TRYING TO SOLVE THE BIOFOULING PROBLEM

by Mary Ellen Curtin

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Test panels designed to mimic the effects of saltwater conditions on ships' surfaces. *Top:* The surface is covered by a relatively early stage of biofouling. *Bottom:* Barnacles, the biofouling climax community, eventually attach to the test surface.

Food and chemical applications of marine biotechnology involve getting useful things out of the water. Biological techniques, however, can also help solve problems that arise from working in the water in the first place. These solutions may be particularly interesting to the biotechnologist because some marine problems overlap with those faced in any industrial fermentation.

Any surface, placed in water, gradually becomes home to a collection of bacteria, algae, and invertebrates. This biofouling has particularly drastic effects on the performance of ships. "A bacterial film only 200 microns thick on the hull of a ship can retard the speed by 20 percent," says Robert Weiner of the University of Maryland (College Park). "A tanker crossing a large body of water like the Mediterranean may use twice as much fuel coming home as it did on the outward journey, due to the drag from fouling organisms."

"Biofouling is a process that has been with us ever since people first put boats into the water. The Phoenecians used essentially the same [antifouling] technique we use today: heavy metal poisoning," notes Mel Simon of the Agouron Institute (La Jolla, CA).

Daniel Morse of the University of California (Santa Barbara) says that long-term treatment of ships with metals has resulted in pollution problems. "These are 'sacrificial coatings,'" he explains. "They must leach into the water to work. The organotin compounds most commonly used are highly toxic to vertebrates, including the workers who must manufacture the coatings and paint or refinish the ships."

Research on non-toxic marine coatings takes two forms: making products that organisms cannot stick to—low-energy coatings along the line of Teflon—or using knowledge of bacterial and invertebrate settling mechanisms to make products the organisms won't want to stick to. Simon says the problem with the low-energy approach is that "these coatings are very expensive, and they are fragile: they crack and give fouling organisms a place to lodge. Besides, I feel that eventually there will be organisms that will be able to colonize these things—marine organisms have evolved for many millions of years to colonize different surfaces."

The first step in fouling is the adhesion of macromolecules, which occurs on any surface placed in water. Simon and co-workers at Agouron are focusing on the second step: settlement of bacteria and microalgae. "We've invented a series of methods that allows us to define which genes turn on when an organism attaches to a surface. This research is beginning to give us specific biochemical targets involved in bacterial colonization, steps in which we can intervene in a meaningful way." Simon envisages that coatings will eventually be designed to elude bacterial sensing mechanisms: "a kind of 'stealth' coating to evade bacterial radar."

Weiner is one of a number of researchers concentrating on the third step in biofouling: invertebrates that settle on top of the initial bacterial or algal colonizers. This settling may be stimulated by neurotransmitter-like molecules secreted by the microfouling organisms, or may occur in response to the polysaccharide-based "slime" microfoulers produce.

The first coatings generated from biofouling research are starting to enter the market. "We began our studies by looking at the properties of natural nonfouling surfaces like the skin of dolphins or the inside of your mouth," says Robert Baier of the State University of New York (Buffalo). "We found that there was no way, no matter what we did to surfaces, to stop the deposition of that first layer of macromolecules. The important point is that on certain types of surfaces the macromolecular layer and the fouling organisms built up on it peel off very easily. It's not a sacrificial surface—the original layer of biofouling is sacrificial."

Baier's studies were initially aimed at solving fouling and deposition problems in medical devices such as the artificial heart. But surfaces with the properties he has outlined—an intermediate surface energy state that is neither particularly hydrophobic nor hydrophilic, to which proteins do not bond in any strong way—are finding applications in marine technology and fermentor design as well. The ideal surface has not been discovered yet but, according to Baier, "that's because it's a difficult problem in material science, not because of the biology."

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