al saltwater sources of biomass, researchers are seeking marine microorganisms with unusual capabilities. John Waterbury of the Woods Hole Oceanographic Institution (Woods Hole, MA) and his associates discovered bacteria that can both digest cellulose and fix nitrogen. The bacteria, which are members of an as yet unnamed genus, live in symbiotic relationships with molluscs that can subsist entirely on a diet of wood. Because the bacteria are being patented, Waterbury only recently began sending out cultures.

"We've had about equal interest from academics and industry," Waterbury reports. He says the bacteria are particularly attractive for producing single-cell protein from cellulose because they would eliminate the need to add fixed nitrogen.

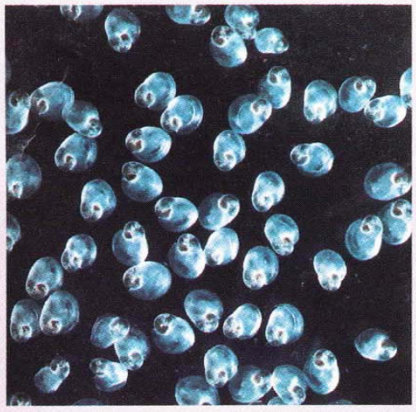
Such single-cell protein might conceivably be recycled back into the marine system as food for aquacultured species. Phillips Petroleum (Bartlesville, OK) is testing the efficacy of its own yeast-derived single-cell protein as a feed for such animals as lobster, shrimp, and trout.

Holger Jannasch of Woods Hole is working with another unusual bacterium. Originally isolated from a deep sea hot vent, this bacterium can metabolize hydrogen sulfide, a common waste product, and procure its other nutrients from normal seawater in an "artificial vent" situation. This bacterial biomass can then be fed to mussels. Jannasch says he and his coworkers have already demonstrated that the mussels will consume the bacterium without ill effect. "All that is needed now is the bioengineering to go to a larger scale pilot plant," he says.

**Improving Aquaculture**

The application of biotechnology to culturing finfish and shellfish represents a real opportunity to increase food production. Seafood is a comparatively inexpensive source of protein, so it is not surprising that world's aquaculture production capacity has doubled over the past five years. Japan, China, and India are the largest

# REGULATING THE LIVES OF SHELLFISH



***Left:*** **Results of conventional abalone hatchery technology.** ***Right:*** **Results of "biochemical engineering," in which parallel-cultivated abalone were induced to settle and metamorphose by the addition of the neurotransmitter gamma amino butyric acid (GABA) seven days following fertilization. Identical results were obtained when neurotransmitter-mimetic peptides were used in place of GABA.**

Abalone is a tasty, scarce, and expensive shellfish, difficult to grow in aquaculture. Now a researcher at the University of California in Santa Barbara (UCSB) has discovered some surprising ways of overcoming the abalone's low reproduction and survival rates. These findings may also have unexpected implications for human medicine.

Daniel Morse, a UCSB professor of molecular genetics and biochemistry, discovered that prostaglandin regulates reproduction in abalone, as it does in many other animals. Once one shellfish starts spawning, it releases the hormone, which triggers nearby individuals of the gregarious abalone to spawn too. This increases the chance for successful fertilization of the sperm and egg cells released into the water. Morse found that a trace of hydrogen peroxide added to the breeding tank stimulates prostaglandin synthesis, resulting in simultaneous and vigorous spawning. This simple stimulus also works on oysters, clams, scallops, and mussels. The marine biologist says the hydrogen peroxide provides free oxygen radicals needed in an enzymatic step in the formation of prostaglandin.

Successful and predictable spawning is only the first hurdle. The tiny, free-floating abalone larvae die by the thousands or millions if they do not find a suitable substrate on which to settle and grow into adults. Morse screened many rock surfaces, looking for a clue to the abalone's preference. He eventually isolated a chemical signal—a close relative of the neurotransmitter gamma amino butyric acid (GABA)—from a red algae that colonizes rocks. Without GABA, Morse found, only one percent of the abalone larvae survive. When GABA is added, 95 percent attach themselves to the rocks.

"We've been discussing the neurotransmitter-mimetic peptides (NMPs) with pharmaceutical companies interested in diagnosis," Morse says. "To do positron emission tomography (PET) scans, you need specific neuronal ligands. Right now, the available ligands show low specificity; they bind to too many brain cells. We can use NMPs to design new ligands, which can be tailor-made through biotechnology."

Morse is also employing genetic engineering tools to produce and characterize the GABA-mimicking compound because it also has great potential in human therapy. GABA controls about 40 percent of all brain nerve transmissions, involving muscle tone, sleep, wakefulness, and a range of psychological states. He hopes that GABA mimetics, which bind up to a hundred times more tightly to the GABA receptors, could one day replace commonly used drugs, which often have undesirable side effects.

"We have now isolated several classes of GABA mimetics, also from marine bacteria," Morse says. His goal is to transfer the GABA mimetic genes into *Escherichia coli* for more convenient study and development of a production system. **—Bruni Kobbe**

PHOTO COURTESY DANIEL MORSE, UCSB