New antifouling solutions sail into view

Leslie Bienen

Biofouling – the buildup of organisms on surfaces immersed in water – has been a problem for thousands of years. Greeks and Romans covered boat hulls with metal sheathing, nails, pitch, or animal hides to discourage the growth of barnacles, algae, protozoa, and bacteria. Today, the cost to industry due to biofouling is substantial; shipping companies, for instance, spend more than $5 billion annually on this problem. Fouling also harms the environment by increasing drag on ships, so that more fuel is consumed (40–70%), and by introducing invasive species.

Unfortunately, protective paints are also important sources of ecological damage. In the 1960s, tetrabutyl tin-containing paints (TBTs) emerged as cheap alternatives to copper, arsenic, and mercury-containing products and were thought to be less harmful. By the 1970s, TBTs were nearly ubiquitous on ocean-going vessels, but were later discovered to be highly toxic to non-target marine organisms (causing defective shell growth in oysters and the development of male characteristics in female dogwhelks – *Nucella lapillus*), and potentially harmful to humans. In October 2001, the International Maritime Organization passed the International Convention on the Control of Harmful Anti-Fouling Systems on Ships, a treaty which mandates that no TBTs shall remain in use after January 2008.

So, the hunt is on for less harmful alternatives. The products must be cheap to apply in large quantities, must release properly and over long periods of time, and be active against many classes of organisms (at least 4000 species have been identified as fouling culprits).

Peter Steinberg (University of New South Wales, Sydney, Australia) is a co-founder of the Centre for Marine Biofouling and Bio-Innovation. "Oceans are full of living surfaces that avoid being colonized", he says. "The challenge is to understand the ecology and mechanisms of these surfaces' antifouling defenses, and then take some of those defenses into the applied world." Steinberg and his colleagues are studying a red alga, *Delisea pulchra*, which produces compounds known as halogenated furanones. "These furanones inhibit bacterial signaling systems and are also active against a wide array of other organisms", he explains. "We think telling organisms to go away, rather than killing them, will make resistance [to antifouling products] less of a problem. Colonization of aqueous surfaces is a problem in many arenas. Catheters, contact lenses, implants – they all get colonized by bacteria. It's the same problem in a different context."

Photo by R De Nys

Delisea pulchra *may help solve fouling problems.*

Charles Derby (Georgia State University, Atlanta, Georgia), PM Johnson, and their colleagues are looking at natural biocides to kill fouling organisms. They have isolated a protein called Escapin from the ink of the sea slug *Aplysia californica*, and have successfully expressed the protein in cell lines. "Escapin is highly effective at very low concentrations for killing or inhibiting the growth of a diversity of microbes", notes Derby. "It's very stable over a wide range of temperatures, and we know that only a portion of the molecule is necessary for its activity." Derby's group is hoping that these qualities "will help turn Escapin into an affordable antimicrobial agent, effective in combating biofouling".

Biofouling is essentially a problem of controlling adhesion, according to Dr Maureen Callow (University of Birmingham, Birmingham, UK), an editor of the journal *Biofouling*. "Nature", she says, "unlike technology, has conquered the problem of sticking to wet surfaces. Optimizing the design and manufacture of non-stick surfaces necessitates an understanding of wetting, and of the many types of adhesives used by fouling organisms. We know algal and barnacle glues are proteins, so one strategy is to use enzymes to degrade them."

The idea that nature can provide blueprints to help solve environmental problems includes investigating how the outer layers of animals and plants discourage fouling. Dr Wil-fried Meyer and his colleagues (Anatomical Institute, School of Veterinary Medicine, Hannover, Germany) have found that "in certain marine mammals, such as dolphins, a nanorough surface that is smoothed by a shear-resistant gel at the epidermal surface prevents biofoulers". This kind of basic research could help guide the development of new antifouling products.

For the immediate future, until more environmentally friendly antifouling solutions can be mass-marketed, copper paints will play a large role in replacing the outlawed TBT paints. Although the technology of copper paints has been improved, Steinberg warns, "issues of toxicity and non-target environmental effects remain". However, he and other researchers are optimistic that organic antifouling solutions will eventually be used on a large scale. "The environmental movement has developed a reputation as naysayers", says Steinberg. "But there are ways to do things positively using natural models, rather than just stopping people from doing things. This is a great opportunity for positive change." ■