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Think Like a Diatom

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We humans are mainly H_2O (up to 78% by volume). Water not only sustains us individually, it also helped form our solar system, and, among its other services, it regulates the climate of our planet. We are united with all organisms through our codependence on water. "Codependence" is actually too weak a term to apply to our relationship with this molecule, yet it reminds us that water also depends on us. The availability and quality of freshwater, which constitutes only about 0.3% of our planet's accessible water supply, is almost entirely dependent on our use of it. Our demand for freshwater for consumptive, agricultural, and industrial use has far exceeded its availability. Today, some 1.2 billion people cannot get enough to drink, and waterborne diseases remain the largest source of mortality in developing countries. Many bodies of water no longer provide suitable habitat for natural assemblages of aquatic organisms because of the pollutants we put on the landscape. The future of freshwater resources is even more tenuous, given continued population growth, wasteful water abuse, and climate change.

Societies have symbolically shown appreciation for water in many ways, including using it as a common religious representation of renewal and new life. Present practices, however, are not in keeping with this ancient and pervasive symbolism: while individuals and governments have taken some important steps to reduce the use and abuse of water, we are far from affording it the protections necessary to sustain life on earth as we know it. This negligence is sur-

Diatoms matter! They produce approximately 30% of the world's oxygen, and they are useful tools in detecting and forecasting the pace of environmental change. If we succeed in relating to this remarkably different organism, we might even hope to relate to one another for the good of all creation.

prising, given the extent of our codependency and our exposure to the effects of water's abuse.

Consider the Diatom

As an educator (and optimist), I imagine this is due to a lack of sufficient understanding of the complexities of our codependency rather than a blatant disregard of its importance. To better understand our codependency with water, let's turn to an organism that conveys this well: the diatom. In the remaining discussion, I will not only explain some basics of what diatoms are but also hope to convince you that by "thinking like a diatom" we can better understand what it means to be in a codependent relationship with water and perhaps also with each other.

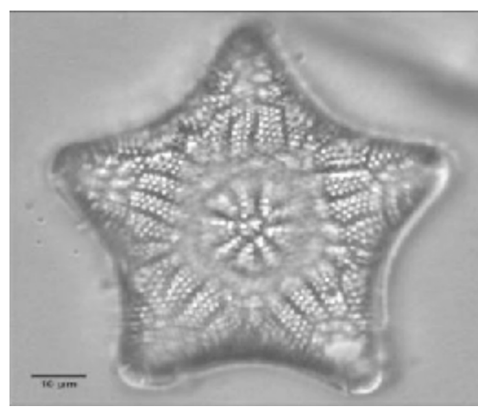

Fig. 1. The star-shaped diatom called *Triceratium pentacrinum* shows why diatoms are often called "jewels of the sea." Photo by author.

Diatoms are known as "algae living in glass houses" (fig. 1). Like other algae, they breathe in carbon dioxide and breathe out oxygen, but they uniquely make a cell wall out of silica (hydrated silicon dioxide) called a frustule. The frustule is ornamented with thick and thin places, holes and spikes that are arranged in precise patterns. Diatoms are found in all environments that at least occasionally contain water (for example, they can be found in mosses, on trees, and even in water vapor), and they are one of the most abundant forms of phytoplankton in the world's oceans and lakes. They produce approximately 30% of the world's oxygen, form the base of most aquatic food webs, and provide an important sink for carbon when they fall to the bottom of oceans and lakes. Diatoms appeared on the planet and took over its silica cycle during the Jurassic period (about 185 million years ago) or perhaps before, and today there are between 20,000 and 1 million species living on earth. How interesting that this estimate of diversity is so unresolved! It is both exciting and frustrating that there is so much left to find out about diatoms—exciting because of the outstanding opportunity for discovery but frustrating because our understanding of them does not match their importance in our world.

Diatoms have elicited a sense of awe and wonder since their discovery in the early 1700s. The diversity of geometric shapes and intricately ornamented frustules has been the subject of art, ranging from the time of the first microscopes (fig. 2)[1]

[1]For more on the Hamburg exhibition dedicated to Möller's work, see http://www.mikrohamburg.de/HomeBurba_E.html (accessed October 29, 2011).

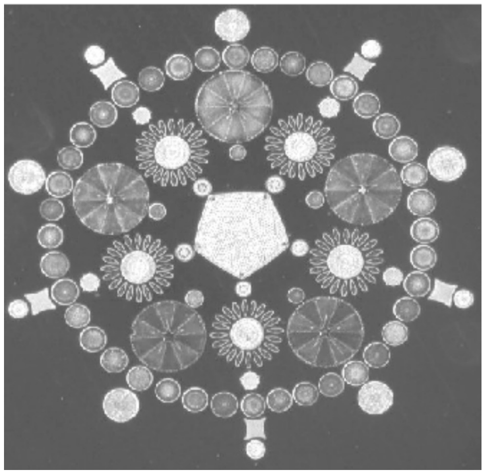

Fig. 2. Early microscopists like John Diedrich Möller (1844–1907) painstakingly arranged diatoms into strikingly beautiful arrangements on microscope slides using a very fine bristle (often a hair of a fetal pig). This photograph was taken by Matthias Burba and was part of a special exhibition dedicated to Möller at the Naturwissenschaftlicher Verein in Hamburg, Germany, in 2007.

to modern applications using state-of-the-art microscope imagery, and even of sculpture. An appreciation of diatoms by the devout is also evident in the lineage of influential microscopists: Carl Adolph Agardh (1785–1859) made very important contributions to diatom science while serving as the Bishop of Karlstad (Sweden);[2] the Rev. William Smith of the Church of England (1853) wrote the first beautifully illustrated *Synopsis of the British Diatomaceae*;[3] and Francis Wolle (1894), a Lutheran minister, published the first account of the diatoms of North America.[4] Darwin himself said (1859) that "few objects are more beautiful than the minute siliceous cases of the diatomaceae: were these created that they might be examined and admired under the higher powers of the microscope?"[5]

While early microscopists often dedicated their work on these living beauties to the "glory of God," others have taken this notion to the extreme. Today's fundamentalist theological literature is full of arguments about how the truly astounding complexity present in these primitive organisms and the many unanswered biological mysteries about them are evidence of God's creative design, rather than an evolutionary process dependent on chance events. This belief ultimately draws us further from—rather than closer to—an honest understanding of creation and our role in it. Rather than simply attributing what we don't understand about diatoms to miracle, we need to spend more time trying to understand these mysteries so that we can be the good environmental stewards that we are called to be. Unravelling some of earth's mysteries through scientific discovery does not threaten our capacity to marvel! Instead it gives us more to be thankful for by providing a means of intelligently interacting with other living beings, giving us hope for a sustainable future.

[2]Carl Adolph Agardh, *Systema Algarum* (Lund: Litteris Berlingianis, 1824).

[3]William Smith, *A Synopsis of the British Diatomaceae: With Remarks on Their Structure, Function and Distribution* (London: John van Voorst, 1853).

[4]Frances Wolle, *Diatomaceæ of North America* (Bethlehem, PA: Comenius Press, 1890).

[5]Charles Darwin, *The Origin of Species by Means of Natural Selection*, Harvard Classics, vol. 11 (New York: P. F. Collier and Son, 1909) 211.

"THINK LIKE A DIATOM!"

For fifty years, this phrase has resounded off the walls of Iowa Lakeside Laboratory, where the science of diatom taxonomy and ecology has been taught, much of it by premier North American diatomist Dr. Charles Reimer. He not only coined this phrase but taught its meaning to generations of aspiring diatom scientists until his heartbreaking passing in 2008. To gain hands-on experience in field biology, many students of biology head to remote stations, often in wondrous tropical places such as Costa Rica or Panama. But budding diatomists go to Iowa. The coursework there and its subject matter instills a passion that is surely equal to that gained in the living laboratory counterparts in tropical paradise. Reimer believed that in order to interpret the world from a diatom's perspective, we need to think like one. This means scaling yourself down in size so that you could throw a party for more than 1,000 of your friends on the head of a pin. You are not only tiny, but you are porous, so it matters quite a lot whether there are 10,000 or 100,000 ions in the water around you. Whether the remaining droplet of water in the bovine hoofprint in which you live is drying out matters just as much as whether a huge (well, pinhead sized) planktonic cyclopoid copepod has its one eye trained on you! Consider a pair of much larger eyes peering at you through the opposite end of a microscope! Creepy, yes, but the giant hominid having a look at you has much to gain.

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Because diatoms are very much influenced by the tiny water world around them, their assemblages are highly diagnostic of water quality conditions. Each species occupies a distinct part of the large spectrum of aquatic habitat types available in the world. When their habitat changes, the inhabitants leave or die and are replaced by others who can thrive there. A trained diatom taxonomist can look at an eyedropper-full of water from a puddle, lake, or stream and, by "thinking like a diatom," tell quite a bit about the quality of that water from the diatom species that live there. Further, when diatoms die, their glass frustules with all of their diagnostic features accumulate in the mud. Because this year's dead diatoms typically land on top of last year's diatoms, a sequential environmental history can be told from their remains. Under the right conditions, these histories can extend back thousands to millions of years, providing evidence for environmental changes that may be difficult to "read" from other types of fossils. Indeed, some our best evidence for rapid evolution through natural selection comes from diatom remains in finely-resolved lake sediments.[6]

[6] E. C. Theorit et al., "Late Quaternary Rapid Morphological Evolution of an Endemic Diatom in Yellowstone Lake, Wyoming," *Paleobiology* 32 (2006) 38–54.

The sensitivity of diatoms to water availability and quality enable diatomists to tell stories of environmental change around the planet. Some of these stories have provided the evidence necessary to establish important environmental protection legislation. For example, in the 1980s and 1990s, many diatomists working with sediment records were documenting a midcentury shift to acid-loving species in lakes around the world. These records confirmed the fear that widespread acidification of our atmosphere caused by industrial emissions was indeed causing environmental damage, and in the United States they were instrumental in helping establish the Clean Air Act, which subsequently reversed these trends. Today, diatoms are regularly used to establish pollution criteria for streams and lakes and as indicators of a wide array of environmental changes, including altered rainfall patterns, and temperature and sea-level rise rates due to postindustrial climate warming. Particularly useful applications include diatom-based drought severity indices that help farmers predict the probability of crop failure in a given year; lake temperature reconstructions that help resolve the pace of climate warming; and reconstructions of the rates of salinization of coastal waters that are helping coastal communities plan for further seawater inundation. Diatoms now receive widespread recognition for their utility in detecting and forecasting the pace of environmental change.[7]

For all of these reasons, diatoms have held a consecrated place in the minds of those who study them. There is a wonderfully poignant translation of Ps 150 ("An African Canticle") that calls "all you *tiny* things" to "bless the Lord"—tiny things, including "wriggling tadpoles and mosquito larvae, flying locusts and water drops" (water drops that surely would have to include diatoms)—along with "all you *big* things," like "Mount Kilimanjaro," "Lake Victoria," and "fat baobabs and shady mango trees."[8] Diatoms are indeed a blessing in so many ways: they remind us of our own capacity to care for the beauty of the earth. Diatoms are both lovely and trustworthy "sentinels" of the state of our water resources, and by thinking like them, we should be able to more responsibly care for our threatened planet. Practicing "thinking like a diatom" may help us in other ways as well. If we succeed in relating to an organism as different from us as a glass-house-dwelling, single-celled alga, then this raises our hopes for how effectively we can relate to each other for the good of all creation.

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[7] J. P. Smol and Eugene F. Stoermer, eds., *The Diatoms: Applications in Environmental and Earth Sciences*, 2nd ed. (Cambridge: Cambridge University Press, 2010).

[8] Traditional African, "An African Canticle," in Desmond Tutu, *An African Prayer Book* (New York: Doubleday, 1995) 7–8.