one oxygen. These atoms are of different sizes and charges, which creates the asymmetry in the molecular structure and leads to strong bonds between water and other polar molecules, including water itself.

Water is the "Universal Solvent"

As a polar molecule, water interacts best with other polar molecules, such as itself. This is because of the phenomenon wherein opposite charges attract one another: because each individual water molecule has both a negative portion and a positive portion, each side is attracted to molecules of the opposite charge. This attraction allows water to form relatively strong connections, called bonds, with other polar molecules around it, including other water molecules. In this case, the positive hydrogen of one water molecule will bond with the negative oxygen of the adjacent molecule, whose own hydrogens are attracted to the next oxygen, and so on (Figure 1). Importantly, this bonding makes water molecules stick together in a property called cohesion. The cohesion of water molecules helps plants take up water at their roots. Cohesion also contributes to water's high boiling point, which helps animals regulate body temperature.

Furthermore, since most biological molecules have some electrical asymmetry, they too are polar and water molecules can form bonds with and surround both their positive and negative regions. In the act of surrounding the polar molecules of another substance, water wriggles its way into all the nooks and crannies between molecules, effectively breaking it apart are dissolving it. This is what happens when you put sugar crystals into water: both water and sugar are polar, allowing individual water molecules to surround individual sugar molecules, breaking apart the sugar and dissolving it. Similar to polarity, some molecules are made of ions, or oppositely charged particles. Water breaks apart these ionic molecules as well by interacting with both the positively and negatively charged particles. This is what happens when you put salt in water, because salt is composed of sodium and chloride ions.

Water's extensive capability to dissolve a variety of molecules has earned it the designation of "universal solvent," and it is this ability that makes water such an invaluable life-sustaining force. On a biological level, water's role as a solvent helps cells transport and use substances like oxygen or nutrients. Water-based solutions like blood help carry molecules to the necessary locations. Thus, water's role as a solvent facilitates the transport of molecules like oxygen for respiration and has a major impact on the ability of drugs to reach their targets in the body.

Water Supports Cellular Structure

Water also has an important structural role in biology. Visually, water fills cells to help maintain shape and structure (Figure 2). The water inside many cells (including those that make up the human body) creates pressure that opposes external forces, similar to putting air in a balloon. However, even some plants, which can maintain their cell structure without water, still require water to survive. Water allows everything inside cells to have the right shape at the molecular level. As shape is critical for biochemical processes, this is also one of water's most important roles.

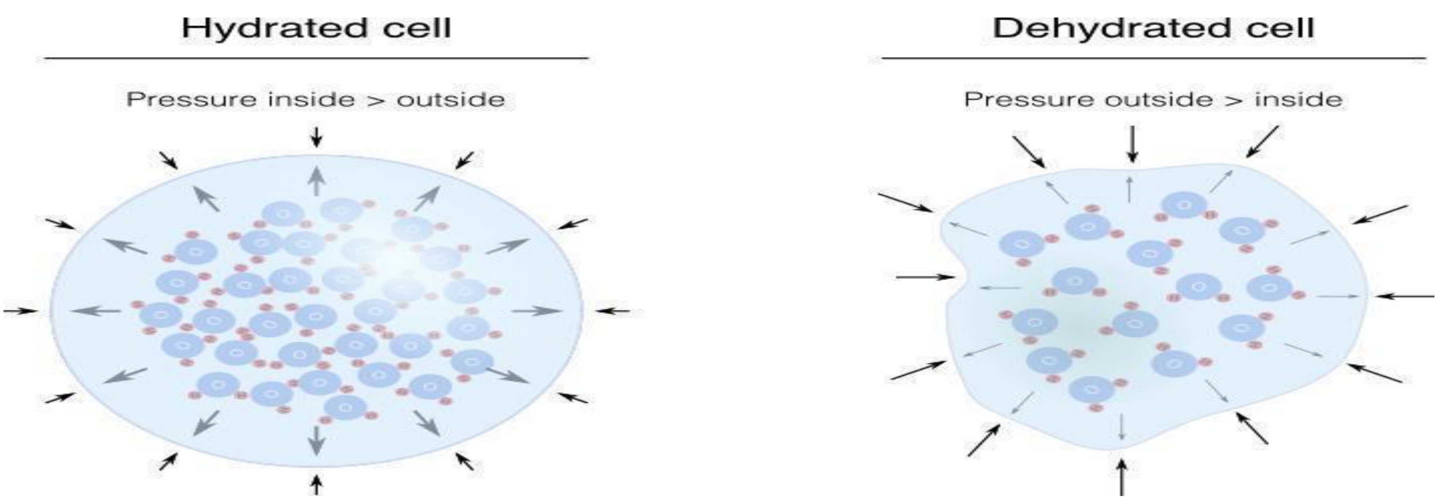

Figure 2: **Water impacts cell shape.** Water creates pressure inside the cell that helps it maintain

shape. In the hydrated cell (left), the water pushes outward and the cell maintains a round shape. In the dehydrated cell, there is less water pushing outward so the cell becomes wrinkled.

Water also contributes to the formation of membranes surrounding cells. Every cell on Earth is surrounded by a membrane, most of which are formed by two layers of molecules called phospholipids (Figure 3). The phospholipids, like water, have two distinct components: a polar "head" and a nonpolar "tail." Due to this, the polar heads interact with water, while the nonpolar tails try to avoid water and interact with each other instead. Seeking these favorable interactions, phospholipids spontaneously form bilayers with the heads facing outward towards the surrounding water and the tails facing inward, excluding water. The bilayer surrounds cells and selectively allows substances like salts and nutrients to enter and exit the cell. The interactions involved in forming the membrane are strong enough that the membranes form spontaneously and aren't easily disrupted. Without water, cell membranes would lack structure, and without proper membrane structure, cells would be unable to keep important molecules inside the cell and harmful molecules outside the cell.

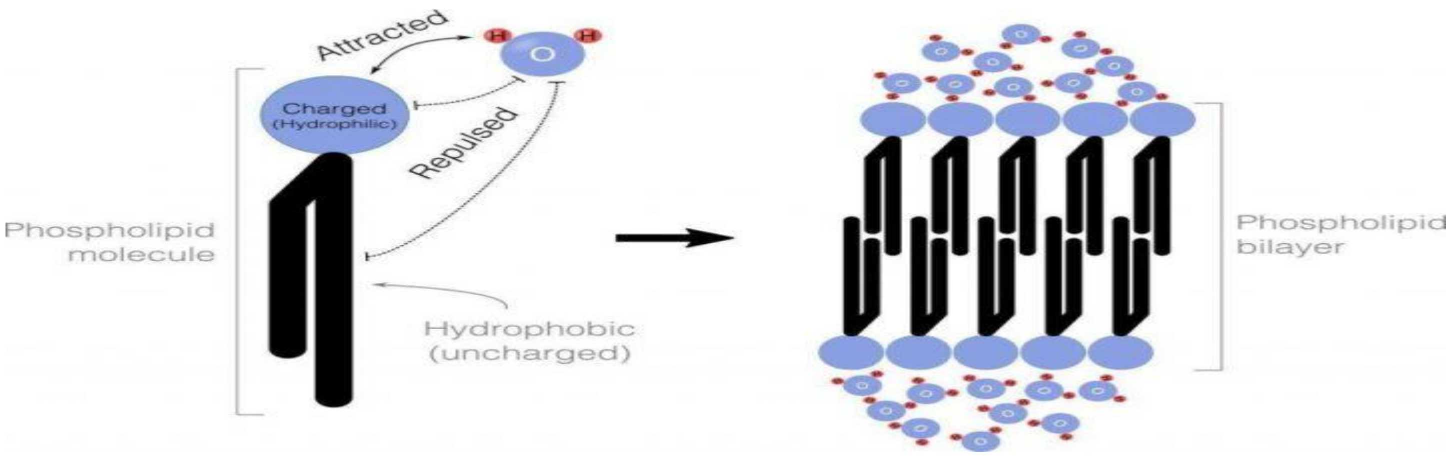

Figure 3: **Phospholipid bilayers.** Phospholipids form bilayers surrounded by water. The polar heads face outward to interact with water and the hydrophobic tails face inward to avoid interacting with water.

In addition to influencing the overall shape of cells, water also impacts some fundamental components of every cell: DNA and proteins. Proteins are produced as a long chain of building blocks called amino acids and need to fold into a specific shape to function correctly. Water drives the folding of amino acid chains as different types of amino acids seek and avoid interacting with water. Proteins provide structure, receive signals, and catalyze chemical reactions in the cell. In this way, proteins are the workhorses of cells. Ultimately proteins drive contraction of muscles, communication, digestion of nutrients, and many other vital functions. Without the proper shape, proteins would be unable to perform these functions and a cell (let alone an entire human) could not survive. Similarly, DNA needs to be in a specific shape for its instructions to be properly decoded. Proteins that read or copy DNA can only bind DNA that has a particular shape. Water molecules surround DNA in an ordered fashion to support its characteristic double-helix conformation. Without this shape, cells would be unable to follow the careful instructions encoded by DNA or to pass the instructions onto future cells, making human growth, reproduction, and, ultimately, survival infeasible .

Chemical Reactions of Water

Water is directly involved in many chemical reactions to build and break down important components of the cell. Photosynthesis, the process in plants that creates sugars for all life forms, requires water. Water also participates in building larger molecules in cells. Molecules like DNA and proteins are made of repetitive units of smaller molecules. Putting these small molecules together occurs through a reaction that produces water. Conversely, water is required for the reverse reaction that breaks down these molecules, allowing cells to obtain nutrients or repurpose pieces of big molecules.

Additionally, water buffers cells from the dangerous effects of acids and bases. Highly acidic or basic substances, like bleach or hydrochloric acid, are corrosive to even the most durable materials. This is because acids and bases release excess hydrogens or take up excess hydrogens, respectively, from the surrounding materials. Losing or gaining positively-charged hydrogens disrupts the structure of molecules. As we've learned, proteins require a specific structure to function properly, so it's important to protect them from acids and bases. Water does this by acting as both an acid and a base (Figure 4). Although the chemical bonds within a water molecule are very stable, it's possible for a water molecule to give up a hydrogen and become OH–, thus acting as a base, or accept another hydrogen and become H3O+, thus acting as an acid. This adaptability allows water to combat drastic changes of pH due to acidic or basic substances in the body in a process called buffering. Ultimately, this protects proteins and other molecules in the cell.

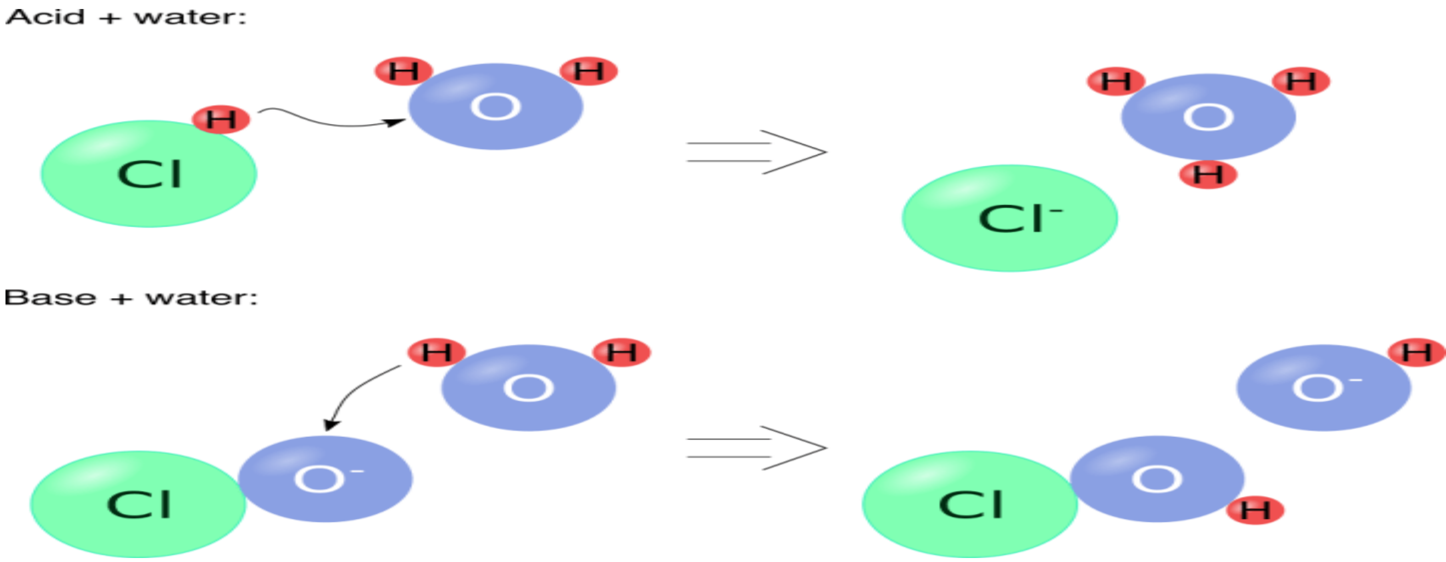

Figure 4: **Water acts as a buffer by releasing or accepting hydrogen atoms.**

In conclusion, water is vital for all life. Its versatility and adaptability help perform important chemical reactions. Its simple molecular structure helps maintain important shapes for cells' inner components and outer membrane. No other molecule matches water when it comes to unique properties that support life. Excitingly, researchers continue to establish new properties of water such as additional effects of its asymmetrical structure. Scientists have yet to determine the physiological impacts of these properties. It's amazing how a simple molecule is universally important for organisms with diverse needs.

Introduction to biomolecules:

Biomolecules are the most essential organic molecules, which are involved in the maintenance and metabolic processes of living organisms. These non-living molecules are the actual foot-soldiers of the battle of sustenance of life. They range from small molecules such as primary and secondary metabolites and hormones to large macromolecules like proteins, nucleic acids, carbohydrates, lipids etc.Let us study them in brief.

Types of Biomolecules

There are four major classes of Biomolecules – Carbohydrates, Proteins, Nucleic acids and Lipids. Each of them is discussed below.

Carbohydrates

Carbohydrates are chemically defined as polyhydroxy aldehydes or ketones or compounds which produce them on hydrolysis. In layman's terms, we acknowledge carbohydrates as sugars or substances that taste sweet. They are collectively called as saccharides (Greek: sakcharon = sugar). Depending on the number of constituting sugar units obtained upon hydrolysis, they are classified as monosaccharides (1 unit), oligosaccharides (2-10 units) and polysaccharides (more than 10 units). They have multiple functions' viz. they're the most abundant dietary source of energy; they are structurally very important for many living organisms as they form a major structural component, e.g. cellulose is an important structural fiber for plants.

Proteins

Proteins are another class of indispensable biomolecules, which make up around 50per cent of the cellular dry weight. Proteins are polymers of **amino acids** arranged in the form of polypeptide chains. The structure of proteins is classified as primary, secondary, tertiary and quaternary in some cases. These structures are based on the level of complexity of the folding of a polypeptide chain. Proteins play both structural and dynamic roles. Myosin is the protein that allows movement by contraction of muscles. Most enzymes are proteinaceous in nature.

Nucleic Acids

Nucleic acids refer to the genetic material found in the cell that carries all the hereditary information from parents to progeny. There are two types of nucleic acids namely, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). The main function of nucleic acid is the transfer of genetic information and synthesis of proteins by processes known as translation and transcription. The monomeric unit of nucleic acids is known as nucleotide and is composed of a nitrogenous base, pentose sugar, and phosphate. The nucleotides are linked by a 3' and 5' phosphodiester bond. The nitrogen base attached to the pentose sugar makes the nucleotide distinct. There are 4 major nitrogenous bases found in DNA: adenine, guanine, cytosine, and thymine. In RNA, thymine is replaced by uracil. The DNA structure is described as a double-helix or double-helical structure which is formed by hydrogen bonding between the bases of two antiparallel polynucleotide chains. Overall, the **DNA structure** looks similar to a twisted ladder.

Lipids

Lipids are organic substances that are insoluble in water, soluble in organic solvents, are related to fatty acids and are utilized by the living cell. They include fats, waxes, sterols, fat-soluble vitamins, mono-, di- or triglycerides, phospholipids, etc. Unlike carbohydrates, proteins, and nucleic acids, lipids are not polymeric molecules. Lipids play a great role in the cellular structure and are the chief source of energy.