Is water necessary for life?

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The universality of water as the solvent for life is usually justified by its role in supporting the rich organic chemistry. It has been pointed out, however, that even richer synthetic chemistry is possible in other organic solvents [1,2]. Does it mean that water is not necessary for life? Here, other, essential criteria for solvent for life that have not been sufficiently considered are discussed.

In biological systems, complex molecules are not only constantly synthesized but also degraded. Solvent-mediated degradation is essential for regulating cell content, preventing overcrowding and allowing for recycling organic material. Achieving a balance between synthetic and degradative processes is facile in water, but not in many other organic liquids. Thus, the so-called "water paradox" according to which water is both necessary to life and toxic to biopolymer synthesis [3] might not be paradoxical at all.

The machinery of life is based on non-covalent interactions that do not involve making or braking chemical bonds. Their strength needs to be properly tuned. If they are too weak, there might be undesired response to natural fluctuations of physical or chemical parameters. If they are too strong, the kinetics and energetics of cellular processes could adversely influenced. The solvent must allow for balancing these interactions, which provides strong, universal constraints on the medium for life [4].

Water influences non-covalent interactions mainly by two mechanisms. First, it reduces strong, electrostatic interactions between molecules, chemical groups or atoms carrying electric charge or dipole. Second, it induces the hydrophobic effect, the tendency to remove nonpolar (hydrophobic) molecules and groups from direct contact with aqueous solution and, instead, interact with each other. In living systems, the hydrophobic effect is largely responsible for self-organization of molecules to more complex structures, such as agregation of lipid molecules to form biological membranes and protein folding. Water exists as stable liquid in a large temperature range, and the hydrophobic effects [5-8] are a consequence of the temperature insensitivity of essential properties of its liquid state [4,8]. In summary, water accomplishes an amazing feat – it reduces strong interactions between dissolved species and simultaneously increases the strength of weak interactions, bringing all of them to the right range. Once we consider not only synthetic capabilities but also other required traits of the solvent for life, no viable alternative to water is currently known.

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