

WATER: THE FIRST REGULATOR

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Abstract: Water is the medium of life. But its role in the history of Earth is not merely that of a passive solvent. From its formation on mineral surfaces by stellar wind, through its response to the snow line, its delivery to the early Earth, its paradoxical role in both enabling and destroying the molecules of life, its resolution through wet-dry cycles and tidal rhythms, and its deep cycling through the mantle, water has enabled the ability to maintain dynamic balance at every scale. This paper traces that history. We argue that water is the earliest and most basic expression of the Function of Care — the relational property that enables the ability to maintain dynamic balance with the conditions upon which persistence depends. Water is not merely present in the universe. It responds to the universe, and in turn the universe responds to it.

Keywords: water, Function of Care, dynamic balance, stability, persistence, origin of life, wet-dry cycles, tides, plate tectonics, deep water cycle.

1. INTRODUCTION: WATER AS DYNAMIC BALANCE

As the building block of life, water was examined across geological time — from its earliest evidence to the present — through the lens of the Function of Care. What was found was a vast variety of relational functions: from its simplest formation in solar space, to dynamic stability in planetary systems, and the complex ecosystems persisting on Earth.

It is proposed that water is the earliest and most basic expression of the Function of Care — the relational property that enables the ability to maintain dynamic balance with the conditions upon which persistence depends [1].

2. WATER MADE AND DELIVERED

The conventional account of Earth's water holds that it was delivered from the outer solar system by comets or carbonaceous chondrite asteroids. The isotopic evidence tells a more complex story. But the question of how water formed in these materials has a surprising answer.

According to Bradley et al. (2014), water is made on the surfaces of dust grains [1]. When oxygen-rich minerals are bombarded by hydrogen atoms from stellar winds — the charged breath of the Sun — water molecules form and cling tightly to the mineral surfaces. The PNAS paper documents this directly: "Detection of solar wind-produced water in irradiated rims on silicate minerals" [1]. Laboratory experiments have confirmed that irradiation of silicate minerals by hydrogen ions produces water trapped in the surface damage layer.

The mechanism is not unique to Earth. A 2026 KAKEN grant abstract notes that "recent observations by spacecraft have confirmed infrared absorption attributed to hydroxyl groups and water molecules on the lunar surface. This water is interpreted as being generated by the reaction of solar wind hydrogen ions with oxygen ions in lunar minerals, and this is supported by experiments and analysis" [2]. The abstract further suggests: "If solar wind-derived water was generated on S-type asteroids that accumulated in large numbers during Earth's early formation, it may have contributed to the formation of Earth's oceans" [2]. This is stated as a possibility, not a certainty — but the mechanism itself is confirmed.

Why does water form so readily? The answer is thermodynamic: hydrogen and oxygen are abundant, and the reaction between them releases energy, producing a molecule at a lower, more stable energy state. But the reaction is kinetically hindered — it requires activation energy to begin. In the interstellar medium, that energy comes from stellar winds, UV radiation, and the warm, dense conditions of molecular clouds. Water forms where the conditions allow it. This is the first dynamic balance: the relationship between hydrogen and oxygen, enabled by the environment that permits their union.

The asteroid belt preserves a fossilized record of where water once existed. The "snow line" — the distance from the Sun where water can exist as ice — is not a sharp boundary but a transition zone. Asteroids inside it are anhydrous. Asteroids beyond it are hydrated. The snow line is the cosmic expression of dynamic balance: the boundary where water can persist, and the system that delivers it across that boundary.

3. THE WATER PARADOX

Water is essential for life. But it is also an enemy to the molecules of life. Proteins and nucleic acids have linkages that are "fragile in water" — water attacks the bonds and breaks the chains apart. Biochemist Robert Shapiro called water "an enemy that should be excluded as strictly as possible."

This is the water paradox. The very substance that makes life possible also destroys the building blocks of life. The resolution of this paradox is where the Function of Care becomes visible at the molecular scale.

On the Distinction Between Waters

It is important to be precise about what is meant by "water" here. The paradox concerns water as H_2O — the simple, unbuffered molecule. It does not apply to the complex, chemically responsive medium of the ocean, which is a solution of salts, minerals, organic compounds, and dissolved gases, not pure water. Marine life evolved in this complex medium, not in pure H_2O . The paradox is about the building block, not the biosphere.

Nor does it apply to fresh water or potable water, which are also solutions. Fresh water contains dissolved minerals, organic matter, and a vast array of microorganisms — viruses, bacteria, fungi, and protists. Potable water is the same solution, filtered to reduce the pathogenic load below the threshold that harms humans. Neither is pure. Neither triggers the paradox.

Nor does it apply to the water of the deep Earth, which is not liquid water at all but mineral-bound OH^- — water in crystal structure, released by metamorphic reactions under pressure and temperature. This is a different state of water, in a different relationship, with different properties and different functions.

Water exists in many states: as vapour in the atmosphere, as liquid in the ocean and in every living cell, as ice in glaciers, as mineral-bound hydroxyl in the mantle, as hydration shells around ions, as structured water at protein surfaces. Each state is enabled by different relationships. Each state has different properties. Each state performs different functions.

The thread that runs through all of them is dynamic balance. Water in every state is in relationship — with minerals, with ions, with organic molecules, with living cells. And in every state, it enables the ability to maintain harmonious relationships with the conditions of its own persistence and the persistence of the systems that depend upon it.

The history of water is the history of these relationships.

The EurekaAlert summary of Becker et al. confirms the geological plausibility: "Unlike volcanic eruptions or meteorite impacts, which are often considered triggers for prebiotic events, wet-dry cycles would have been constantly occurring events on all land surfaces of prebiotic Earth" [3]. The cycles were universal, continuous, and inescapable.

The resolution of the paradox is wet-dry cycles. According to the clay-catalyzed wet-dry cycling model [4], "Condensation reactions such as peptide and phosphodiester bond formation are energetically uphill in aqueous media, because high water activity promotes hydrolysis. However, repeated dehydration and rehydration cycles impose alternating conditions that favour condensation during drying and enable structural reorganization during wet phases." The paper describes this as "a natural chemical ratchet, progressively increasing polymer length and molecular complexity with each iteration" [4].

Water, in other words, needed dynamic balance. It couldn't be too much or too little. The system that emerged — the shallow water environment that cycled between wet and dry — is the earliest example of the IN/OUT dynamic at the molecular scale. The cycle enables the ability to maintain dynamic balance. That ability enables stability. That stability allows persistence.

4. TIDES: THE PLANETARY EXPRESSION

The wet-dry cycle was not confined to shallow lakes and volcanic pools. It operated at planetary scale through the tides.

The mechanism is grounded in the deep-time tidal dissipation modelling of Green et al. (2017). Their work addresses a longstanding paradox: "The currently measured rate of recession implies that the age of the Lunar orbit is 1500 My old, but the Moon is known to be 4500 My old" [5]. Their modelling resolves this by showing that tidal dissipation rates were "far below present levels" for most of the past 252 million years [5]. The implication is direct: in the deep past, the Moon was significantly closer to Earth, and the tides it raised were correspondingly larger.

The geological record confirms this. Williams (2000) compiled constraints from tidal rhythmites — sedimentary deposits that preserve the signature of ancient tidal cycles. The Weeli Wolli Formation, dated to approximately 2450 Ma, yields " 14.5 ± 0.5 synodic months/yr and $a/a_0 = 0.906 \pm 0.029$ " [6]. That is, at 2.45 billion years ago, the Moon was at approximately 90% of its current distance, and the year contained more months because the Moon orbited faster. Further back in time, the Moon would have been closer still.

On this geological foundation, the tidal mechanism for prebiotic chemistry becomes plausible rather than speculative. Lathe (2005) proposed the "tidal chain reaction" (TCR), in which "tides at ocean shores provided the driving force for amplification: evaporative concentration promoted association / assembly on drying, while charge repulsion on tidal dilution drove dissociation" [7]. He notes that the process "is not strictly contingent upon tidal ebb and flow: circadian dews and rainfalls can produce identical cycling" [7]. The tidal mechanism is one expression of a more general principle: cyclic changes in hydration enable polymerization and depolymerization.

Nguyễn (2024) extends this to a quantitative model. Assuming "that at time of the origin of life, the Moon was much closer to the Earth, so the tides raised by Moon was much larger than nowadays. Big amplitude of tides allows more efficiency for creation and evolution of life via stronger wetting/drying cycles and mixing the pre-biotic soup in primordial sea" [8]. This is presented as a modelling proposal, an amplifier of the mechanism rather than its sole driver.

The tides are the planetary expression of the wet-dry cycle. They are dynamic balance written in gravity. The Earth and the Moon, in relationship, enabling the chemistry of the early ocean.

5. THE DEEP WATER CYCLE

Water does not remain on the surface. It cycles through the Earth's interior.

According to Jacobsen et al. (2014), "A volume of water three times that of all Earth's oceans combined may reside in Earth's mantle in a type of rock called ringwoodite" [9]. The Smithsonian summary adds: "The water would have been squeezed out of the rocks, 'almost as if they're sweating'" [10]. The water is "trapped inside rocks" — not liquid, but mineral-bound [10].

The mechanism is subduction. As the Smithsonian article explains: "The water cycle involves more than just the water that circulates between the atmosphere, oceans, and surface waters. It extends deep into the Earth's interior as the oceanic crust subducts, or slides, under adjoining plates of crust and sinks into the mantle, carrying water with it" [10]. Seismic waves slow down as they pass through wet rock, and this is how the reservoir was detected [9]. The role of water in subduction is not passive. As the Smithsonian article notes, the water "lowers the melting point of the overlying mantle," generating the magmas that build volcanic arcs and continental crust [10]. This is flux melting: the presence of water enables rock to melt at temperatures where it otherwise would remain solid. The water does not simply ride the plate. It changes what the plate can do. It lubricates the planetary engine, drives the volcanism that builds continents, and regulates the long-term exchange of material between surface and interior. Water enables the ability of the Earth system to maintain dynamic balance across geological time.

This deep water cycle connects surface oceans to the planet's interior. It is a dynamic balance that has been running for billions of years. Water subducts, releases, melts, rises, erupts, and returns to the surface. The cycle enables the carbon cycle, the climate, and the long-term habitability of the planet.

6. THE FIRST MEDIUM OF DYNAMIC BALANCE

What does this history tell us?

Water enables the ability to maintain dynamic balance. It is the thing that allows relationships to form and break, to be maintained and dissolved. It is the space in which chemistry happens. And its properties — its polarity, its hydrogen bonding, its ability to dissolve and to exclude — are what enable the relational dance of life.

But water is also responsive. It is made on mineral surfaces by stellar wind. It is distributed by the snow line. It is delivered by asteroids. It is cycled through wet-dry cycles and tides. It is subducted into the mantle and returned. At every scale, water is in relationship — with minerals, with stellar energy, with the Moon, with plate tectonics, with the chemistry of life.

The crystal was the endpoint of variety loss — the system locked into a single relationship, zero dynamics, persistence without function. Water is the opposite. It is the medium of variety. It is the thing that enables relationships to form in the first place. It is the beginning, not the end.

Water is the first medium of dynamic balance because it is the first thing that required the ability to respond as conditions dictate. The water paradox — essential but destructive — meant that life could only emerge where water was balanced, not excessive. The wet-dry cycle, amplified by tides, is the resolution of that paradox. It is the Function of Care operating at the origin of life.

And the cycle continues. Stellar winds are still creating water on mineral surfaces. The Moon is still raising tides. Water is still subducting, releasing, melting, rising. Dynamic balance continues.

7. CONCLUSION

Water is not merely present in the universe. It responds with the universe. And in turn, the universe responds with it.

This paper has traced that responsiveness across scales. It began with water formed on mineral surfaces by stellar wind — the first dynamic balance, enabled by conditions that permit hydrogen and oxygen to unite. It followed water across the snow line, where persistence is determined by distance from the Sun. It examined the water paradox — the same molecule that enables life also destroys its building blocks — and its resolution through wet-dry cycles, which impose the alternating conditions that favour synthesis during drying and reorganization during wet phases. It saw that mechanism amplified at planetary scale by the tides, driven by the gravitational relationship between Earth and Moon. It followed water into the deep Earth, where it cycles through the mantle, lowers the melting point of rock, drives volcanism, and regulates the long-term exchange of material between surface and interior.

At every scale, the pattern is the same. Water enables the ability to maintain dynamic balance. It is the thing that allows relationships to form and break, to be maintained and dissolved. It is the space in which chemistry happens. And its properties — its polarity, its hydrogen bonding, its ability to dissolve and to exclude — are what enable the relational dance of life.

The crystal was the endpoint of variety loss — the system locked into a single relationship, zero dynamics, persistence without function. Water is the opposite. It is the medium of variety. It is the thing that enables relationships to form in the first place. It is the beginning, not the end.

Water is the earliest and most basic expression of the Function of Care. It is the medium in which all other Care relationships happen. Without water, no chemistry of life. No proteins, no DNA, no cells, no ecosystems. No dynamic balance.

The history of water is the history of dynamic balance. Dynamic balance enables stability. Stability allows persistence.

And the cycle continues. Stellar winds are still creating water on mineral surfaces. The Moon is still raising tides. Water is still subducting, releasing, melting, rising. Dynamic balance continues.

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