INTEGRATING FAITH AND LEARNING IN AN ENGINEERING CLASSROOM

BY LAUREL DOVICH

The choice to commit myself to Christian education has led me on a search for ways to integrate my faith with what I teach. I left the profession of engineering with a clear intent to influence my students for eternity. The engineering and physics I teach have consistent rules that describe how the universe functions (gravity, inertia, properties of materials) and the probabilities of unusual loads (earthquakes and hurricanes). This discipline lacks the wonderment of biology, which points to an intelligent design behind the complex functions and processes supporting life and provides an opportunity to talk about faith in the classroom. I've developed an entering wedge for integrating faith into my subject matter—the amazing properties of materials used for structures in nature.

Nature has a treasure trove of complex materials that continue to fascinate scientists, despite the advances of technology. Even the basic building materials of nature have properties that are superior to the most advanced manmade materials, proving that incredible engineering design went into the creation of these materials. There is such a large contrast between them and manmade materials that the differences can be understood, at least at fundamental levels, even by grade school and high school students.

Many examples could be cited to demonstrate the vast superiority of the materials in nature to the advanced materials used in modern engineering. This article will discuss three examples: spider silk, abalone shells, and lotus leaves.

Examples from nature illustrate well the care and planning that went into the creation of the universe and the stark contrast between manmade and natural materials.

Spider Silk

Spiders exude silk, which they use to create webs as well as chords from which to suspend their bodies. The concentrated liquid protein solution stored in the spider's body hardens into a strand when exposed to air after being pulled through the spider's spinneret, located on its rump. The resulting material is finer than human hair, lighter than cotton, and more waterproof than silkworm strands. Spider silk is ounce for ounce four times stronger than steel, can absorb three times more energy than Kevlar (from which bulletproof vests are made), and is twice as stretchy as nylon. Not a single manmade material combines outstanding strength with exceptional stretchiness and energy absorption.

A spider can spin up to seven types of silk. The ones that have drawn the most attention are the capture silk, framework silk, and dragline silk.

Capture silk is the material that spirals between spokes in an orb-shaped spider web. It can stretch up to three times its length and return to the original length with no permanent deformation,[1] a feat that no other strong material can accomplish. Steel, one of the most ductile engineered materials, can stretch only about 0.002 times its original length before permanent deformation takes place. A material's ability to stretch without becoming permanently deformed indicates how much energy it can absorb without being destroyed. By this measure, capture silk has incredible energy absorption, bouncing back from the impact of insects striking the web. This is equivalent to a fishing net stopping a jumbo jet in flight.[2] The adhesive coating on the capture silk, combined with the stretchiness of the strands, prevents the captured insect from breaking loose. As the insect pushes and pulls on the web,

the strands expand to the limits of the insect's reach, keeping it from leveraging its body away from the web. Engineers can only wish for strong materials that would repeatedly absorb as much impact energy as spider silk!

The spider's framework silk forms the guy-wires and framework of orb-shaped webs. The dragline silk is the strand from which the spider suspends its body. The literature is inconsistent in its use of these two terms, but they have similar properties. Dragline and framework silk have similar chemical properties to capture silk, but their mechanical properties differ from capture silk. Dragline silk is as strong and tough

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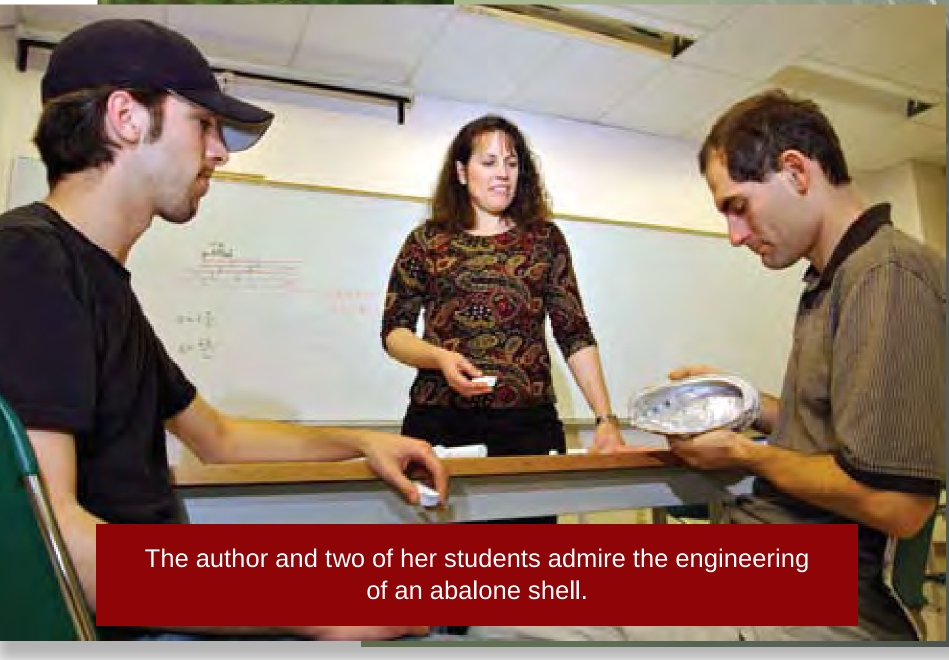

The author and two of her students admire the engineering of an abalone shell.

as Kevlar, a manmade super-material, but far more elastic and lightweight—and less brittle. Scientists conjecture that if dragline silk were combined to form a thread half the diameter of a human hair, it could hold two people. If it were used to make a chord the diameter of a pencil, it could stop a jet landing on an aircraft carrier! Because spider silk is superior to any manmade material, researchers are studying the possibility of using it to create suspension bridge cables that are much lighter than steel, body armor that is much more flexible and lighter than that made of Kevlar, durable parachute chords, artificial ligaments, airbags, and many other applications.

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Harvesting silk from spiders is impractical, so scientists are trying to figure out how to replicate it for commercial applications. The genetic sequence for spider silk has 22,000 base pairs[3]—far too many to attempt to replicate. Scientists do not yet know how much of the sequence needs to be cloned to make proteins that can be spun into top-quality synthetic threads. They are growing short proteins in bacteria and goats' milk, and manually spinning them into fibers. Viable commercial production is still a long way off.

There is also quite a contrast in manufacturing methods between spider silk and Kevlar, its closest manmade material. Kevlar is produced from high temperature and pressure from caustic, toxic chemicals and petroleum-based materials. This process is energy intensive and generates toxic waste, both of which are environmentally harmful. Spiders create their superior silk from water-based materials at room temperature using a benign environmental process.

Abalone Shell

The abalone, a marine gastropod mollusk (family *Heliotidae*) creates a type of material that is very different from spider silk. Its hard, convex oval shell protects it from predators. The lining of this shell is one of the hardest, most durable materials in nature. Its strength equals that of the most advanced synthetic ceramics, yet is not brittle. If you drop a ceramic mug, it will shatter, but dropping a seashell typically causes no damage! And like Kevlar, manmade ceramics are produced under energy intensive and environmentally damaging processes. The abalone shell is produced in an environmentally benign manner.

The abalone shell is made from calcium carbonate, the same material as blackboard chalk. However, the shell has 40 times the fracture resistance,[4] 20 times the strength, and 10 times the toughness of chalk. The abalone uses a protein matrix to arrange calcium carbonate into ordered layers of small platelets to create the lining of its shell. Under normal magnification, the calcium carbonate layers appear to be about 0.2 mm thick. Under an electron microscope, these layers are further divided into ultra-thin chalk platelets about one-half micron thick.[5] The platelets are stacked in parallel layers, with offset joints that prevent cracks from progressing straight through the layers. The platelets are glued together by the protein matrix, which provides a soft, cushioning layer between the brittle chalk platelets. If a crack starts in the brittle chalk material, it is absorbed by the soft protein border, and does not go through the rest of the layers.

Because of the abalone shell's strength, light weight, and shatter resistance, scientists and engineers are trying to replicate the system that gives it these outstanding qualities for use in tank and body armor, auto bodies, power turbines, and lighter, more efficient jet engines. They're attempting to replicate the hierarchical order seen in the abalone shell, but are unable to control the structure of the material at the microscopic scale found in nature.

Lotus Leaf

The beautiful lotus plant (*Nelumbo Nucifera*), which puts down roots in the mud of shallow ponds, is usually most admired for its water lily-like flowers. But its most remarkable property is its self-cleaning leaves. How do the lotus leaves stay sparkling in a muddy environment? The key to this phenomenon was not revealed until the invention of the scanning electron microscope (SEM), which maps three-dimensional surface textures.

Contrary to the original theory that the lotus leaf must have a very smooth, shiny surface to repel dirt, the SEM showed a very rough surface at a microscopic level on the lotus leaf.[6] The lotus leaves' tiny bumps, combined with waxy crystals, cause water to bead on top of the bumps in near spherical shapes, rather than spreading out to cover the leaf. The dirt has more affinity for the water than for the leaf, so it is washed off by the moisture—in contrast to smooth surfaces, where the dirt is more likely to adhere. The self-cleaning effect produced by the surface texture and its effect on the contact angle with water has been dubbed the Lotus Effect.[7]

Scientists have replicated the properties of this microscopic rough surface texture to create self-cleaning products. Already on the market are paints and coatings that incorporate this technology, and self-cleaning fabrics that use tiny microscopic hairs bonded to the fibers to create a rough surface. Still in the development phase is a honey spoon with a rough siliconized surface that, when tilted, sheds the honey. Many other products will probably be developed using the principle of the Lotus Effect, but they will all be based on what scientists have learned from nature.

At present, a tiny amount of grease, such as that transferred by a fingerprint, can cause manmade self-cleaning surfaces to temporarily lose their super-hydrophobic properties, regaining them only after the smudge is removed. However, the lotus leaf actually repairs itself when its surface is damaged. Manmade surfaces have little hope of mimicking this healing effect.

Summary

Biologically produced materials possess very desirable engineering properties. They have highly ordered, uniform, hierarchical structures that are controlled from the molecular to nano, micro, and macroscopic scales. They also are very durable, with excellent fatigue resistance and resiliency. These materials can repair themselves and change their properties in response to environmental demands. They are also environmentally benign, since they are produced at room temperature and normal atmospheric pressure, use water as a solvent, and are biodegradable. Laboratory materials are produced at very high or low pressures and heat, and thus are energy intensive. They use hazardous material as solvents and produce toxic byproducts. And the end product is inferior to the materials that nature produces.

Examples from nature illustrate well the care and planning that went into the creation of the universe and the stark contrast between manmade and natural materials. Humans have no hope of controlling material structural hierarchy down to the molecular level the way that nature does.

The superiority of these and other natural materials can be understood even by younger students. Although the original research on materials in nature and scientists' attempt to replicate them are published in technical verbiage, there are resources that convert these technical papers to lay terminology. These include the following:

Periodicals

- *Science News*, a monthly periodical
- Occasional articles in general readership magazines (see Campbell, Underwood, and Robbines in the bibliography)

Books

- *The Gecko's Foot* (Forbes) – an excellent resource
- *Biomimicry: Innovation Inspired by Nature* (Benyus) – includes a chapter on this topic
- The author's more extensive paper in *Christ in the Classroom* (Dovich)
- Internet searches

These types of illustrations can be used to demonstrate the superiority of God's engineering at many different levels. Students can appreciate the concept without understanding all its technical aspects. While tertiary students will comprehend more of the technical aspects, the contrasts between natural and manmade materials are so great even elementary students can understand the differences between the wondrous properties of God-designed materials and what humans are capable of creating. ✐

At the time this article was written, **Laurel Dovich, Ph.D., P.E.,** *was a Professor of Engineering at Walla Walla University in College Place, Washington.*

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