Water and Nature's Geometry

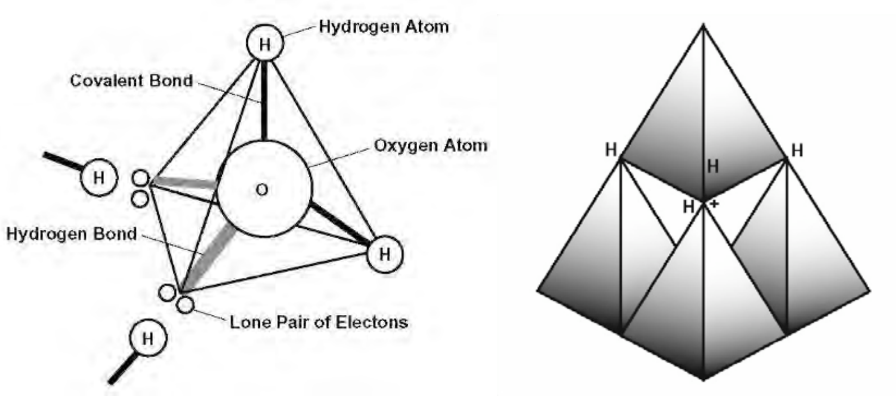
West Marrin, Water Sciences & Insights

WATER'S GEOMETRY

Perhaps the late twentieth century's most startling discovery about liquid water was that it consists of a vast interconnected network, rather than just a random collection of agitated molecules. Individual water molecules serve as the network's *components*, which constitute the building blocks for the primary water network. These components of water's molecular network are connected to one another via magnetic-type linkages known as *hydrogen bonds*. The network is characterized as highly dynamic inasmuch as the linkages between components are constantly exchanged among one another.

In solid water, or ice, each water molecule bonds with all four of its nearest neighbors in forming a perfect tetrahedron, which is a three-sided pyramid comprising the most basic molecular geometry of water (see Figure 1) and, perhaps, the most basic structure of the universe. Inventor and philosopher Itzhak Bentov suggested that the tetrahedron's geometry and associated mathematics apply to the *fine structure constant* (defined as 1/137) that characterizes the interaction among charged particles comprising the structure and displaying the patterns of all matter.[1]

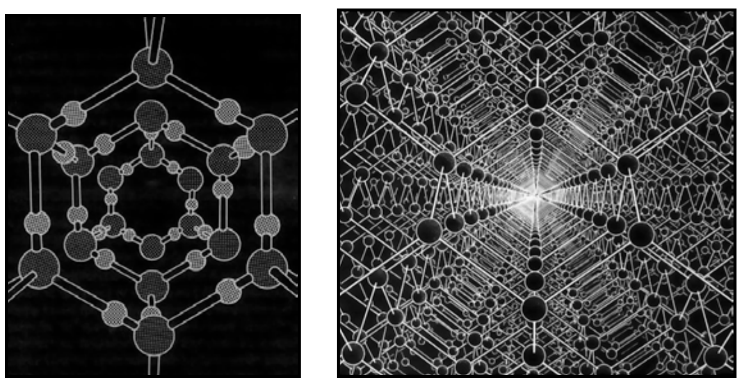
FIGURE 1. The schematic on the left represents the simplest unit of water's hydrogen bonded network. The large oxygen atom serves as the center vertex of a tetrahedron, while the smaller hydrogen atoms serve as its four outer vertices. Two of the hydrogen atoms are covalently bonded to the oxygen atom, comprising the individual water molecule (H_2O). Water molecules are hydrogen-bonded to each other via two pairs of electrons associated with each oxygen atom. These electron pairs attract two hydrogen atoms (each donated by a different neighboring water molecule) in forming a tetrahedron composed of one oxygen atom and four hydrogen atoms. Covalent bonds (thick black lines) create a water molecule by linking atoms together, whereas hydrogen bonds (thick gray lines) create a water network by linking molecules together. The schematic on the right is composed of four hydrogen-bonded water molecules. Linking water molecules together via different geometric arrangements creates water clusters. Figure appears in *Universal Water*.[2]



As ice melts into liquid water, 10% to 15% of the bonds connecting neighboring water molecules are broken at any instant (thus distorting the tetrahedron), while the remaining bonds transition to an ultradynamic state whereby they switch as rapidly as a trillion times per second! Hydrogen bonds are broken only for an instant, permitting water molecules the opportunity to alter their orientation to one another. This frantic switching of linkages permits the water network to flow and to behave as a liquid even though it retains most of the molecular geometry of a solid. Nobel laureate and chemist Linus Pauling reportedly referred to this conservation of hydrogen bonds and network geometry when describing water's transition from a solid to a liquid.[3]

Scientists have long modeled liquid water as a space-filling network of individual water molecules (see Figure 2) in which all potential hydrogen bonds are characterized as either unbroken or broken. Unfortunately, the shuffling (i.e., breaking and forming) of hydrogen bonds within water's network is so rapid and complex that scientists are unable to decipher the rules governing the process. This inability does not imply that switching rules are haphazard—only that science is overwhelmed by water's dynamism, which has been traced to quantum events known as *zero-point vibrations*. These strange vibrations govern the exchange of water's hydrogen bonds and are impossible to predict as a result of the uncertainty inherent in quantum-scale events.[4]

FIGURE 2. This schematic is believed to resemble the network structure of liquid water; however, scientists have been able to observe only a fraction of the network using current technologies. In view **A**, the large dark spheres representing oxygen atoms are connected to the smaller and lighter-shaded spheres representing hydrogen atoms. Hydrogen atoms are situated along the connecting hydrogen bonds. Water's hydrogen-bonded network is difficult to depict at the scale of view **B**; nonetheless, note the seemingly infinite matrix that exists among individual water molecules as hydrogen bonds (white lines) intersect oxygen atoms (black spheres). The network's structural complexity, along with its hydrogen bond dynamics, may prove to be the key to water's magic. Figure appears in *Altered Perceptions*.[5]

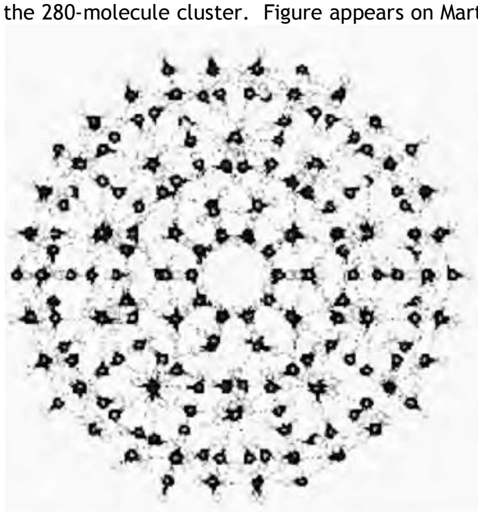


A **B**

While water's ever-changing molecular network may not sound magical, its dynamics are believed to be responsible for most of its unusual properties. *Systems theorists* working in many different fields have postulated that relatively simple dynamic networks can account for a wide range of complex behaviors. They maintain that interconnected components can exhibit varying responses to differing stimuli that emerge from a set of rules for switching network connections.[6] If true, the complex behaviors of an entire system (i.e., any entity composed of many similar components) may simply relate to the way that connections between individual components are switched among one another. Researchers who work at the fringes of postmodern science maintain that water's vast and ever-changing network may serve as a kind of massive information system—not unlike the binary systems that characterize today's computers. While there are no scientifically accepted data to confirm such hypotheses, the results from mathematical simulations have suggested that liquid water's molecular network may exhibit at least two kinds of behavior—ordered and chaotic—that are frequently associated with its clustered and bulk components, respectively. Theorists maintain that the complexity of any system arises between the states of order and chaos, which really represent two very different types of order.

Water's three-dimensional tetrahedral lattice is configured so that its concentric coordination spheres form the templates for so-called sacred geometries (e.g., Platonic solids, Flower of Life).[7] Professor and water scientist Martin Chaplin has proposed that the most stable of water's large clusters assumes the three-dimensional geometry of an icosahedron (see Figure 3). This icosahedral network of molecules is a component of the larger water network and is composed of individual tetrahedral units, representing the most basic molecular geometry of water. Specifically, fourteen tetrahedral units are packed into the icosahedral cluster, which is composed of 280 water molecules that form large internal cavities appropriate for storing solutes.[8] Additionally, the edges of internal tetrahedral units form a dodecahedron that can alternate positions within the icosahedron based on changes in hydrogen bonding within the cluster.

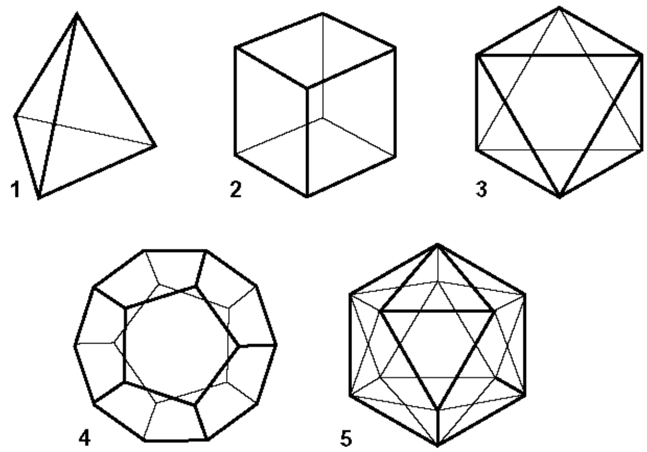
FIGURE 3. A two-dimensional representation of an icosahedral water cluster. The dark spheres represent the large oxygen atoms and the lighter shaded spheres represent smaller hydrogen atoms that are bonded to one another in forming the 280-molecule cluster. Figure appears on Martin Chaplin's website.[9]



SACRED GEOMETRY

During the fifth century B.C., the philosopher Empedocles proposed that all matter in the universe was composed of differing combinations of four original substances and two moving forces. Empedocles referred to these four substances as the Elements of fire, air, water, and earth, and he identified love and strife as the moving forces. The moving forces essentially energized the combining or dissociating of Elements, such that matter could neither be created without love nor uncreated (destroyed) without its opposite moving force of strife. So stated, this theory of the four Elements has stood as a fundamental understanding of nature for an astonishing number of ancient cultures around the world (e.g., Greek, Aztec, Hawaiian). Whereas the mix of Elements differed slightly among some cultures (e.g., the Chinese recognized wood and metal in lieu of air), all recognized water as a fundamental constituent of our world. The four Elements and the mysterious etheric substance from which they were believed to have emerged were later associated with a special set of three-dimensional geometries known as the Platonic solids, which appear in Plato's *Timaeus* and are shown in Figure 4.

FIGURE 4. The five regular Platonic solids are the only angular three-dimensional geometries that are composed entirely of regular polygons and, when spun about their center vertex, create a sphere. The *faces* constitute the sides or exterior panels of the Platonic solids and are represented by a triangle, square, or pentagon. The *edges* are the straight lines that outline each of the faces, whereas the *vertices* are the points where two or more edges converge. The solids include a tetrahedron (1), a cube (2), an octahedron (3), a dodecahedron (4), and an icosahedron (5). Figure appears in *Universal Water*.[2]



The five regular Platonic solids, along with their number of faces, edges, and vertices, and their corresponding Elements are listed in Table A. These regular solids are correctly understood in an extended sense, whereby spinning them about the center vertex creates a circumscribed sphere. Sacred geometry associates the sphere with the infinite and undifferentiated realm of Spirit and, as such, the Platonic solids are the only angular three-dimensional geometries that form a perfect interface with the primordial chaos. It is through these solids that our material world (as angular geometries) was believed to connect to the primordial chaos (as a sphere). The icosahedron and dodecahedron (related to the so-called *golden ratio*) share a reciprocal geometry and are considered to represent transcendent principles, whereas the octahedron and cube (related to 2 and its square root) share a reciprocal geometry and operate at the level of the manifested world.[10] The tetrahedron is self-reciprocating and, as previously noted, the most basic or fundamental of the solids.

TABLE A. The five Platonic solids as described by their number of edges, faces, and vertices, as well as by their corresponding Element. Although aether was occasionally considered to be one of the fundamental Elements, it was usually designated as their source.

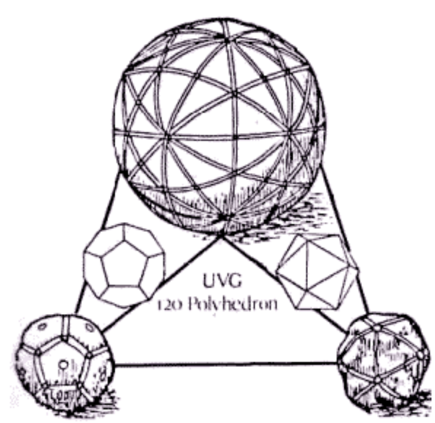
	TETRAHEDRON	CUBE	OCTAHEDRON	DODECAHEDRON	ICOSAHEDRON
Edges	6	12	12	30	30
Faces	4	6	8	12	20
Vertices	4	8	6	20	12
Element	Fire	Earth	Air	Aether	Water

The reciprocal geometric relationship between the icosahedron and dodecahedron (note the number of their respective edges, faces, and vertices) was believed to symbolize the intimate relationship between water and aether. For example, the ancient Hawaiian word for water (*wai*) was commonly substituted for that of the etheric or life force (*mana*) when describing its movements in the manifested world.[11] In the material world, water basically symbolized the perceptible counterpart and mediator of the imperceptible aether. Because the material world (represented by the cube) supposedly emerged from the aether via the mediator of water, it follows that the icosahedron and dodecahedron are mathematically related to the cube according to the golden ratio. The golden ratio is a so-called irrational number, which was considered by many ancient cultures as the primary mathematical relationship underlying the observable world. Also referred to as *phi*, the golden ratio is present in nature and man-made creations (e.g., flora, fauna, architecture, music) and in all geometries possessing five-fold symmetry (e.g., the dodecahedron and icosahedron).

THE UNIVERSE'S GEOMETRY

In addition to the icosahedron's place in water's molecular geometry and sacred traditions, it has been a central component in the evolution of mathematics and in a very recent theory that purports to explain the vast array of particles comprising both matter and forces in our universe. The German mathematician Felix Klein recognized that the icosahedron and dodecahedron were related to both the pentagram and golden ratio and that the icosahedron serves as a mathematical "object" through which the major branches of mathematics (e.g., projective geometry, group theory, differential equations) can be connected. During the late nineteenth century, Klein revived the so-called *icosahedral-dodecahedral doctrine* that was originally formulated by scientists and philosophers to describe the structure of the universe and all of its physical forms. The interwoven icosahedron-dodecahedron geometry appears as a kind of an angular sphere (see Figure 5) that was reportedly recognized by numerous ancient cultures and adopted by inventor Buckminster Fuller in his creating domes and other types of geodesic structures.[12]

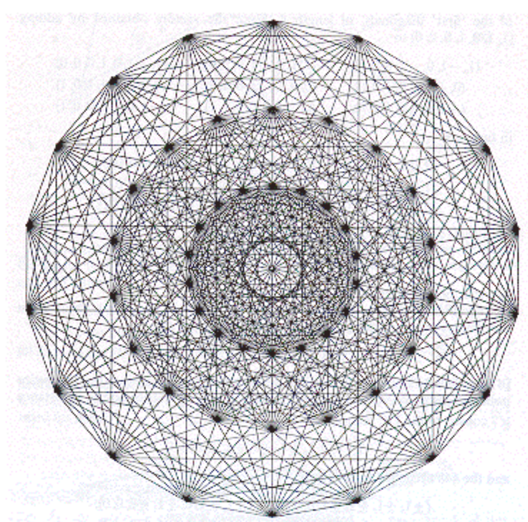
FIGURE 5. Overlaying an icosahedron (lower right) on a dodecahedron (lower left) produces a polyhedral sphere composed of 120 triangles that was reportedly considered by some ancient cultures to represent Earth's so—called grid pattern. This illustration of the controversial planetary grid, which is based on the icosahedral-dodecahedral patterning, appears in a paper authored by William Becker and Bethe Hagens.[12]



Apparently, the ancient Greeks used the dodecahedron overlain on the icosahedron to create a grid of 120 triangles that was used as a marked stone (or girded sphere) for purposes of mapping and measuring the Earth and also as a celestial basket (or armillary sphere), which served various astronomical tasks such as predicting the equinoxes and solstices. When laid over a globe, the edges and vertices of a regular icosahedron coincide with some of the major features of Earth's surface (e.g., mountain ranges) and, perhaps, with the boundaries of tectonic plates.[13] Tectonic plates are enormous sheets of Earth's lithosphere or crust upon which the continents and ocean floors migrate and transform over geologic time periods. The plates themselves fit together somewhat like pieces of a puzzle in forming the planetary surface. On smaller scales, icosahedral geometry and its renowned five-fold symmetry have been recognized in the modern fields of microbiology, crystallography, metallurgy, astronomy, and many others.

Recently, a young physicist (and big wave surfer) has proposed that the number, relationship, and grouping of elementary particles that comprise both matter and forces in our universe are represented by a mathematical pattern known as the E8 Lie geometry.[14] The E8 geometry is based on the regular icosahedron and is a member of the so-called Lie Group, which is a continuous family of symmetries that represent algebraic expressions. There is at least one Lie Group for every regular polygon (tetrahedron, octahedron, etc.), and the term "continuous family" denotes that the geometries build upon one another in a manner that results in a structural relationship progressing from the simplest to the most complex geometry. The most complex geometry of the Lie Group is the E8, which is able to incorporate all the simpler geometries of the family (see Figure 6).

FIGURE 6. A two-dimensional projection of the E8 Lie geometry contains a total of 240 vertices (i.e., 120 vertices in each of the two dimensions presented on this page). The mathematics and geometry of the E8 are based on the regular icosahedron. In the full eight dimensions of this geometry (not possible to portray on a flat piece of paper), the E8 has 248 vertices and contains within it the simpler Lie geometries.



Symmetry exists when a dividing line or an axis of rotation can be inserted through a geometric volume in such a way that each division mirrors all others or that the object appears identical at every point along the path of its rotation. Mathematicians have discovered that, not unlike complex forms of matter, symmetrical objects can be broken down or reduced to indivisible symmetrical objects. This is why the E8 geometry is able to incorporate the simpler members of the Lie Group. So, why is there suddenly so much scientific and mathematical interest in the symmetrical spins of rather abstract objects like Platonic solids or higher dimensional forms? The answer lies in symmetry's relevance to everything from the efficiency of data transmission to the discovery of new particles.

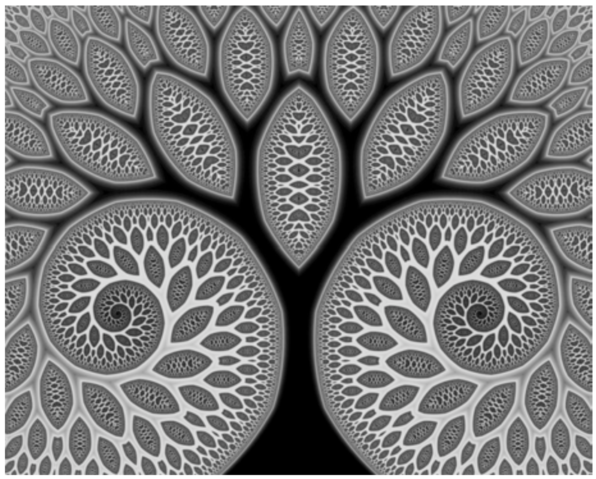
The surfer physicist, Garrett Lisi, was looking for a so-called Theory of Everything that could link gravity with the three other fundamental forces of nature (i.e., the strong and weak nuclear forces plus electromagnetism). Such a theory has eluded physics since the time of Einstein and has attracted quantum and string theorists alike. Lisi reportedly noticed that some of his equations looked similar to those describing the E8 geometry; hence, he began to match up the 248 vertices of the E8 to the elementary particles that supposedly comprise all matter and forces.[14] He was able to match individual E8 points with all but 20 of the known particles, and those 20 are particles are predicted to exist according to the rules of supersymmetry. Further, his arrangement of particles within the E8 geometry accurately reflects both the relationships and symmetries among particles. E8 has been labeled as the most elegant structure in mathematics, and now it seems that space-time itself may be composed of E8's different sectors (corresponding to the other regular polygons of the Lie Group) that fit together in a specific fashion.

MIMICKING NATURE'S GEOMETRY

Although Bucky Fuller's geodesic domes are perhaps the most well-known structures to incorporate the geometry and mathematics of the icosahedron and tetrahedron, humans have employed them in building everything from ancient pyramids to water treatment systems. Water flow forms are man-made cascade systems engineered to mimic the flow of water in nature (or at least to create specific geometries) for purposes of purifying water.[15] Flow forms frequently incorporate phi-based mathematics in their cascading basins in order to impart a particular kind of spin to the water. Although this technology has been applied only to small-scale systems on a limited basis, it has the potential to supplement traditional wastewater designs that incur greater costs, as well as health and environmental impacts. An analogous design for agriculture is reflected in the ancient Hawaiian's use of terraces, which utilize water for irrigation in a series of stepped plots that follow the natural course of streams and divert only a fraction of the water used for conventional irrigation. The water is returned to the stream before being degraded (e.g., with silt or organic material) to the point that the stream's natural cleansing mechanisms are overwhelmed. This method of utilizing water for agriculture is preferable to modern methods, which substantially diminish in-stream flows, create highly degraded (and often toxic) return flows, and displace waters from their watershed.

Another application of mimicking water's natural behavior is inherent in so-called water sensitive urban designs, which often include bio-retention trenches and vegetated swales that both store and treat stormwater along natural drainage patterns.[16] In addition, constructed wetlands and natural sands are used as bioreactors and filters, respectively, to treat wastewater before it returns to the natural environment. Perhaps not surprisingly, a geometric relationship exists between these alternative water technologies and phi-based or fractal mathematics inasmuch as water's natural flow patterns reflect the braiding and spiraling movements of water itself (see Figure 7). The spatial distribution patterns of microorganisms that treat the wastewater within natural soils have also been recognized as fractal and correlated with the anisotropic, or non-uniform, flow of water through sands and other kinds of porous materials.

FIGURE 7. This "water fractal" portrayed by artist Germán Ariel Berra illustrates the types of patterns created by water on both macroscopic and microscopic scales. Note the similarity between this fractal and the shells of marine organisms, the satellite images of wetlands, or the networks of blood capillaries. Figure appears as a 123RF download.



Both the complex motions of seawater within the oceans and the flow paths of surface or ground water within watersheds can be described by 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 animal and plant species.[17] Garrett Lisi noted that nature may be pure geometry and that it may have chosen the E8 geometry in structuring itself.[14] Whether or not nature chose E8 or just is E8, the geometry of the icosahedron (and the complementary dodecahedron) serves as a template for water and, perhaps, for the planet itself. Could designs that incorporate the natural patterns of water and nature facilitate our living more sustainably on the Earth? Whatever the answer, geometry serves as a visible and invisible blueprint for the material world—an observation that has been made by ancient philosophers and naturalists as well as by modern scientists and mathematicians.

REFERENCES

1. Bentov, Itzhak, and Mirtala Bentov. *A Cosmic Book*. New York, NY: E.P. Dutton, 1982.
2. Marrin, West. *Universal Water: The Ancient Wisdom and Scientific Theory of Water*. Maui, HI: Inner Ocean Publishing, 2002.
3. Green, Bill. *Water, Ice & Stone*. New York, NY: Harmony Books, 1995.
4. Matthews, Robert. "The Quantum Elixir," *New Scientist* (8 April 2006): 32-37.

5. Marrin, West. *Altered Perceptions: Addressing the Real Water Crises*. Bloomington, IN: Unlimited Publishing, 2006, 2007.
6. Varela, Francisco, Evan Thompson, and Eleanor Rosch. *The Embodied Mind*. Cambridge, MA: MIT Press, 1991.
7. Smirnov, Igor, Vladimir Vysotskii, and Alla Kornilova. *Introduction to the Biophysics of Activated Water*. Boca Raton, FL: Universal Publishers, 2005.
8. Chaplin, Martin. "A Proposal for the Structuring of Water," *Biophysical Chemistry* 83 (2000): 211-221.
9. Water Structure and Science website [http://www.lsbu.ac.uk/water].
10. Lawlor, Robert. *Sacred Geometry: Philosophy and Practice*. London, UK: Thames & Hudson, 1982.
11. Long, Max Freedom. *The Secret Science at Work: Unveiling the Huna Tradition of the Ancient Polynesians*. Marina del Rey, CA: DeVorss & Co., 1953.
12. Becker, William, and Bethe Hagens. "The Planetary Grid – A New Synthesis," *Quarterly Journal of SITU* 17 (1984): 50-72.
13. Stakhov, Alexey. "Mathematical Connections in Nature, Science, and Art" In: *Museum of Harmony and the Golden Section* [HTML 44 pp.], 2001.
14. Merau, Zeeya. "Is This the Theory of Everything?" *New Scientist* (17 November 2007): 8-10.
15. Wilkes, John. *Flowforms: The Rhythmic Power of Water*. Edinburgh, UK: Floris Books, 2003.
16. Wiese, R.N., L.J. Dallmer Roach, and M.B. Liebman. "Mimicking Environmental Flows is Not a Pipe Dream," *Storm Consulting*, NSW, Australia (2005): 7 pp.
17. Krot, Alexander, and Palina Tkachova. "Investigation of Geometric Shapes of Hydrodynamic Structures for Identification of Dynamical States of Convective Liquid." In: V. Kumar et al. (Eds.) *ICCSA 2003*, pp. 398-406. Heidelberg, Germany, Springer-Verlag, 2003.

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