Water: Truth, Beauty and Goodness

"The entire science of mathematics, the whole domain of philosophy, the highest physics or chemistry, could not predict or know that the union of two gaseous hydrogen atoms with one gaseous oxygen atom would result in a new and qualitatively superadditive substance — liquid water. The understanding knowledge of this one physiochemical phenomenon should have prevented the development of materialistic philosophy and mechanistic cosmology." (TUB 12:9.3 (141.4)) (1934)

This quote is intriguing in that it points out the weakness of our human (mind) derived epistemological systems to understand a substance that is basic to life on this planet. Looking at both the adjectives used and the phenomenon mentioned perhaps will give some understanding of what the authors were attempting to impart.

Qualitatively is the adverb derived from the noun quality which is defined as: 1) a peculiar and essential character; an inherent feature or 2) a degree of excellence; superiority in kind. Both sets of definitions could be applied with each imparting a different nuance. Many times quality is defined by contrasting it to quantity. Quality (qualitative) is subjective while quantity (quantitative) is definitive.(1)

Superadditive is a mathematical term (lemma) that was advanced by the mathematician Michael Fekete in 1925. Simply stated:
a sequence $\{ a_n \}$, $n \geq 1$, is called **superadditive** if it satisfies the inequality

$$a_{n+m} \leq a_n + a_m \quad \text{for all } m \text{ and } n. \quad (2)$$

In the case of water this would imply that the addition of two hydrogen atoms and one oxygen atom equals more (greater) than expected from mixing two gases. Also, perhaps this was the closest in meaning, extant, English word available.

It is interesting to note that the descriptive term "qualitatively superadditive" combines a subjective (def.: based on or influenced by personal feelings, tastes or opinions) adverb modifying a definitive (def.: conclusive) mathematical adjective to describe liquid water.

Physiochemical refers to physiological chemistry, which is in the domain of science that is currently referred to as biological chemistry or biochemistry. A simple definition is the study of chemical processes within and relating to living organisms. (3, 4)

Physiology – a brief history
The term physiology was first used by Jean Fernel (1497-1558) who first described the spinal canal and was mainly concerned with what science now considers gross anatomy. Almost a century later William Harvey explained the circulatory system (1628) and physiology began to develop from structural (anatomical) descriptions to descriptions of gross processes like circulation, digestion and respiration. But it took almost 200 years before the cell theory of Schleiden and Schwann(1838) brought physiology into the "modern era" by postulating the first two tenets of the theory. The first two tenets are: 1) all living organisms are composed of one or more cells and 2) the cell is the most basic unit of life. Then in 1855, Rudolf Virchow added the third tenet: all cells arise only from pre-existing cells. This theory is the foundation of physiology today. The first tenet has

been disputed in that viruses are non-cellular but are sometimes considered life forms. (5,6,7,8)

Water – a brief history
Though Lavoisier named oxygen (1778) and hydrogen (1783) it was Cavendish (1731-1810) who figured out the chemical composition of water (1783). They were contemporaries with Lavoisier discovering oxygen and Cavendish discovering hydrogen (1766). An historical note is that James Watt was the first to publish the composition of water though Cavendish actually did the first experiments but published second so a controversy over priority ensued. (9)

The purpose of the histories is an attempt to locate in time when science knew both the chemistry of water and enough physiology for the term physiochemical to be meaningful. With the addition of the third tenet of physiology (1855) this hallmark seems to have been met in that the idea of spontaneous generation and similar theories were disproven.

So why is this date relevant to the discussion? The authors state that an understanding of the physiochemical phenomenon, liquid water, should have prevented the development of materialistic philosophy and mechanistic cosmology. Prevention is not possible without the discoveries of both the chemical composition of water and how it participates in the life process. So from 1855 until the 1930's what was not being understood?

Materialistic philosophy or materialism is "as old as philosophy" stated Frederick Lange in 1865. Lange took three volumes to detail the history of materialism and a criticism of its importance at the time he was writing. One of Lange's notable statements was "to think clearly about materialism is to refute it". (10) The most basic statement of philosophical materialism "is a form of philosophical monism which holds that matter is the fundamental substance in nature, and that all things are material interactions". Monism attributes oneness or singleness to a concept, in this case matter. Classically, matter was anything that has mass and takes up space. But with the evolution of quantum and relativity theories, advances in biochemistry and neurosciences, matter has been expanded to include the 16 elementary particles in the Standard Model of particle physics, mental states and consciousness. (11,12,13)

Mechanistic cosmology has been in recorded evidence since the Babylonians (~3000 BC). Mechanistic defined as: relating to a mechanism or the doctrine of mechanism did not appear in English until 1884 according to Merriam-Webster. The doctrine of mechanism is a philosophical term that in its older incarnation was referred to as universal mechanism. Universal mechanism held that the universe is reducible to completely mechanical principle, which was motion and matter. But after the scientific revolution starting with Copernicus in 1543 and ending with Newton in 1687 a new cosmology emerge. All phenomena could be eventually explained in terms of 'mechanical' laws, natural laws, that governed everything and consequently all phenomena, past, present or future must be completely determined. Cosmology is concerned with the Universe as a whole. So mechanistic cosmology can be described as both reductionist and deterministic. (1,14,15, 16,17)

Let us review some of the basic science about liquid water and some of the more recent discoveries to perhaps further our understanding and appreciation of why water should have such an impact on how we think about life and the universe we inhabit.

Water! The most scientifically studied substance on the planet. There is no life form on this planet that does not require water. Water is considered to be the most anomalous substance known to science. In other words, it does not follow "rules", does the unexpected and should never be taken for granted. Martin Chaplin BSc PhD CChem FRSC is Emeritus Professor and Visiting Professor of Applied Science at London South Bank University and maintains the website, Water Structure and Science. The site lists as of September 16, 2019, 4350 published references and communications and approximately 400 external website references. If you want to educate yourself about water it is the best place to start. What follows is the basic chemistry of the water molecule that was in the previous paper about snowflakes to give a foundation for discussing some of the wonders of water. (18)

Water is one of the most stable molecules known. The stability is because of what each element, oxygen and hydrogen, brings to the molecule. The electron orbital theory describes how electron pairs orbit around the nucleus of an atom. The first orbit can contain at maximum two electrons, one pair. Having two electrons in the first orbital lends stability but hydrogen only has one. Oxygen has eight electrons: two in its first orbital and six in the second orbital. But the second orbital can contain eight electrons for maximum stability. So when one oxygen and two hydrogen atoms come together, or bond, each hydrogen now has two electrons in their first orbital shell by sharing an electron pair with the oxygen. The oxygen now has a total of eight electrons in the second orbital shell because of this sharing with the two hydrogen atoms. This sharing of electron pairs is called a covalent chemical bond.

In H2O, only two of the six outer-shell electrons of oxygen are used for this sharing, leaving four, non-shared electrons, which are organized into two non-bonding pairs.

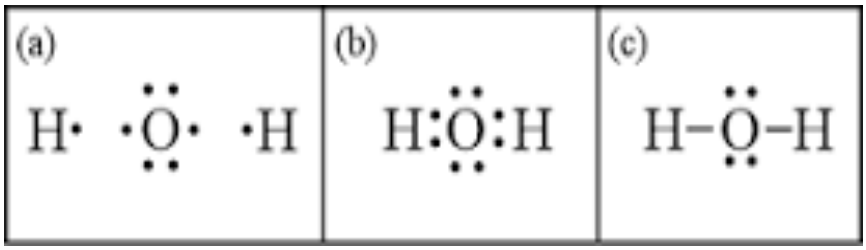

Figure 1. Cartoon referred to as a Lewis dot structure. When hydrogen and oxygen combine to form water. The solid lines (c) represent the covalent chemical bond. (19)

The four electron pairs surrounding the oxygen tend to arrange themselves as far from each other as possible in order to minimize repulsions between these clouds of negative charge. This would ordinarily result in a tetrahedral geometry in which the angle between electron pairs (and therefore the H-O-H *bond angle*) is 109.5°. However, because the two nonbonding pairs remain closer to the oxygen atom (because they are not "sharing"), these exert a stronger repulsion against the two covalent bonding pairs, effectively pushing the two hydrogen atoms closer together. The result is a distorted tetrahedral arrangement in which the H—O—H angle is 104.5 – 106.0°. (18)

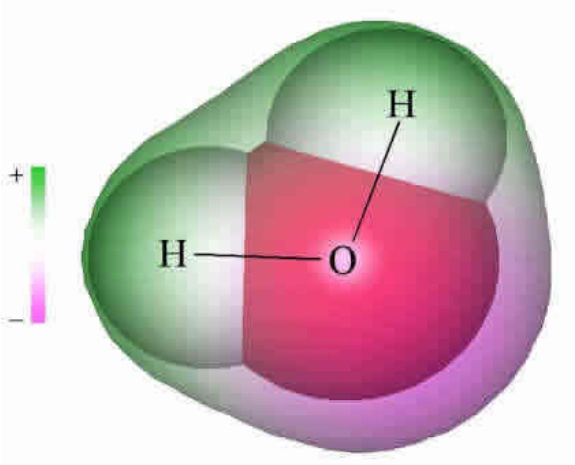

Figure 2. Although the water molecule carries no net electric charge, its eight electrons are not distributed uniformly; there is slightly more negative charge (purple) at the oxygen end of the molecule, and a compensating positive charge (green) at the hydrogen end. The resulting *polarity* is largely responsible for water's unique properties. (20)

"The opposite charges on the oxygen and hydrogen atoms cause different water molecules to attract each other. This attraction is particularly strong when the O-H bond from one water molecule points directly at a nearby oxygen atom in another water molecule, that is, when the three atoms O-H O are in a straight line. This is called 'hydrogen-bonding' as the hydrogen atoms appear to hold on to both O atoms. This attraction between neighboring water molecules, together with the high-density of molecules due to their small size, produces a great cohesive effect within liquid water that is responsible for water's liquid nature at ambient temperatures. " (18)

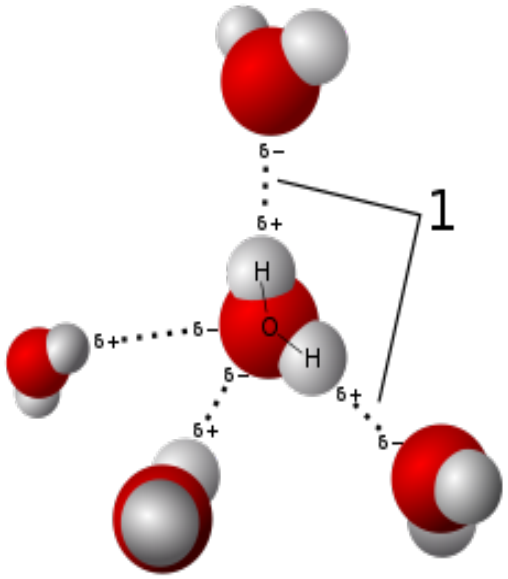

Figure 3. Hydrogen bonding [1] of water molecules. (21)

The hydrogen bond is about 1/20th as strong as the covalent bond (492.2 kJ/mol vs 23.3 kJ/mol). Hydrogen bonds form, last ~ 1 ps, break and then reform. "In liquid water, water molecules are connected within an extended dynamical hydrogen-bonded network with the individual hydrogen bonds vary between being shorter, straighter and stronger and longer, bent and weaker. They may even be broken for very short periods of time (< 100 fs)." (1) But one could readily argue that this rather weak, flexible, dynamic bond is how life even exists. In the diagram below very small changes in the bond strength have huge ramifications for the physical properties of liquid water. Look at the red line, which represents viscosity. The -4% bond strength change, represent less than 1 kJ of energy (~ 0.24 k calorie) which would render water at body temperature close to the viscosity of acetone (nail polish remover). The +2% bond strength change would change the water viscosity to that of mercury. (22)

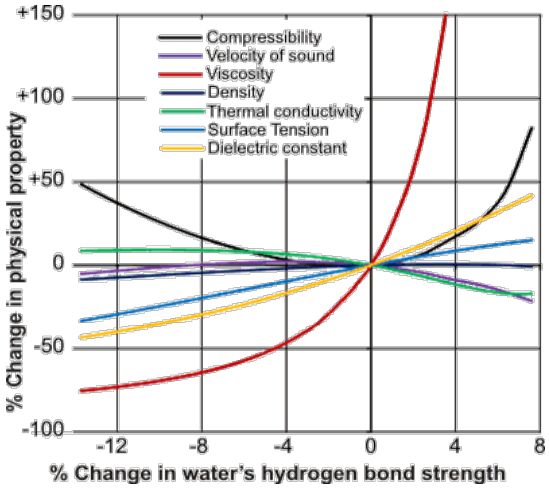

Figure 4. Hydrogen bond strength change versus physical property change. (18)

Physiologically, DNA would not become helical, proteins would not fold, ions could not flux and oxygen exchange across the plasma membranes of the alveoli of the lungs could not happen. These can all occur because "the hydrogen bond in water is neither too weak nor too strong, it is sometimes regarded as having "Goldilocks" strength". (18)

"As liquid water is so common-place in our everyday lives, it is often regarded as a 'typical' liquid. In reality, water is most atypical as a liquid, behaving as a quite different material at low temperatures to that when it is hot, with a division temperature of about 50 °C. It has often been stated that life depends on these anomalous properties of water. The anomalous macroscopic properties of water are derived from its microscopic structuring and reflect the balance between low-density and high-density structures." (18)

Martin Chaplin lists seventy-four anomalous properties of water, divided into five sub-groups: phase, density, material, thermodynamic and physical. All seventy-four come with explanations, so much is know about the "odd" properties of water. Research continues and new data continues to inform how unusual water really is. (18)

One of the physiochemical "facts" of water is that it makes up about 50 - 60% of the human body. In an adult male weighing 72 kg (~165 lbs) there is about 40 liters of fluid with ~ 25 liters being intracellular (within cells). In 2008 Philip Ball posed a number of questions about the enduring mystery of water but one very intriguing one was: "Is most of the water in cells structurally akin to the pure liquid at all?" (23)
The answer to that question is most likely no. The water in your bottle looks like this:

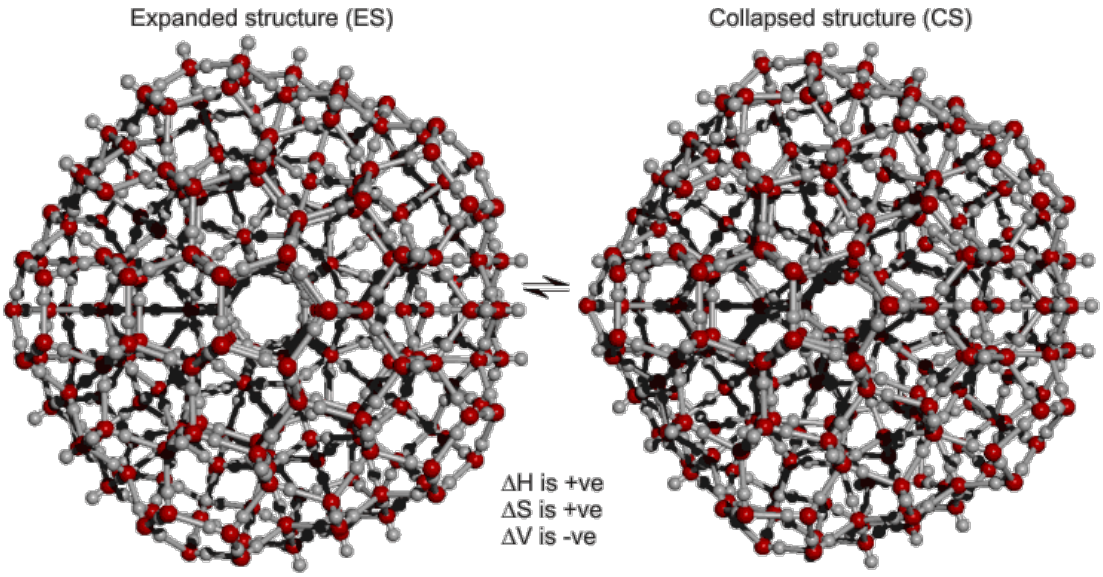

Figure 5. Expanded structure of a water cluster (low-density) and the collapsed structure of a water cluster (high-density). (18)

This is how water interacts with DNA:

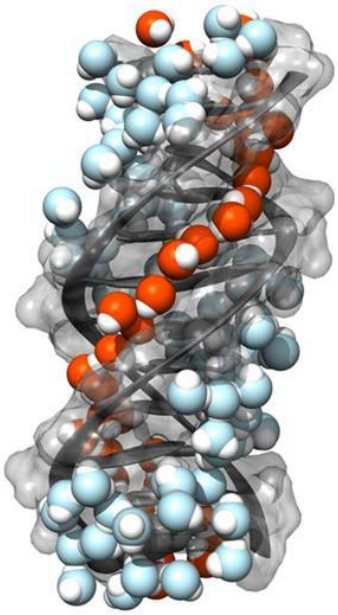

Figure 6. Water and DNA. (24)

This is water interacting with a protein that helps other proteins fold.

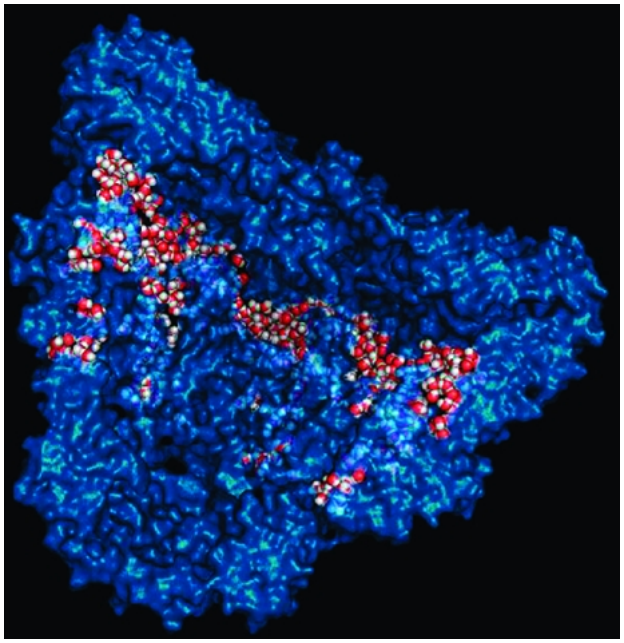

Figure 7. Model of bacterial chaperonin GroEL with water. (25)

In 2016, experiments demonstrated that water could undergo quantum tunneling. Quantum tunneling is the quantum mechanical phenomena where a particle passes through a potential barrier. In classical mechanics if the particle does not have enough energy to overcome the energy barrier it is either reflected or absorbed. When particles are treated as having wave characteristics there is a probability that some portion of the wave will pass through the barrier and appear on the other side.

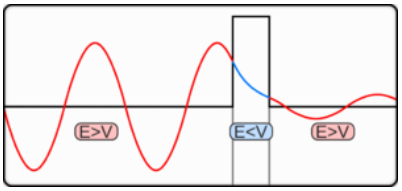

Figure 8. Quantum tunnelling through a barrier. The energy of the tunnelled particle is the same but the probability amplitude is decreased. (26)

"Tunneling is the "quantum super power" that lets particles go through microscopic barriers in a single bound. A study of water trapped in an emerald-like crystal reveals tunneling of water molecules among multiple orientations, so that each molecule is essentially in six configurations at once. The researchers showed with neutron scattering experiments that the tunneling causes the water's hydrogen atoms to spread out into ring-like distributions. This new form of water is a more symmetric structure that is predicted to have zero electric dipole moment—the property that normally allows water to form hydrogen bonds and perform well as a solvent." (27)

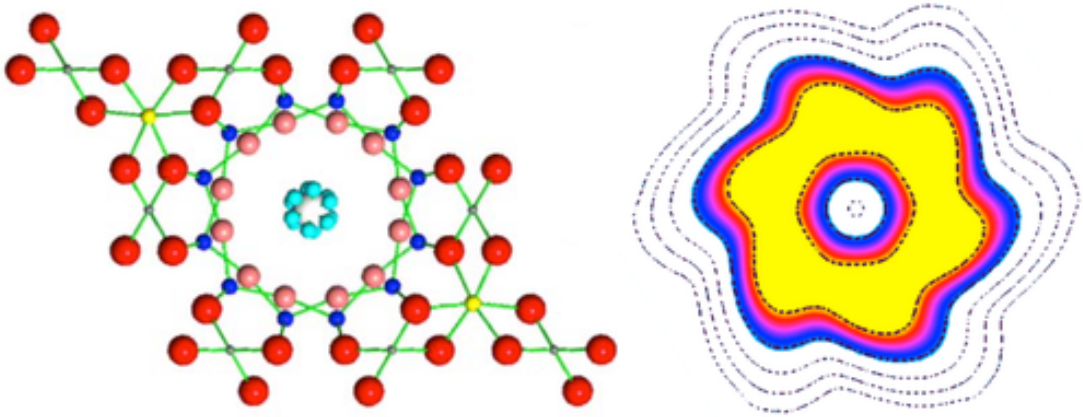

Figure 9. A single water molecule can be confined inside a hexagonally shaped channel of the gemstone beryl (left). The light-blue spheres show the positions of one hydrogen atom in a water molecule as it takes on six different rotational orientations simultaneously. Tunneling among these orientations means the hydrogen atom is not located at one position, but smeared out in a ring shape. The right panel has an expanded spatial scale and shows the calculated hydrogen charge density, going from blue (lowest) to yellow (highest). (28)

"The existence of the tunneling state of water shown in 'this' study should help scientists better describe the thermodynamic properties and behavior of water in highly confined environments such as water diffusion and transport in the channels of cell membranes, …." (29) The water molecule has now been shown, that under confined conditions, to display the probabilistic wave phenomena of quantum mechanics.

In 2019, the scientific database on liquid water has multiplied many fold since the 1930's yet both materialistic philosophy and mechanistic cosmology still persistently develop and in many instances heavily influence the scientific endeavor.

Materialistic philosophy, materialism, today is often referred to as physicalism to separate the philosophical discipline from the social/economic connotation of avarice/greed. The old "matter is the fundamental substance of nature" has given way to "all things, including mental states and consciousness are the results of material interactions". (13) Materialism/physicalism remains reductionist and perhaps even more deterministic. This can be imagined by explaining thought, behavior, consciousness, emotions, experience, memory, etc as the manifestations of neuro-chemical processes within certain regions of brain tissues, which are made up of highly evolved cells. The reduction arguments can be advanced to the molecular level of enzymes, neurotransmitters, hormones, etc and then further to the atomic/quantum level of hydrogen bonds, proton donors/acceptors, energy transport, etc. Becoming more deterministic when invoking causality (cause and effect) in areas like physics, chemistry, genetics and evolution. As in: 'this mutation causes this disease'; 'this chemical reaction results in this product'; ' this environmental pressure caused this adaptation'.

There is a rather "radical" form of philosophical materialism espoused by the Canadian philosophers Paul and Patricia Churchland called eliminative materialism.
"Just as we came to understand that there are no such things as demons (because nothing at all like demons appear in modern accounts of strange behavior), so too, eliminative materialists argue that various folk psychological concepts—like our concept of belief—will eventually be recognized as empty posits that fail to correspond with anything that actually exists. Since there is nothing that has the causal and semantic properties we attribute to beliefs (and many other mental states) it will turn out that *there really are no such things.*" (30)

Mechanistic cosmology, pursued to a logical (though arguably hypothetical) conclusion, would produce the elusive TOE….Theory of Everything or a grand unified theory. All physical aspect of the universe would be explained and linked in one all encompassing, coherent framework. This is considered one of the, if not the most, major problems in physics.

In 1913, Lawrence Joseph Henderson published *The Fitness of the Environment.* (31) "Henderson discusses the importance of water and the environment with respect to living things, pointing out that life depends entirely on the very specific environmental conditions on Earth, especially with regard to the prevalence and properties of water." (32) This was the first statement of the proposition that the universe is "fine-tuned" to allow for life. The proposition languished until 1961, when physicists began to take note how very small changes in certain universe physical forces (the number of spatial dimensions in spacetime, the ratio of the strength of electromagnetism to the strength of gravity for a pair of protons, the strength of the strong nuclear force, the third lowest energy state of carbon-12, etc) would preclude the existence of life.

In *A Brief History of Time,* Stephen Hawking wrote: "The laws of science, as we know them at present, contain many fundamental numbers, like the size of the electric charge of the electron and the ratio of the masses of the proton and the electron. ... The remarkable fact is that the values of these numbers seem to have been very finely adjusted to make possible the development of life."(33) This proposition continues to engage scientists, philosophers, theologians and religionists.

So from 1855 until the 1930's what was not being understood about liquid water? Perhaps Henderson was the unnoticed beacon. He noticed the connection between the small, anomalous, ubiquitous molecule, liquid water, and life.

As students of The Urantia Books we have all become familiar with the triads that are found through out the papers. Though a very teleological assessment this author proposes the addition of another triad to the list.

Truth	Beauty	Goodness
Thing	Meaning	Value
Mind	Matter	Spirit
Philosophy	Cosmology	Divinity
Water	Life	Survival

The truth of water: All of the material facts that have been discovered.

The beauty of water: Water is essential to life on Earth.

The goodness of water: This life gives the opportunity for the eternal adventure, survival.

Thanks to Jeff Wattles and Phil Rolnick for philosophical advice and encouragement. Thanks you to Patricia Clem and DD Nicolau for their enduring friendship and the support while I undertook this project.

References

1. *Merriam-Webster.com. 2019.* Web. 1 Oct. 2019 https://www.merriam-webster.com
2. Wikipedia contributors. "Superadditivity" *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 5 Aug. 2019. Web. 1 Oct. 2019. https://en.wikipedia.org/wiki/Superadditivity
3. *Lexico.com. 2019.* Web. 1 Oct. 2019 https://www.lexico.com/en
4. Wikipedia contributors. "Biochemistry" *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 7 Oct. 2019. Web. 1 Oct.2019. https://en.wikipedia.org/wiki/Biochemistry
5. *Encyclopedia.com 2019*"Jean François Fernel ." Science and Its Times: Understanding the Social Significance of Scientific Discovery . . Web 1 Oct. 2019 https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/jean-francois-fernel
6. Wikipedia contributors. "Physiology" *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 2 Oct. 2019. Web. 1 Oct. 2019. https://en.wikipedia.org/wiki/Physiology
7. Schwann T. Ueber die Analogie in der Structur und dem Wachsthum der Thiere und Pflanzen. *Neue Not Geb Nat Heil*, 1838;Jan:33–36; 1838;Feb:25–29; 1838;Apr:21–23.
8. Wikipedia contributors. "Cell theory." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 15 Sept. 2019. Web. 1 Oct.2019. https://en.wikipedia.org/wiki/Cell_theory
9. Wikipedia contributors. "Properties of water." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 8 Oct. 2019. Web. 1 Oct. 2019. https://en.wikipedia.org/wiki/Properties_of_water
10. Lange, Frederick Albert, *The History of Materialism and Criticism of its Present Importance*, London, England: Kegan Paul, Trench, Truber & Co. Lts. 1865.
11. Smart, John Jamieson Carswell, "Materialism" *Enclyclopaedia Britannica,* Enclyclopaedia Britannica, Inc, 28 April 2016. Web. 1 Sept.2019. https://www.britannica.com/topic/materialism-philosophy
12. Stoljar, Daniel, "Physicalism" *The Stanford Encyclopedia of Philosophy,* Metaphysics Research Lab, Stanford University, Winter 2017. Web. 1 Oct 2019. https://plato.stanford.edu/archives/win2017/entries/physicalism/
13. Wikipedia contributors. "Materialism" *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 15 Oct. 2019. Web. 1 Oct. 2019. https://en.wikipedia.org/w/index.php?title=Materialism&oldid=921414994
14. Rubenstein, M-J. 2016. *Worlds Without End: The Many Lives of the Multiverse*. Columbia University Press.
15. Ross, Kelley L. 2018 "A Summary of Modern Cosmology" *The Proceedings of the Friesian School,* http://www.friesian.com/cosmolog.htm
16. Gale, George, "Cosmology: Methodological Debates in the 1930's and 1940's" *The Stanford Encyclopedia of Philosophy,* Metaphysics Research Lab, Stanford University, Summer 2019. Web. 1 Oct 2019. https://plato.stanford.edu/archives/sum2019/entries/cosmology-30s/

17. Wikipedia contributors. "Cosmology" *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 4 Oct. 2019. Web. 1 Oct. 2019. https://en.wikipedia.org/w/index.php?title=Cosmology&oldid=919511616
18. Chaplin, Martin. *Water Structure and Science*. London South Bank University, 26 Sept. 2019. Web. 1 Oct. 2019. http://www1.lsbu.ac.uk/water/water_structure_science.html
19. Unknown,. "Chemistry Stack Exchange". *Chemistry.stackexchange.com*. N.p., 2016. Web. 1 Apr. 2016. http://chemistry.stackexchange.com
20. Lower, Steven. *A gentle introduction to water and its structure.* 14 Dec. 2016. Web Apr. 2016. http://www.chem1.com/acad/sci/aboutwater.html & http://www.chem1.com/acad/webtext/states/water.html
21. Wiki Commons image, accessed October 1, 2019. Wikipedia/Qwerter
22. http://hyperphysics.phy-astr.gsu.edu/hbase/Tables/viscosity.html)
23. Ball, Philip (2008) "Water – an enduring mystery", Nature 452, 291-292.
24. McDermott, M L , H Vanselous, S A Corcelli and P B Petersen, *ACS Centr. Sci.*, 2017, DOI: 10.1021/acscentsci.7b00100
25. England, J.L. , D. Lucent and V.S. Pande, *J Am Chem Soc,* 2008, DOI: 10.1021/ja802248m
26. Wikipedia contributors. "Quantum Tunneling" *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 1 Oct. 2019. Web. 1 Oct. 2019. https://en.wikipedia.org/w/index.php?title=Quantum_tunnelling&oldid=920999545
27. Schirber, Michael *(22 April 2016).* "Water Molecule Spreads Out When Caged". *Physics.* **9**.43. https://physicsworld.com/a/physicists-discover-new-state-of-the-water-molecule/
28. Kolesnikov, Alexander I. , George F. Reiter, Narayani Choudhury, Timothy R. Prisk, Eugene Mamontov, Andrey Podlesnyak, George Ehlers, Andrew G. Seel, David J. Wesolowski, and Lawrence M. Anovitz, Phys. Rev. Lett. 116, 167802 (2016).
29. Walli, Ron, "New state of water molecule discovered". *Phys.org*. Retrieved 23 . April 2016. https://phys.org/news/2016-04-state-molecule.html
30. Ramsey, William, "Elimanative Materialism" *The Stanford Encyclopedia of Philosophy,* Metaphysics Research Lab, Stanford University, Spring 2019. Web. 1 Oct 2019. https://plato.stanford.edu/archives/spr2019/entries/materialism-eliminative/
31. Henderson, Lawrence Joseph, 1913. *The fitness of the environment: an inquiry into the biological significance of the properties of matter,* The Macmillan Company.
32. Wikipedia contributors. "Fine-tuned universe" *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 20 Sept.. 2019. Web. 1 Oct. 2019. https://en.wikipedia.org/w/index.php?title=Fine-tuned_universe&oldid=916832227
33. Hawking, Stephen, 1988. *A Brief History of Time*, Bantam Books.