# Physical chemist imitates structures found in nature

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Joanna Aizenberg and her lab partners have synthesized hairlike bundles, shown here hugging a bead. Image: Stephanie Mitchell

(PhysOrg.com) -- As a graduate student, Harvard physical chemist Joanna Aizenberg acquired a passionate curiosity about — of all things — sponges. She particularly liked the ones made of glass, whose apparent fragility belied the fact that they could withstand terrific pressure in the deep sea.

Sponges are now among the central artifacts in an emerging branch of science Aizenberg is helping to pioneer: biomimetics. That’s the study of whatever nature does well — and how that may inspire better tools, materials, and processes.

Aizenberg is particularly interested in how living organisms form robust and elegant inorganic structures. The glass fibers framing those deep-sea sponges, for instance, are stronger and more optically efficient than anything humankind can yet make.

She outlined the nature of her work in an abundantly illustrated lecture Nov. 19 at the Radcliffe Gymnasium, “Connecting Engineering, Physics, Chemistry, Biology, and Architecture Through Biomimetics.”

Aizenberg — a trained mathematician and chemist who earned a doctorate in the biology of materials — has the chops to connect all those disciplines. She is the Gordon McKay Professor of Materials Science at the Harvard School of Engineering and Applied Sciences (SEAS) and the Susan S. and Kenneth L. Wallach Professor at the Radcliffe Institute for Advanced Study, where she is a fellow this year.

To illustrate the kind of work done at her SEAS laboratory, Aizenberg focused on Venus’ Flower Basket, a milky-looking undulant sponge shaped like a tapering tube. Though common in hobbyist’s aquariums, it is native to the deep ocean, thriving in cold, crushing pressures a thousand feet below the surface.

For materials scientists like Aizenberg, Venus’ Flower Basket is an intriguing package. At 500 million years old, it’s very low on the evolutionary tree. But its layered superstructure of glass illustrates how strong nature makes things, and with what apparent ease.

The first commercially practical glass fibers were not invented until the 1930s, said Aizenberg, yet “sponges knew how to do it a half-billion years ago.”

And they knew how to do it better, she pointed out. The glass fibers of Venus’ Flower Basket are a hundred times stronger than the man-made version. Intricately layered, and reinforced with a still-mysterious glue, these glass fibers stop cracks fast.

The sponge also forms glass fibers at ambient temperatures and without any special steps. Man-made glass fibers require high temperatures — 2,000 degrees F — as well as chemical treatments in an expensive and energy-intensive “clean” lab.

Low temperatures also assure that the hollow centers of the sponge’s glass fibers, though only 200 nanometers wide, are not deformed by intense heat.

Both man-made and sponge glass fibers “guide light,” said Aizenberg, but nature does it better. Along the length of a sponge’s glass fiber, spines multiply the efficiency of collecting light from nearby biophosphorescent organisms. “You can think of it as a Christmas tree,” she said. “Not just the tip collects light.”

Venus’ Flower Basket illustrates nature’s grasp of optics, said Aizenberg, but it also offers insight into architecture.

The resilient sponge is made of square cells reinforced by strutlike diagonal buttresses. In fact, a very modern principle of design and civil engineering, she said, “is present in this [cellular] structure.”

But these robust structures are present on a nanoscale, mechanically stable because of layered hollow glass fibers a hundredth as wide as a human hair. If they could be replicated at that scale, the resulting man made materials would be all the stronger. This is a “rich system,” said Aizenberg, and studying it may prompt the design of new materials.

The Venus’ Flower Basket may even offer new ways of looking at human-scale architecture — lessons in how structures best respond to force, for instance. The sponge is attached to the ocean floor, an anchoring point where shifting currents exert the highest stresses. But the sponge has evolved a clever strategy, connecting itself to the seabed by a system of flexible fibers. This swaying glass structure, said an admiring Aizenberg, "can survive any pressure that you can imagine."

She has already used models from the sea to inspire invention. A few years ago, while with Bell Laboratories at Lucent Technologies, she helped prove that crystalline optical arrays on the arms of the brittle star, a relative of the starfish, focus light better than any man-made device.

Mimicking nature's strategy — in this case, fluid pigment transfer — led to patents and patent applications for a new generation of "tunable" lenses.

But Aizenberg wants to go beyond the lessons nature offers in efficient optics, robust construction, and resilient materials. She is exploring "biomineralization." That's the way nature uses organic catalysts to prompt inorganic materials to "grow" into lenses, glass fibers, and other useful structures.

In the aptly named Aizenberg Biomineralization and Biomimetics Lab at SEAS, researchers are looking into the "self-assembly" of inorganic materials the way nature might do it: efficiently and in ambient temperatures.

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