Biological importance of water and lipids

Water is arguably the most " essential building block of life"; it is the most abundant molecule in cells, whole organisms, and on Earth. Every single organism contains water, typically forming 70 – 95% of the mass of a cell; a typical human being is compromised of 60% water. Without water, life cannot exist. Water also provides an environment for the organisms that need it to live, as three quarters of the Earth are covered in water.

Water is an excellent solvent in general, including polar molecules (eg. glycerol and sugars) and ions. This is because the water molecules are attracted to, collect around, and separate/dissociate the atoms from each other (as the forces of attraction between the negatively charged part of the water molecule and positively charged sodium cation is greater than the forces of attraction between the sodium and chloride ions). Once a chemical is free in its solution, it is then free to roam about and react with other chemicals – most processes in organisms are done via this way in solution. In stark contrast, non-polar molecules such as lipids are insoluble in water; when surrounded by water, they tend to be pushed together, as the water molecules become attracted to each other. This is extremely important in reactions such as hydrophobic interactions in protein structure (reactions where atoms dissociate from each other) and in membrane structure, as it increases the stability of these structures. Some molecules have strong intramolecular forces, and do not dissociate in water; however, some do have charged regions on their surface, which result in attracting a layer of water around the molecules. These regions attract water molecules, which are surrounding and are weakly bound to the molecule and cannot move away from its surface – this is known as a colloidal suspension. This helps create a concentration gradient for the process of osmosis, as it would for example, assist in drawing water into the blood vessels. Because water is such an effective solvent, it can transport essential substances necessary for the functioning of cells/whole organisms eg. glucose, amino acids, fats, vitamins, respiratory gases etc. Similarly, metabolic reactions (catalysed by enzymes) occur in solution. So, the charged nature of a water molecule means it can act as a solvent, an essential property to living organisms.

Water is the transport medium in the blood, in the lymphatic, excretory and digestive systems of animals, and in the vascular tissues of plants. When minerals are absorbed by plants from the soil across root hairs, the minerals are in an aqueous solution of water. The water based movement of sugars, amino acids and hormones (eg. in phloem) and transpiration stream are also in solution. All the transport fluids used in animals like cytoplasm, blood, plasma and tissue fluid are water based. Essential metabolites dissolve completely in water, like glucose, amino acids, minerals and vitamins. Larger molecules like proteins are transported as colloids (molecules which are weakly bound to water molecules). Water being essential to the transportation of necessary substances correlates strongly to water being an excellent solvent, as it is mostly through solution that these substances can get to where they are required. However, water does have other properties which make it suitable for transportation; the low viscosity of water also enables it to flow easily through tubes eg. xylem vessels.

Water is a polar molecule, in which it has both positively and negatively charged areas; water consists of two positively charged hydrogen atoms and one negatively charged oxygen atom. As a result of this polarity, opposite (one positive hydrogen atom, one negative oxygen atom) water molecules are attracted to each other and a hydrogen bond is formed. The individual hydrogen bonds are weak, but collectively they make water a very stable medium eg. it remains a liquid over a wide range of temperatures. This property is vital to sustain life in all living organisms.

Water is effective as a temperature regulator; its high specific heat capacity (it takes 4. 2 Joules of energy to raise one gram of water by 1°C – it takes a lot of heat energy to significantly raise the temperature of water) allows it to act as a buffer, a necessity in endothermic organisms that need to maintain a constant body temperature in order to fulfil its enzyme potential, and therefore regulate metabolism. The high amount of hydrogen bonds in water also makes it difficult for water molecules to evaporate; when they eventually do, a high amount of energy is released, which in turn acts as a cooling mechanism; this is crucial to life, as internal body temperature needs to be maintained at a constant temperature, any fluctuations can result in a breakdown of essential processes. It must be reinforced that water is a polar molecule, which means it remains a liquid over a wide temperature range, which is good for metabolism and to ensure that aquatic animals in the ocean do not freeze. Water actually has a high, latent heat of fusion from solid to liquid; it requires 300 Joules per gram of ice to melt water, which means that water stays liquid. This is vital for cell cytoplasm, which is made of a high percentage of water: once frozen, a cell would be damaged beyond repair. The freezing point of water is also lowered by solutes, as the soluble molecules disrupt the hydrogen bonds, making the water freeze at a lower temperature and easier to melt into ice. There are many solutes in cytoplasm, ensuring the water will not freeze until well below 0°C, protecting the cells. As water cools, its density increases, and the hydrogen bonds between the water molecules take on a more latticed formation (as ice). However, ice floats on the surface of water: this must mean that it must have a lower density than water. Water is at its most dense at 4°C; this is because it is at this temperature that the bonds are closest together. When water freezes, the lattice arrangement of its structure " loosens" slightly, and it will float on the surface. Thereby, the layer of ice would insulate the water below, maintaining its temperature of 4°C and aquatic life can continue.

Water is useful in sexual reproduction, and is used by animals that use this to create offspring. Water brings male and female gametes together in the process of fertilisation, and in mammals, the foetus develops in a water filled amniotic sac, which provides both physical and thermal stability. Bryophytes (scientific terms for " land plants") release antherozoids (male gametes in plants) in moist conditions, which then use flagella to swim to oospheres by chemotaxis; chemotaxis is the phenomenon in which bodily cells, bacteria, and other single-cell/multi-cellular organism can direct their movements according to certain chemicals in their environment.

Lipids constitute an essential component of a cell, and has tremendous biological importance. Triglycerides are a major group of lipids – formed by the combination of three fatty acid molecules with one glycerol molecule – and are the main source of energy in animals. One gram of lipid on oxidation release 9. 3 kilocalories of heat – however, the same amount of carbohydrate only release 4. 5 kilocalories in comparison. These are found in adipose tissue (occupying around 90% of the cell volume), which consists of fat cells designed for constant synthesis and decomposition of triglycerides by the enzyme lipase to produce high-caloric energy. A lot of migratory birds depend on their stored energy to fuel their long distance flights. ATP (Adenosine triphosphate) can be produced when fatty acids are oxidised. Triglycerides can be easily stored as they are insoluble in water, meaning they will not dissolve in anything but chloroform, ethanol and ether. This is due to the long hydrocarbon tails of the fatty acids (consists of a chain of carbon atoms combined with hydrogen). Unlike polar water molecules, the fatty acid tails have no uneven distribution of electrical charge – therefore, triglycerides will not mix freely with water molecules.

An animal cell membrane is a flexible lipid bilayer. The lipid molecules (mostly phospholipids) that make up the membrane have a polar, hydrophilic head and two hydrophobic hydrocarbon tails. When the lipids are immersed in an aqueous solution, the lipids rapidly bury the tails together, and leave the hydrophilic heads exposed. This is therefore a very useful membrane, as it can easily automatically repair itself if torn. There are three different major types of lipid molecules: phospholipids, cholesterol, and glycolipids. Different membranes have different ratios of the three lipids. A special feature about these lipid membranes is the presence of different proteins on the surface, used for different functions such as cell surface receptors, enzymes, surface antigens, and transporters. Many of the membrane-associated proteins have hydrophilic and hydrophobic regions. The hydrophilic regions are used to help “ anchor” the protein inside of the cell membrane; some proteins extend across the lipid bilayer, others cross the bilayer several times.

Lipids are an excellent energy reserve, as they are very rich in carbon-hydrogen bonds, even more so than in carbohydrates. A given mass of lipid would thereby yield more energy on oxidation than the same mass of carbohydrate (it has a higher calorific value). Fat is stored in a number of places in the human body, especially just below the dermis of the skin and around the kidneys. Below the skin, it acts as an insulator against the loss of heat. Blubber is an example of a lipid found in sea mammals (eg. whales), which functions in both providing insulation and buoyancy. The myelin sheath is a dielectric material that is made up of approximately 80% lipid and 20% protein, and forms an insulating layer around the axon, as well as increasing the speed of impulses, due to there being " gaps" in the myelin sheath (nodes of Ranvier). Fat serves as a protective cushion and provides structural support to help prevent injury to vital organs, such as the heart, liver, kidneys, and spleen. In the lungs, surfactants are an example of a lipid barrier. Surfactants reduce tension, as without it, the wet surfaces of the alveoli in our lungs would stick together, and the lungs would not be able to expand, thus rendering breathing impossible. Fat insulates the body from heat loss and extreme temperature changes; simultaneously, fat deposits under the skin may be metabolized to generate heat in response to lower skin temperatures. Lipids can also act as a metabolic source of water; when oxidised in respiration they are converted to carbon dioxide and water – the water could be important in dry habitats eg. the desert kangaroo rat never drinks water, instead surviving on its metabolic water from its fat intake.

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