Gerald H. Pollack

The Fourth Phase of Water: Beyond Solid, Liquid, and Vapor

How can a Jesus Christ lizard walk on water? Why do pollen grains jitterbug in a puddle? Why do fair weather clouds form such lovely puffy white shapes? Why do your joints work without squeaking? Why does water show a density maximum at 4°C?

Answering these questions requires an understanding of water. Given water's simplicity and pervasiveness through nature, we presume that water must be completely understood, but in fact precious little is known about how water molecules line up—until recently.

Students learn that water has three phases: solid, liquid and vapor. But there is something more: in our laboratory at the University of Washington we have uncovered a fourth phase.[1] This phase occurs next to water loving (hydrophilic) surfaces. It is surprisingly extensive, projecting out from surfaces by up to millions of molecular layers. And it exists almost everywhere throughout nature, including the human body.

The existence of a fourth phase may seem unexpected. However, it should not be entirely so: a century ago, the physical chemist Sir William Hardy argued for the existence of a fourth phase, and many authors over the years have found evidence for some kind of "ordered" or "structured" phase of water. Fresh experimental evidence not only confirms the existence of such an ordered, liquid-crystalline phase, but also details its properties. Those properties explain everyday observations and answer questions ranging from why gelatin desserts hold their water to why teapots whistle. But more importantly, the presence of the fourth phase also carries many surprising implications and potentially useful applications.

Does Water Transduce Energy?

The energy for building water structure comes from the sun. Radiant energy converts ordinary bulk water into ordered water, building this ordered zone. We found that all wavelengths ranging from ultraviolet through visible to infrared can build this ordered water. Near-infrared energy is the most capable. Water absorbs infrared energy freely from the environment, and it uses that energy to convert bulk water into liquid crystalline water (fourth phase water)—which we also call "exclusion zone" or "EZ" water because it profoundly excludes solutes, i.e., substances that create a solution when dissolved in a solvent. Hence, the buildup of EZ water occurs naturally and spontaneously from environmental energy. Additional energy input creates additional EZ buildup.

Of particular significance is the fourth phase's charge: commonly negative (Figure 1). Absorbed radiant energy splits water molecules; the negative moiety constitutes the building block of the EZ, while the positive moiety binds with water molecules to form free hydronium ions, which diffuse throughout the water. (Hydronium is what you get when you put water and hydrogen ions together.) Adding additional light stimulates more charge separation.

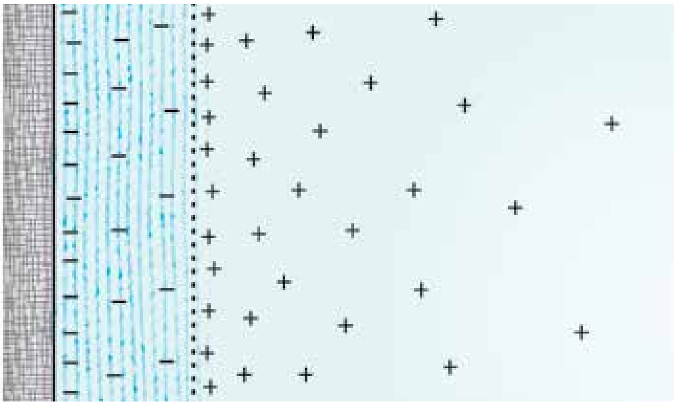


Figure 1. Diagrammatic representation of EZ water, negatively charged, and the positively charged bulk water beyond. Hydrophilic surface at left.

This process resembles the first step of photosynthesis. In that step, energy from the sun splits water molecules, with hydrophilic chromophores (light absorbing molecules) catalyzing the splitting. The process considered here is similar but more generic: any hydrophilic surface may catalyze the splitting. Some surfaces work more effectively than others.

The separated charges resemble a battery. That battery can deliver energy in a manner similar to the way the separated charges in plants deliver energy. Plants, of course, comprise mostly water, and it is therefore no surprise that a similar energy conversion takes place in water itself.

The stored electrical energy in water can drive various kinds of work, including flow. An example is the axial flow through tubes. We found that immersing tubes made of hydrophilic materials into water produces flow through those tubes, similar to blood flow through blood vessels (Figure 2). The driving energy comes from the radiant energy absorbed and stored in the water. Nothing more. Flow may persist undiminished for many hours, even days. Additional incident light brings faster flow. This is not a perpetual motion machine:

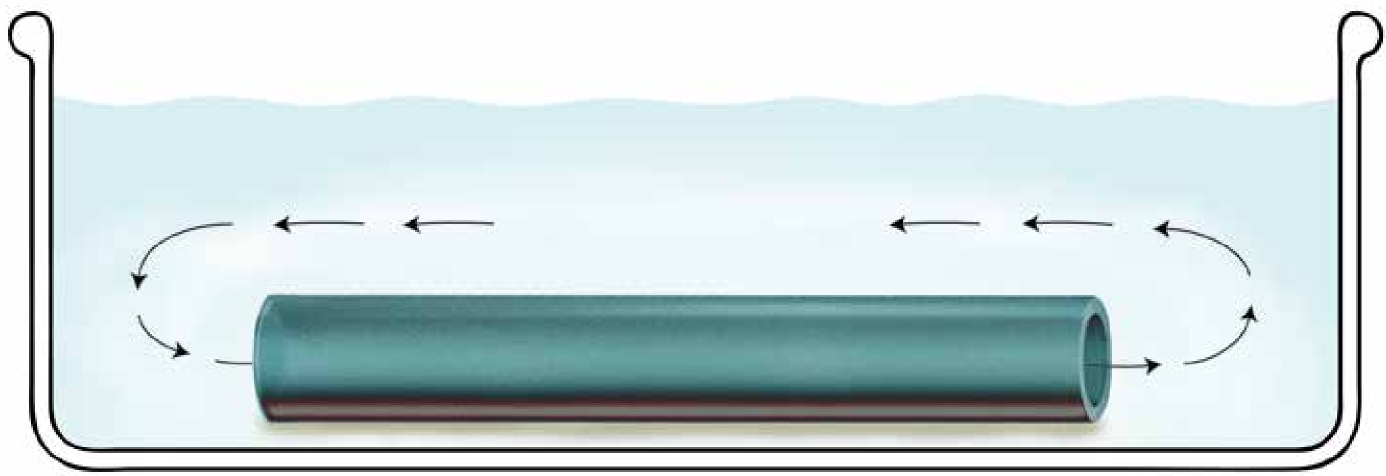


Figure 2. Practically incessant flow occurs through hydrophilic tubes immersed in water.

incident radiant energy drives the flow in much the same way that it drives vascular flow in plants.

Applications in Biological Flow and Atmospheric Science

The water-based energy conversion framework is rich with implication for many systems involving water. These systems may range from biology and chemistry all the way to atmospheric science and engineering. The fourth phase appears nearly everywhere: all that's needed is water, radiant energy, and a hydrophilic surface. The latter can be as large as a slab of polymer and as small as a dissolved molecule. The liquid crystalline phase inevitably builds, and its presence plays some integral role in the system's behavior.

Let me provide a few representative examples.

One example is the human body. Two thirds of your cells are water—by volume. By molecular fraction, more than 99% of your molecules are water molecules because water molecules are so small compared to the other molecules. Modern cell biology considers 99% of your molecules mere background carriers of the "important" molecules of life such as proteins and nucleic acids. Conventional wisdom asserts that 99% of your molecules don't do very much.

However, EZ water envelops every macromolecule in the cell. Those macromolecules are so tightly packed that the enveloping liquid crystalline water largely fills your cells. In other words most of your cell water is liquid crystalline, or EZ water. This water plays a central role in everything the cell does.[2]

What we have discovered in our lab is the role of radiant energy: incident radiant energy powers many of those cellular functions. An example is the blood flowing through your capillaries. That blood eventually encounters high resistance: capillaries are often narrower than the red blood cells that must pass through them; in order to make their way through, those red cells need to bend and contort. Resistance is high. You'd anticipate the need for lots of driving pressure; yet, the pressure gradient across the capillary bed is negligible. The paradox resolves if radiant energy helps propel flow through capillaries in the same way that it propels flow through hydrophilic tubes. Radiant energy may constitute an unsuspected source of vascular drive, supplementing cardiac pressure.

Why you feel good after a sauna now seems understandable. If radiant energy drives capillary flow and ample capillary flow is important for optimal functioning, then sitting in the sauna will inevitably be a feel-good experience. The infrared energy associated with heat should help drive that flow. The same applies when you walk out into sunlight: we presume that the feel-good experience derives purely from the psychological realm, but the evidence implies that sunlight may build your body's EZs. Fully built EZs around each protein seem necessary for optimal cellular functioning.

A second example of the EZ's central role is weather. Common understanding of weather derives from two principal variables: temperature and pressure. Those two variables are said to explain virtually everything we experience in terms of weather. However, the atmosphere also contains water: it is full of micrometer-scale droplets commonly known as aerosol droplets or aerosol particles. Those droplets make up atmospheric humidity. When the atmosphere is humid, the many droplets scatter considerable light, conferring haze; you can't see clearly through that haze. When the atmosphere contains only few droplets, you may see clearly over long distances.

Our lab at the University of Washington has presented evidence for the structure of those droplets. It shows that EZ water envelops each droplet, while hydronium ions occupy the droplets' interior. Repelling one another, those internal hydronium ions create pressure, which pushes against the robust shell of EZ water. That explains why droplets tend toward roundness.

How do those aerosol droplets condense to form clouds? The droplets' EZ shells bear negative charge. Negatively charged droplets should repel one another, precluding any condensation into clouds. Those like-charged aerosol droplets should remain widely dispersed throughout the atmosphere.

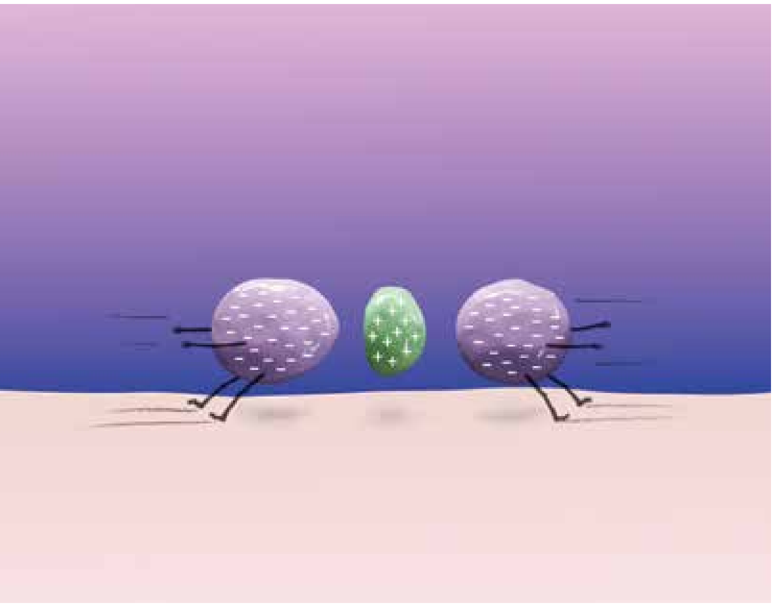


Figure 3: Like-charged entities attract because of an intermediate of opposite charge.

However, droplets do often condense into clouds, and the question is how that can happen.

The reason they condense is because of the unlike charges that lie in between the droplets. Richard Feynman, the legendary Nobel Prize physicist of the late 20th century, understood the principle, opining that: “like-likes-like because of an intermediate of unlikes.” The like-charged droplets “like” one another, so they come together; the unlike charges lying in between those droplets constitute the attractors (Figure 3).

The like-likes-like principle has been widely appreciated but also widely ignored: after all, how could like charges conceivably attract? A reason why this powerfully simple concept has been ignored is that the source of the unlike charges has been difficult to identify. We now know that the unlike charges can come from the splitting of water—the negative components building EZ shells, while the corresponding positive components provide the unlike attractors. With enough of those attractors, the negatively charged aerosol droplets may condense into clouds.

These two phenomena, radiant energy-induced biological function and like-likes-like cloud formation, provide examples of how water’s energy can account for phenomena not otherwise explained. The fourth phase is the key building block that allows for construction of an edifice of understanding.

Anomalies Resolved

Water science has brought many anomalies.[3] Anomalies imply something amiss with current understanding, and I would suggest that the new paradigm containing a fourth phase of water has the capacity to resolve many of those “anomalies.” Here I consider two of them: water’s unexpectedly high heat capacity and its paradoxical density maximum at 4°C.

The central feature of the fourth phase paradigm is the radiant-energy-induced buildup of EZ water. Energy builds order and separates charge. A major driving source for this buildup is infrared energy—heat. Heat builds order and separates charge; i.e., it yields potential energy (which can drive flow; see Figure 2).

This energy buildup changes the way we look at water. The common perception is that radiant input to water goes solely into raising the temperature. However, that is not so: much of the energy gets used to build potential energy. For that reason the water doesn’t “heat up” as much as anticipated—which is another way of saying that water’s heat capacity is anomalously high.

A second “anomaly” occurs when water is cooled down. Cooling increases water’s density every so slightly. Once the temperature descends beyond 4°C, however, further cooling brings expansion, not contraction. When additional cooling eventually turns the water to ice, the volume expands appreciably (Figure 4). Ice floats on water.

Responsibility for this seemingly inexplicable density maximum at 4°C lies in the presence of water’s fourth phase. Fourth phase (EZ) structure resembles the structure of ice. Ice consists of parallel honeycomb planes linked together by protons. Removal of those protons creates EZ. Or the reverse: beginning with EZ, add protons and obtain ice (Figure 5). We found that the transition from water to ice requires passing through the EZ phase.

EZ structure is denser than ice and also denser than water. This is known from the fact that EZ’s refractive index exceeds that of water. It is higher by up to 11%. The higher density makes sense structurally: because charges in one plane abut opposite charges in the adjacent plane, the honeycomb planes pack tightly next to one another. That tight packing produces especially high density.

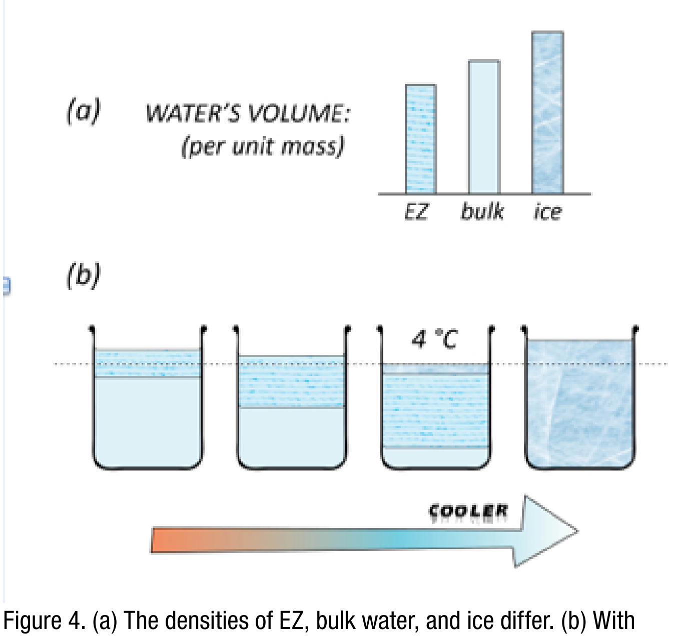


Figure 4. (a) The densities of EZ, bulk water, and ice differ. (b) With cooling, the volume changes in a way predictable from the quantity of each phase.

When considering temperature-dependent density changes, then, it's necessary to consider what phases may be present in the water at each temperature. At high temperature, water is largely bulk water. When the temperature descends, experimental evidence shows increasing amounts of EZ water; therefore the mean density increases. As the temperature descends further, isolated EZs begin turning to ice, bringing expansion. Finally, massive ice formation begins at approximately 0°C, and the density diminishes appreciably.

Hence, the density maximum at 4°C has nothing to do with any idiosyncratic feature of the H_2O molecule. It is a reflection of the dominating fraction of EZ water, whose density exceeds that of bulk water and ice.

Practical Applications

Beyond pure science, the discovery of the fourth phase has practical applications. They include flow production (already mentioned), electrical energy harvesting, and even filtration. I briefly mention the latter two applications.

Filtration occurs naturally because the liquid crystalline phase massively excludes solutes and particles in much the same way as does ice. Accordingly, fourth phase water is essentially solute free. Collecting it provides solute-free and bacteria-free water. A working prototype has confirmed this expectation. Purification by this method requires no physical filter: the fourth phase itself does the separation with the energy coming from the sun.

Energy harvesting seems straightforward: light drives the separation of charge, and those separated charges constitute a battery. Harvesting electrical energy should be realizable with proper electrodes. This technology development is underway in our laboratory, and has the potential to replace standard photovoltaic systems with simpler ones based on water.[4]

Water and Healing

During childhood illness, grandmothers and doctors will often advise: "drink more water." In his now-classic book, titled *Your Body's Many Cries for Water: You Are Not Sick, You Are Thirsty,* the Iranian physician Fereydoon Batmanghelidj confirms the wisdom of this quaint advice. The author documents years of clinical practice showing reversal of diverse pathologies simply by drinking more water. Hydration is critical.

Batmanghelidj's experience meshes with evidence of healing from special waters such as those from the Ganges and Lourdes. Those waters most often come from deep underground springs or from glacial melt. Spring waters experience pressure from above; pressure converts liquid water into EZ water because of EZ water's higher density. So, spring water's healing quality may arise not only from its mineral content but also from its relatively high EZ content.

The same for mountain water: it too should have high EZ content. Our studies have shown that ice formation requires an EZ intermediate: bulk water does not convert directly to ice; it converts to EZ, which then converts to ice. Similarly for melting: melting ice forms EZ, which subsequently converts to bulk water. Fresh ice melt contains abundant EZ water.

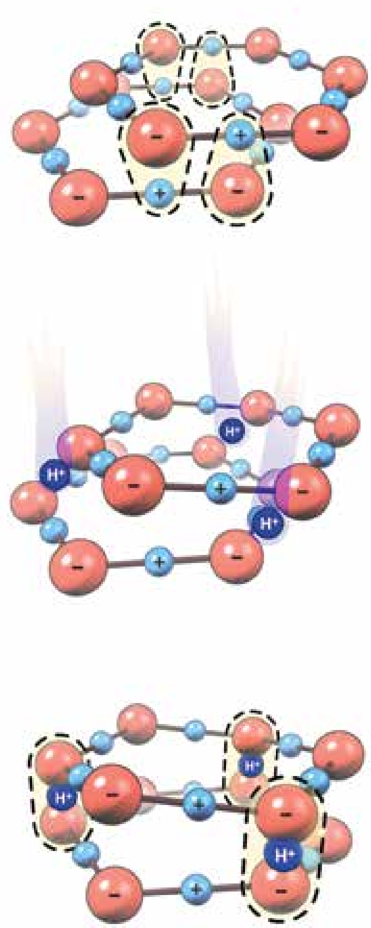


Figure 5: Transition from EZ (a) to ice. The transition requires protons (b) and planar shift (c).

For spring water and fresh ice melt, then, the high EZ content may explain the recognized health benefits. EZ water should rehydrate tissues better than ordinary water because of its higher dipole moment. To appreciate this argument, picture a bean, with positive charge localized at one end and negative at the other. The positive end of that dipole orients toward the negatively charged cell, which then strongly draws in that dipole. The larger the dipole, the stronger will be the draw. Since EZs contain masses of separated charges, or large dipoles, EZ water should hydrate cells better than ordinary water. That's why EZ water may particularly promote good health.

Negative Charge and Antioxidants

Humans are considered neutral, but I suggest that we bear net negative charge.

Physical chemists reasonably presume that all systems tend toward neutrality because positive charge attracts negative charge. The human body being one of those "systems," we assume that the body must be neutral.

Not all systems are neutral, however. The earth bears net negative charge, while the atmosphere bears net positive charge. Water itself can bear charge: Anyone watching MIT professor Walter Lewin's stunning demonstration of the Kelvin water dropper, where separated bodies of water eventually discharge onto one another, will immediately see that bodies of water can bear net charge.[5] If any doubt remains, then the experience of getting an electric shock from touching certain specially prepared drinking waters (which my colleagues and I have personally experienced) should eliminate that doubt.

Charges can remain separated if input energy keeps them separated—something like recharging your cell phone battery and creating separated negative and positive terminals. Since we constantly absorb external energy from the environment, the theoretical possibility exists that we may bear net charge.

Consider the arithmetic. Cells make up some 60% of our body mass, and they are negatively charged. Extracellular tissues such as collagen and elastin are next in line, and those proteins bear negative charge and adsorb negatively charged EZ water. Only some of the smaller compartments are positively charged with protons (low pH), and they commonly expel: urine, gastrointestinal system; sweat, and expired air (containing hydrated CO_2 or carbonic acid). They help rid the body of positive charge.

So, the arithmetic shows not only that our body bears net negative charge, but also that the body makes every effort to maintain that negativity by ridding itself of protons. It is as though maintaining negativity is a "goal" of life. Plants do it easily: they connect directly to the negatively charged earth; animals need to struggle a bit more to maintain their body's charge, in exchange for greater mobility.

How does our body's negative charge relate to the benefits of antioxidants?

Answering this question returns us to basic chemistry. Recall that "reduction" is the gain of electrons, while "oxidation" means electron loss. Oxidation strips molecules of their negative charge, working against the body's attempt to maintain high negativity. To guard against that loss we employ anti-oxidants. Antioxidants may keep us healthy simply by maintaining proper negativity.

The Future

Water's centrality for health is nothing new, but it has been progressively forgotten. With the various sciences laying emphasis on molecular, atomic, and even sub-atomic approaches, we have lost sight of what happens when the pieces come together to form the larger entity. The whole may indeed exceed the sum of its parts: 99% of those parts are water molecules. To think that 99% of our molecules merely bathe the "more important" molecules of life ignores centuries of evidence to the contrary. Water plays a central role in all features of life.

Until recently, the understanding of water's properties has been constrained by the common misconception that water has three phases. We now know it has four. Taking into account this fourth phase allows many of water's "anomalies" to vanish: those anomalies turn into predictable features. Water becomes more understandable, and so do entities made largely of water, such as oceans, clouds, and human beings.[6]

The insights described here arose out of a departure from the mainstream science route. They were gleaned mainly from simple observations and logical interpretations. I have purposefully ignored the usual foundation of the "generally accepted," having some skepticism that all accepted principles are necessarily valid. I believe this skepticism has brought us some gains.

If this outcome is representative, then similarly unorthodox approaches in other fields may yield rich bounties, especially in those fields that have shown little signs of real progress.

I hope this example inspires other such unconventional approaches.

REFERENCES

1 This newly identified phase of water is described in detail in *The Fourth Phase of Water: Beyond Solid, Liquid and Vapor* by Dr. Gerald Pollack, published in 2013 by Ebner and Sons Publishers (http:// www.ebnerandsons.com).

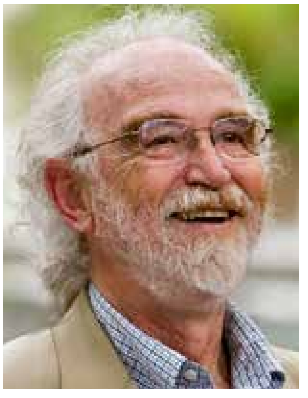
2 See *Cells, Gels and the Engines of Life* by Dr. Gerald Pollack, published in 2001 by Ebner and Sons Publishers.

3 An extensive list appears on the popular website of Martin Chaplin http://www1.lsbu.ac.uk/water.

4 More detail on these practical applications can be found in the Pollack laboratory homepage: http://faculty.washington.edu/ghp.

5 Shortcut to Walter Lewin's YouTube video: http://tinyurl.com/2kom5w.

6 Various hour-long talks, available on YouTube videos, describe these fresh understandings. One of them is a University of Washington public award lecture (http://tinyurl.com/lna5cdg). Another was delivered more recently (http://tinyurl.com/kqof8lz). A third is a recent TEDx talk (http://tinyurl.com/lp5v6ko).



GERALD POLLACK is a Professor of Bioengineering at the University of Washington and an international leader in the field of water research. He received his Ph.D. from the University of Pennsylvania in 1968. Since then, his research interests have ranged broadly over the scientific spectrum, from cardiac dynamics and electrophysiology, to muscle contraction, cell biology, and more recently to the role of water in nature. Currently, Dr. Pollack runs the Pollack Laboratory at the University of Washington, which focuses on uncovering some of nature's most deeply held secrets. He is also the Editor-In-Chief of the scientific journal *WATER*, a multidisciplinary research journal that brings together water-oriented research from diverse disciplines. He is the author of several books, including most recently of *The Fourth Phase of Water: Beyond Solid, Liquid and Vapor*.

The reason this fourth phase of water is called the exclusion zone or EZ is because the first thing Dr. Pollackâ€™s team discovered is that it profoundly excludes things. Even small molecules are excluded from EZ water. Surprisingly, EZ water appears in great abundance, including inside most of your cells.Â Other inherent differences between regular water and EZ water include its structure. Typical tap water is H2O but this fourth phase is not H2O; itâ€™s actually H3O2. Itâ€™s also more viscous, more ordered, and more alkaline than regular water, and its optical properties are different. The refractive index of EZ water is about 10 percent higher than ordinary water. Its density is also about 10 percent higher, and it has a negative charge (negative electrical potential).