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# University of Dayton, Ohio (url: http://www.udayton.edu/index.php)

## Pearly Parts

**02.11.2008 | Faculty, Research, Science** It's a gem of an idea.

Based on the premise that an irritant introduced into an oyster will produce a pearl, scientists at the University of Dayton Research Institute are prompting oysters to produce pearl-like coatings on metal for applications to range from aircraft corrosion protection to biocompatible medical devices.

UDRI senior research scientist Doug Hansen recently reported to sponsors his team's success in manipulating oyster blood cells to deposit nacre, a natural calcium carbonate ceramic material used for shell and pearl formation, on aluminum, titanium and stainless-steel alloys — not only in vivo (within the oyster body), but in vitro (outside the oyster) as well.

"This is very, very exciting," said Hansen, who has for more than two decades studied biological polymers produced by marine organisms for adhesion and protection. "We're seeing oyster blood cells behaving as if they are growing a shell, but on metal and away from the oyster. Our goal is to grow these ceramic films with a great deal of control over thickness and location onto materials that require strong but lightweight protection."

Sponsored by the Air Force Office of Scientific Research, the program involves biomimetics — harvesting nature's own environmentally friendly yet super-tough organic ceramics to create impact-resistant, corrosion-inhibitive coatings for aircraft, ship hulls and other metal structures requiring a durable protective finish. The researchers also have applied for funding from the National Science Foundation to expand the program for medical use.

"Nacre is one of nature's superior materials in terms of strength and adhesive properties," Hansen said. "When its shell is damaged, an oyster rushes resources to the site to quickly build a layer of interim protection against predators and begin shell repair." Those resources act like "bricks and mortar" that, once hardened, are significantly fracture resistant. "As coatings, they can last a lifetime."

In addition to their strength and light weight, biological ceramics are especially attractive because they are nonhazardous to the environment and can be created safely at room temperature and pressure, while current ceramic coatings comprise multiple layers of toxic components and are produced under high-temperature, high-pressure conditions.

Shell-derived biological ceramics are also well tolerated by the human body, said Karolyn Hansen, also a senior research scientist at UDRI who is working with her husband on the program. "Oyster nacre is shown not to elicit an immune response, making it ideal for use in biocompatible medical devices. Metal implants, such as those used in bone repair and artificial joints, are at risk for immediate rejection or failure over time — as are heart valves, which calcify, and heart stents, which eventually clog as a result of immune response. But coating these medical devices with an organic finish will allow them to integrate well into the surrounding tissue."

Ultimately, the researchers believe they can use the oyster as a model to promote human bone growth and even tissue and organ regeneration, Doug Hansen said. "As different as vertebrates and invertebrates are, they are very similar in terms of cellular biology. There are obvious limits to the kind of research we can do on vertebrates, but once we understand the basic biology model of mollusks, we can apply that to humans as well."

The Hansens have joined forces on the program with Andrew Mount, a professor of biological sciences at Clemson University. In 2004, Mount shook up the world of shellfish biologists by dispelling the long-held belief that oysters create their shells by precipitating calcium carbonate from the seawater they absorb. Instead, Mount proved that the oyster's hemocytes — blood cells — are responsible for shell and pearl formation. His findings, published in the April issue of Science magazine that year, prompted the trio of researchers to wonder whether oyster hemocytes — even removed from the mollusk — would still trigger nacre deposition.

With a $20,000 seed grant from the Ohio Board of Regents to study the question for biomedical purposes, they demonstrated enough initial success to interest the Air Force in funding a larger project related to protective coatings for aircraft. Early in 2007, the researchers successfully fostered a uniform deposit of ceramic crystals on metal inserted into a notch carved into the oyster shell. They recently achieved the same success after removing the oyster's blood cells to various metal alloys in the lab.

"These results are significant because they prove, beyond the shadow of a doubt, that oyster blood cells are indeed responsible for the production of nacre, and because they've brought us a step closer to our goal," said Doug Hansen.

In their next phase of research, the scientists are working to direct in-vitro nacre formation in a controlled manner. "The most fascinating element of this research is that the keys to cultivating bone growth and to growing aircraft coatings are one and the same," he said. "They lie in the'scaffolding' — a protein polymer matrix the oyster secretes as a foundation for depositing calcium carbonate crystals."

Doug Hansen explained that the precise chemical composition of the matrix dictates whether those crystals become pearl or shell — both made of the same material, but whose diverse appearances are determined solely by the orientation of crystals as they are deposited. The researchers are using amino acid analysis to determine the matrix recipe that directs crystals into shell formation, which is structurally even stronger than pearl.

"Once we determine the composition of that matrix, we can synthesize it — creating our own scaffolding to apply anywhere we want oyster blood cells to deposit crystals," Hansen said. "Cells aren't stupid — they know what kind of material they're on and will act accordingly."

In addition to corrosion inhibition and medical use, other currently imagined applications include optical materials, biological semiconductors and permanent adhesives but, ultimately, Hansen added, "the sky's the limit."

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