Synopses

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QUANTUM WEIRDNESS

It turns out that water's hydrogen-bonded molecular network is even more enigmatic and indescribable than scientists first imagined. Recall that the ultrafast dynamics of this massive and complex network permits water to exhibit its strange properties. Hydrogen bond dynamics owe their indescribability to a quantum phenomenon known as "zero-point vibrations," which are not related to the common laws of motion (i.e., kinetics), but rather to an energy that exists even after all conventional energy disappears at a temperature of absolute zero. This energy is sometimes designated as belonging to the aether or A-field, denoting a realm that perhaps contains energy or information but is not part of our observable world—although it does influence our observable world. It is interesting to note that many ancient descriptions of water suggest that it acts as a mediator between the seen and unseen worlds. What is water's connection to this mysterious aether?

WATER AND ROCK

While water and rock are often considered to be mutually exclusive, the former actually plays a pivotal role in the formation and properties of the latter. Most rocks composing the crust of the Earth are produced from extensive ridges lying at the bottom of the world's oceans. The presence of water in molten rock affects its temperature and, ultimately, the thickness of the rock layer that we refer to as "solid earth." When Earth's crust is recycled (or subducted) back into in the molten core, water not only lubricates the subduction of one rock slab past another, it also travels with and influences the melting rock. Besides serving as a component of the hard rocks we commonly encounter on the planet's surface, water is also a component of the molten rock we observe only during the eruption of some volcanoes. It should be noted that water occurs as part of the hard rock's crystalline matrix and not as a separate liquid.

ROCK AND WATER

In addition to affecting rock, water can also be affected by rock. Water's molecular structures and dynamics are obviously influenced by geologic-scale processes; however, tiny bits of rock suspended or dissolved in water (as either colloids or ions) can also transform water. Whereas ions are often detected by water's salty taste, suspended rock is usually indicated by water's cloudy appearance. Finely pulverized rock influences many of water's physical properties (i.e., surface tension), as well as the reported health of those who drink it. Some researchers have postulated that mineral colloids are able to create very small molecular clusters within water that serve to better hydrate biological cells and, thus, reduce the damage caused by aging and pollutants. Even more mysterious (and controversial) is the observation that water need not directly contact the rock to produce some of these physical and biological effects.

PHARM WATERS

In addition to the suite of pesticides, herbicides, industrial chemicals, and fuel components that are routinely found in freshwater ecosystems, there is a relative newcomer to the list. As a result of the Western world's addiction to prescription drugs, trace levels of bioactive substances have shown up in the rivers, lakes, and groundwater aquifers of North America and Europe. It was originally posited that these drugs, which treat everything from depression and impotence to heart disease and high cholesterol, were contributed primarily by pharmaceutical manufacturers that improperly disposed of their wastes. Now it appears that the bulk of the "drug load" is contributed by consumers who throw out or excrete these substances, which are resistant to degradation in wastewater treatment plants. Not only do these drugs adversely affect aquatic organisms, they occasionally end up in our drinking water supplies.

THE DEEP WATER CYCLE

Besides the familiar water cycle that includes the oceans, atmosphere, and soils, there is another global water cycle that lies deep beneath the planet's surface. Often referred to as the "deep water cycle," geologists describe the dynamics of hydrous (water-containing) silicates and of hydrogen and oxygen atoms in solid, semi-solid, and molten layers of Earth's interior. Some researchers posit that this deep-water reservoir is greater than that of surface oceans and is, in fact, what keeps the seawater volume relatively constant. As previously described, water incorporated into the mineral matrix of rocks profoundly influences events such as earthquakes and volcanoes. Speaking of earthquakes, the 2004 megaquake responsible for the Indonesian tsunami left a huge scar in the Earth's crust and mantle that has apparently "healed" faster than anticipated due to water's lessening the stress within the affected rocks.

CHAOTIC FRACTALS

Researchers have found that water's assembly algorithms, representing the rules by which it self-organizes at all hierarchical levels, are a result of fractal-like structures. Fractals represent patterns that remain exactly the same (i.e., possess identical proportions) on different scales (e.g., microcosm and macrocosm). Fractals produced by complex systems have been traced to so-called strange attractors that are associated with chaotic behaviors, a subset of which are applicable to water's hydrogen-bonded network. Moving from microcosm to macrocosm, both the complex motions of seawater within the oceans and the flow paths of surface or ground waters within watersheds can be described by chaos and fractal patterns. Water's patterns are even displayed as basic structural properties of the biosphere, such that common flow forms (e.g., spirals, ripples) are often mimicked in the morphology of aquatic animals and plants.

MAKING MORE WATER

Can we simply produce more water? The answer depends on what exactly is meant by "producing" more water. There is plenty of oxygen gas in the atmosphere to create more water; however, hydrogen gas is not readily available in our environment—at least not in the required concentrations and locations. Hence, we are left to produce more usable freshwater either from unusable freshwater (e.g., currently inaccessible or polluted) or from seawater, both of which require large amounts of energy. There are a number of techniques available for capturing currently inaccessible water. Condensation is a method of converting water vapor to liquid water by cooling humid air; however, it too is energy consumptive. By contrast, practices such as permaculture, graywater usage, and rainwater harvesting have a tremendous potential to maximize water efficiency and to return us to a more "hands-on" relationship with water.

WATER ETHICS

Have many postmodern people lost or compromised their ethics regarding water? A perceived lack of water ethics was recognized at the First World Water Forum, where the Director-General of UNESCO called for a "new attitude" on water. Unfortunately, a United Nations committee cannot simply impose water ethics, which are instead derived largely from people's individual and collective perceptions of water. Forcing people into an ethical relationship with water using legislation, litigation, regulation, or any other well-meaning externality has proven futile. Only when we begin to perceive water differently will we treat it differently; and it seems that an effective means of perceiving water differently is directly and often intimately experiencing it in a manner that transcends its intellectual labels. Issues of water quality, scarcity, allocation and privatization are a consequence of our limited perceptions of water, which will likely require a substantial shift before any lasting solutions begin to appear.

WATER AND ENERGY (part 1)

Whether obtaining, refining, transporting, growing, or disposing of the fuels used to drive our present-day world, water is required to produce power and to cleanup the mess created by its production. Alternative energy sources like wind, solar (small-scale), and fuel cells pose the least water demands, whereas nuclear, fossil, and biomass fuels pose the greatest demands. Using bioethanol as a fuel source requires both a conversion of food to energy crops (diminishing the global food supply) and an expansion of the cultivated land under corporate agriculture (escalating the demand for and pollution of water). Interestingly, a fuel consisting of molecular hydrogen can be produced in water by green algae, along with two different types of bacteria, that collectively regenerate some of the precursors required for sustaining the production of hydrogen. This microbiological process is an example of sustainably producing a renewable fuel.

WATER AND ENERGY (part 2)

Regarding alternative energy sources that are less water demanding, it is interesting to note that the greatest use of water for solar power (at least on a small-scale basis) is in manufacturing the hardware components for photovoltaics, solar panels, and batteries. Designers of a so-called "water car" have demonstrated that converting automobiles to an onboard hydrogen-generating system is perhaps feasible, economical, and averts the problems associated with remotely producing, storing, and transporting large volumes of hydrogen gas. Essentially, the cars are equipped with an electrolysis cell that uses DC current to split water molecules into oxygen and hydrogen atoms, which then combine to form the gases that power the car. In switching from fossil fuels to alternative energy sources, we should keep in mind that the quantity, distribution, and quality of water available to support the switch may prove to be a limiting factor.

SEQUESTERING CARBON

As humans look for a place to dispose of this century's most "inconvenient" contaminant (i.e., carbon dioxide) it should be no surprise that water tops the list. Perhaps the most popular carbon sequestration technique includes pumping liquid CO_2 into the deep ocean, where it is predicted to remain as a dense liquid waste. Even if it were possible to capture, cool, transport, and pump the carbon dioxide without utilizing the same fossil fuels that generate CO_2, the act of disposing this liquid waste represents a huge stress on the local deep sea environment, where many biological organisms will be killed and changes in the pH and redox chemistry of seawater will likely ensue. In our zeal to mitigate global climate change, we should recall the lessons of burying other wastes—namely, that there are no isolated compartments within Earthly environments and that global carbon and global water cycles are intimately linked.

CARBON FOR WATER

If not in the oceans, deep saline aquifers and depleted oil and gas reservoirs have been targeted as just the place to dispose of our excess carbon dioxide. While the subterranean burial of CO_2 is attractive, it could result in the blowout of injection wells, the leakage of CO_2 and other greenhouse gases (e.g., methane) to the atmosphere, the subsiding or uplifting of the ground surface, the initiation of shallow seismic activity, and the contamination of adjacent freshwater aquifers. A less grandiose technology listed under "carbon offsets" is the planting of trees in tropical and subtropical regions that have lost their biomass to logging or slash-and-burn agriculture. However, monoculture tree plantations often disrupt local hydrologic regimes (e.g., reducing surface water flows and increasing the salinity or acidity of soils), increase the susceptibility of trees to disease, and merely constitute a swap of carbon credits for water losses.

VORTEX TECHNOLOGY

Naturalists have long been fascinated with the geometry of natural spirals and the efficiency with which vortices are able to mix water, air, or any other fluid; however, this principle has not been universally applied because standard engineering designs are based on a different approach to fluid mechanics. A Bay Area researcher has designed a small (6x4 inch) stainless steel impeller that looks like the inside of a conch shell and is able to mix water in the large tanks that hold drinking water supplies for a majority of people in the industrialized world. The use of conventional pumps or aerators to mix drinking water, which facilitates its treatment and disinfection, is energy intensive and creates secondary problems. By contrast, the tiny vortex mixer employs nature's inherent efficiency in entraining all of the water in the tank and, thus, mixing it with only a fraction of the energy required by the pumps or stirrers it replaces.

SALTWATER POWER

An innovative conversion of seawater to power is illustrated by the so-called "salinity battery," which is driven by the osmotic gradient created between seawater and freshwater stored on either side of a synthetic membrane. As fresh water moves spontaneously through the membrane to dilute the dissolved salts on the other side, the seawater is pressurized and then piped through a turbine to generate electricity. Challenges to salinity power include developing an optimal membrane and building a facility that can operate in deltas, estuaries, or other locations where rivers and oceans meet. Anticipated environmental impacts include the disposal of brackish water (although less salty than the brines produced by conventional desalination plants) and the presence of platforms or pylons in potentially sensitive aquatic habitats. Nevertheless, this salinity-powered battery is based on emulating a natural process.

RESTORING WETLANDS

The widespread destruction of natural wetlands throughout the world has prompted the design and installation of artificial wetlands; however, the replacements can never fully mimic the original because nature's intricacies are too numerous and complex. Some of the most important design parameters include mimicking hydrodynamics (e.g., extent and duration of flooding, rates of infiltration and evaporation), which requires water inlets, outlets, weirs, and other engineering control structures. In addition, geotextiles for sediment covers, brush for shading and erosion prevention, and rocks for habitat improvement are required to achieve a balance among the mineral, aqueous, and organic phases of the soil. Even after a decade, the functioning of artificial wetlands has been observed to be markedly different than that of natural wetlands, illustrating the challenge that scientists face when emulating nature's water dynamics.

A WATER TREE

Scientists at Cornell University have developed a so-called synthetic tree composed of a special gel that is etched with 80 tiny channels running parallel to one another in a manner that simulates the tube-filled vascular system, or xylem, of a real tree trunk. Essentially, water wicks up in the nanometer-scale pores of a gel under the driving force of capillary action. This tree consists of a couple circles (one representing a root network and the other a leaf network) that could never be mistaken for a real tree; however, the mechanism for their transporting water is similar inasmuch as no added energy is required to pump water against the relentless force of gravity. The operating principle of the synthetic tree is one that employs design, rather than power, to achieve the desired goal and that integrates the behavior of water (as hydromimicry), the biomechanics of trees (as biomimicry), and the properties of gels (as materials science) into a single solution.

LIFE'S TWO WATERS

The molecular mechanisms underlying many biochemical processes remain poorly understood (e.g., how enzymes cleave substrates, how nucleic acids are formed from their components). Water that is integral to all of these processes is believed to exist in one of two states—either low density (expanded) or high density (collapsed) in which hydrogen bonds of different strengths hold the adjacent water molecules together. Organic and inorganic substances have different solubilities in the two types of water, which support distinct kinds of biochemical processes and switch back-and-forth depending on water's exact microenvironment. Hence, regardless of how water may be structured before it enters an organism, biomolecules constantly restructure it inside the organism. Intriguingly, the bonding dynamics between water and biomolecules permit an ultrafast exchange of energy, conformation and, perhaps, information that is transmitted as a change in the state of a biomolecule.

WATER CHANNELS

A need to move water quickly and efficiently in living organisms is paramount; however, the understanding of how water moves through cell membranes is relatively recent. Nobel Laureate Peter Agre discovered that, in addition to simple diffusion, there are proteins (aquaporins) embedded in the membranes that rapidly transport water in and out of cells. A human aquaporin channel can transport about three billion water molecules per second in single file order! The orientation of water molecules moving through the channels is very precise and is believed to correspond to electrical fields formed by atoms comprising the channel walls. In any case, the structuring of water outside the cell does not seem to be preserved inside the cell, and biological life's requirement for rapidly moving water across cellular membranes suggests that it may be essential in ways that remain as mysterious as they are intriguing.

CONTAMINANT PULSES

The use of human engineering to alter the hydrologic connectivity among landscapes, groundwater aquifers, and surface waters (e.g., streams, rivers) has permitted water to be rapidly transported through urban storm drains, agricultural ditches, and diversion canals. This alteration of water's natural flow paths has contributed to the rapid movement of pollutants as so-called contaminant "pulses." These pulses are frequently detected in both terrestrial and coastal waters as a result of the loss of headwaters, wetlands, and other natural features that slow the transport of sediments or pollutants (e.g., silt, metals, nutrients, pesticides) and reduce their concentrations. Often the pulses arrive too rapidly to warn downstream receptors (human or otherwise) of their imminent exposure to pollutants—an occurrence that is now all too commonplace as climate variability has increased. Researchers are working to improve the spatial and temporal resolution of mathematical models in order to better predict such events.

WATER FOOTPRINTS

The concept of a water footprint arose when researchers tried to quantify the per capita volume used for direct (e.g., drinking, cooking, bathing) and indirect (e.g., products, services) purposes. Consumptive use is the most obvious component of the water footprint, but water is also lost to pollution, evaporation, and relocation to places where it cannot be reused. Perhaps not surprisingly, the water inherent in producing food and energy comprises a major portion of a person's water footprint. Americans have the highest water consumption, with an annual per capita use (about 2600 cubic meters) that is more than double the global average. Because of their population density, cities require an area as much as 600 times that of their geographic boundaries to provide sufficient water. Moreover, the electricity required to pump water from productive watersheds to cities comprises a major portion of their total energy footprint.