

Water and the Cell

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PREFACE

This edited volume deals with the state of water in the vicinity of biological interfaces, both intracellular and extracellular. This issue is of critical importance, for the cell is extremely crowded with interfaces, and as a result practically all cell water is interfacial. The character, or state, of this water may therefore be central to cell function.

What is meant by the 'state of water?' Few would question that water coming out of a household tap is a liquid, but water in an ice cube is something altogether different: it is a solid that floats on tap water (also known as bulk water). It is water in the solid state.

The fact that ice floats is an indication that it is less dense than water. Clearly, the physical properties are different. Water molecules below 0°C form a crystal. In this crystal, the two positively charged hydrogen atoms of water bind to the double negative charges of oxygen atoms of two adjacent water molecules. The resulting crystal lattice is arranged in such a way as to be less dense than tap water, and constituent water molecules are also less mobile.

But what of water adjacent to surfaces, be they biological or inanimate? Does this represent yet another state of water, distinct from solid or liquid? Water's positively charged hydrogen atoms might be expected to bond to a negatively charged surface, whereas its negatively charged oxygen atom ought to bond to a positively charged surface. One might then ask if the dipolar orientation of the first bound water layer might provide an arrangement of charges that causes a second layer of dipolar water molecules to form. If so, how many layers might build? How might the physical properties of this water differ from those of bulk water?

These issues are dealt with in depth in the chapters of this volume. Several chapters imply that the ordered interfacial zone may extend considerably farther than generally envisioned.

There is appreciable background for such thinking, both theoretical and experimental. For example, consider the surface of a polished silver chloride crystal. Positive Ag^+ and negative Cl^- charges are spaced at a distance of about 3 Angstroms, or about the diameter of a water molecule. Thus, the surface charges form a checkerboard, whose spacing is equal to the size of a water molecule. In this case the positive charge of one water-hydrogen atom could bind to a negatively charged surface- Cl^- , while the negatively charge of oxygen of another water molecule could bind to a positively charged surface- Ag^+ . Bound water molecules in this first layer could then hydrogen bond to one another to form a highly polarized monolayer that could serve as the nidus for formation of a second layer. In this

situation, it is predicted that numerous water layers could form (Ling 2003). In fact Hori (1956) has demonstrated that water between the surfaces of two quartz or polished glass plates spaced less than 100 μm apart does not freeze at temperatures as low as -90°C . The inability to freeze is an indication of structuring. The span in question is 30,000 water-molecule diameters. Clearly, at these inanimate surfaces, multiple layers of water molecules are perturbed relative to water molecules in bulk.

What about the water in biological systems? Is the state of water in cells similar to bulk water, or is it organized? When a ciliated protozoan, such as *Tetrahymena*, growing in a dilute proteose peptone media is smashed between a microscope slide and a cover slip, the cortex of the cell ruptures, and a water-immiscible substance flows out and separates as a drop of cytoplasm (Cameron, unpublished). Further smashing of such extrusions can fractionate the drop into smaller immiscible droplets. This is a common observation, seen in various forms by many others. It indicates that protoplasm in the cell is immiscible in a dilute solution, and that retarding the flow of fluid/water from the cell protoplasm does not necessarily require an intact cell membrane; it is inherent in the physical features of the protoplasm itself.

These observations alone would appear to cast doubt on the tenet of the cell membrane as the critical water-diffusion barrier between the extracellular environment and the cytoplasm, where the intracellular water is assumed to be relatively free to exit the cell upon membrane disruption. Even in the absence of a membrane, the protoplasm does not dissipate.

The chapters in this monograph deal with water at the interfaces of both inanimate and biological systems. The biological systems include both filamentous and globular proteins, hydrophilic and hydrophobic surfaces, extracellular materials, and cells. What evolves is that water within cells is to a major extent ordered differently than bulk water, and functions not as an inert solvent, but as an active player. Most of intracellular water is adsorbed onto surfaces, which themselves are dynamic.

Understanding water order in biological systems is key to an understanding of life processes and to an understanding of diseases.

The material in the book should be of value to any person interested in the role of water inside the cell. This includes professionals in the area of cell biology, chemistry, and biochemistry. It also includes students interested in understanding the underlying basics of life.

The reader will be richly rewarded with insights difficult or impossible to obtain in current textbooks, which generally treat water merely as a background carrier with limited significance.

It was Albert Szent-Gyorgyi, Nobel Laureate, who stated that 'Life is water dancing to the tune of macromolecules.' Szent-Gyorgyi's famous pronouncement is borne out in the contents of this volume. Water is definitely a major player in the biology of the cell.

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