EXPLORATIONS
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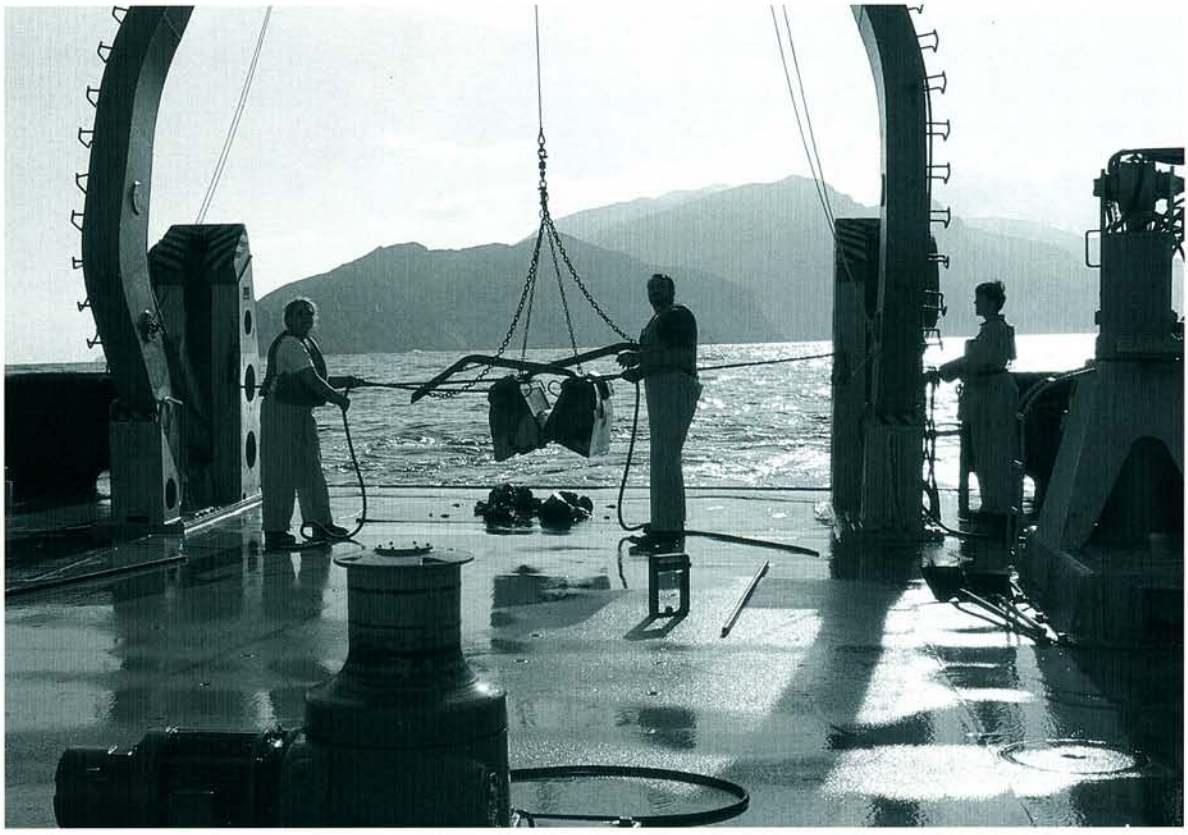
SCIENTIFIC *Clam Dig*

Researchers Delve into Symbiosis

BY PAIGE JENNINGS

On an early October morning, R/V *Robert Gordon Sproul* pulls away from the dock at Scripps's Nimitz Marine Facility, beginning a three-day marine biology collection cruise up the southern California coast. As the sun gains confidence and threatens to crowd out the morning marine layer, Scripps marine biologist Horst Felbeck and a scientific team settle in for the 22-hour haul to the first research station in the Santa Barbara Channel.

For Felbeck, an associate professor in the Marine Biology Research Division, this is one of several cruises he makes yearly to collect two species of clams that he uses in his research. Unlike most clams, these specialized bivalves possess no or only a reduced digestive system. Through symbiotic (mutually beneficial) relationships, they host bacteria in their gills that derive energy from sulfides and other chemicals in the water. The symbiont



A sunny day, calm waters, and a breathtaking view of the Channel Islands provide a perfect working environment while collecting at sea.

Opposite page: Van Veen grab poised in preparation for deployment with *Lucinoma aequizonata* and *Solemya reidi*—the bivalves collected during the scientific clam dig.

CLOSE QUARTERS

Create Teamwork

Research vessels and campus laboratories are places of scientific pursuit, serious concentration, and exacting skills. They also are characterized by a wealth of individual personalities. For many scientists, such as marine biologist Horst Felbeck, doing research both at sea and on land strengthens the the working relationship of the research team.

"It generally helps the atmosphere in the lab if one goes once in awhile on long cruises, because one learns to know everyone else and tolerate the habits of other people. There is no escape, so you are exposed to each other, if you are in a bad mood or not," explains Horst Felbeck.

Although spending up to two months at sea can bring about bad moods and anxiety, many crew members, including Felbeck's group, find outlets through meditation, reading, and lots of physical exercise.

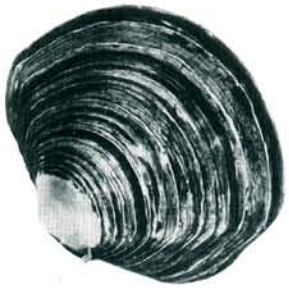
Felbeck, an associate professor and researcher in the Marine Biology Research Division, finds his time at sea vital to the smooth running of his laboratory.

On deck, members of the scientific team share duties and stories as they transfer clams into buckets of collected sediment. Bottom photo, back in his laboratory, Horst Felbeck (center) works with graduate student Debbie Hughes and technician Pati Turner.

Three or four times each year Felbeck's group, consisting of a research technician and three graduate students at different stages of their education, must pack up the laboratory in as many as 250 crates, move it all to the research vessel, unpack and store everything, and prepare for 72-hours to seven weeks of ship time. The shorter cruises take less preparation, but they also do not provide the depth of experience gained during long ventures.

"I think the difference on the short cruises is that we don't do as much scientific work," explains graduate student Debbie Hughes. "It's all manual labor. Collecting animals and working equipment. On the longer cruise you always have to think because you're conducting experiments and doing research. Also, the lifestyle is totally different. You're with 15 to 30 people and that's it, for more than a month."

Many scientific teams at Scripps, such as Horst Felbeck's, have the opportunity to work in and benefit from both environments.



Lucinoma aequizonata

bacteria fix inorganic carbon from the seawater filtered through the clam's gills into organic material, providing the clam with food. In turn the clam provides shelter and protection for the bacteria.

During his 15-year career at Scripps, Felbeck has focused on these specialized interactions between invertebrates and chemoautotrophic bacterial symbionts. He studies a variety of invertebrates, including giant tube worms found at deep-ocean hydrothermal vents and nematodes from Central America.

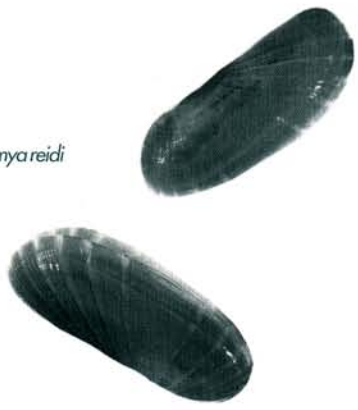
Dressed in dungarees, a tie-dyed tee shirt, sweat jacket, and sandals, Felbeck is ready for another routine trip—a quick escape from life on land.

"These short cruises are fun," explains Felbeck, "but I have done them for 15 years, so they are usually the same experience. One treat is that I can sleep as much as I want. Whenever there is no work, I can go to sleep. And on land I would always feel guilty doing that. It also gives me a lot of time to read."

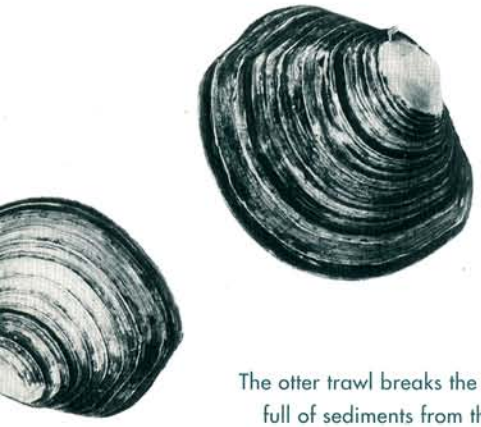
The Van Veen grab is very heavy, tricky to maneuver, and requires a coordinated effort. Graduate student Karen Casciotti and Richard Cosson, a researher from France, prepare to open the grab.

At right, sediments collected near Santa Catalina Island are searched, but no clams found. Below, the grab is carefully moved to its storage site on the ship's port side.

He will not have much time to relax on this day. Ship's Captain Louis Zimm tracks down Felbeck, reading comfortably in his bunk, to let him know that the ship is heading back to port because of mechanical problems. By lunchtime the ship is tied up, equipment is secured onboard, undergraduate



Solemya reidi



The otter trawl breaks the surface, full of sediments from the Santa Barbara Channel. Below, graduate student Debbie Hughes and Horst Felbeck at work onboard R/V *Robert Gordon Sproul.*

students hurry off to afternoon lectures, and Felbeck, with the students from his lab, heads back to Scripps in his 1971 Volkswagen bus.

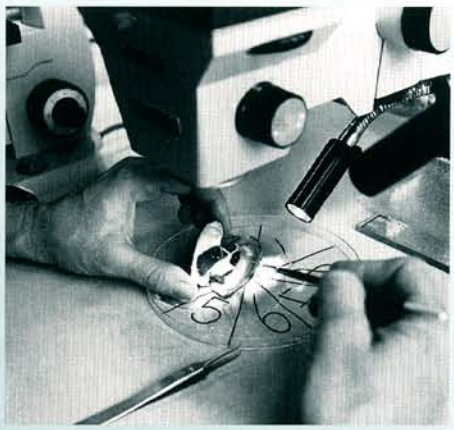
Four days later, with a sense of déjà-vu, the ship is heading back out to sea with the same crew, Felbeck, and a scientific team including UC San Diego undergraduate and Scripps graduate students, a visiting scientist from France, and volunteers. Everything is running smoothly and all quickly convert to shipboard existence. Following a breakfast of fresh fruit, egg sandwiches, and danish, most of the scientific crew have retired to their berths to sleep or read until lunch, which will be followed by another nap. Evening activities will consist of another large meal, a video, or studying for upcoming mid-terms.

SYM**BIOSIS:** *a way of life*

Life in the dangerous and vast ocean world, where food is scarce and predators are many, calls for some creative living arrangements. Throughout the marine environment organisms form symbiotic relationships, in which one or both of the distinct organisms benefit to various degrees through involvement with the other.

Many people consider mutualistic symbiosis, in which both partners directly benefit, as the only kind of symbiosis, but other arrangements also exist. One such arrangement is commensalism, in which one species benefits by eating the "leftovers" discarded by a larger partner that is unaffected. Parasitism is also considered a symbiotic relationship by some, but most researchers do not agree because typically one partner eventually dies.

Marine biologist Horst Felbeck is interested in the basic science behind the mutualistic symbiotic relationship between species in a variety of exotic marine environments, from deep-sea hydrothermal vents to the area surrounding nearshore sewage outfalls. In the latter environment he studies the gutless clam *Solemya reidi* and the bacteria that live in the cells of its gills (see main story). This relationship, in which one organism hosts the other within its body, is endosymbiotic. It is also mutualistic because the clam benefits from food produced by the bacteria, and the bacteria benefit both from a constant stream of sulfide-rich water that the clam pumps past them and by receiving shelter and protection.



Symbiosis between *Lucinoma aequizonata* (pictured here) and the bacteria residing in its gills, is one of many such relationships studied by Horst Felbeck and his group.

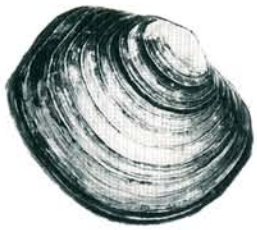
Several students take the cue from Captain Zimm and embark on a half-hour hike around the upper deck. Although the ship's crew works throughout the night, the scientific team's duties will not begin until the next morning, when the ship reaches the first station in the Santa Barbara Channel.

At 5 a.m., Sunday, the first team bundles up and gathers at the fantail to deploy the otter trawl, a 25-foot by 50-foot, green net that will be dragged along the ocean bottom at about 1,600 feet. As the sun illuminates the nearby Channel Islands and the water turns from a murky black to a calm, deep blue, the trawl is drawn tight, lifted, and brought on board, heavy with sediment and life. Felbeck and his helpers snag the trawl and lower it carefully to the deck. The opening of the net is loosened and the contents ooze onto the fantail of the ship. The students descend on the haul as if in search of gold doubloons—not inch-long clams.

Hundreds of clams, *Lucinoma aequizonata*, are collected in the first haul, so the morning's work is almost done. All that is left to do is collect mud in which to house the clams back in the laboratory.

Because so many clams have been collected, Felbeck instructs his team to dissect the gills from a few hundred animals. A circle of students armed with tweezers, scalpels, and scissors bend intently over these small bivalves to begin their delicate surgery. With gentle hands they pry open the shells and snip out the intact gills. The gills are separated by color—white, grey, or black—and then stored in the freezer. Back at Scripps, the gills will be ground up and used by Felbeck and his students for a variety of biochemical studies including measuring the sulfur content, which determines their color. The live specimens will be moved to the experimental aquarium at Scripps, where they can be supported for up to a year in flat tubs full of the mud collected on the trip.

One deployment of the otter trawl supplies Felbeck's group with a bounty of *Lucinoma* clams. Above, the net is hauled onboard, left, the contents are examined, and below, the clams are gathered.



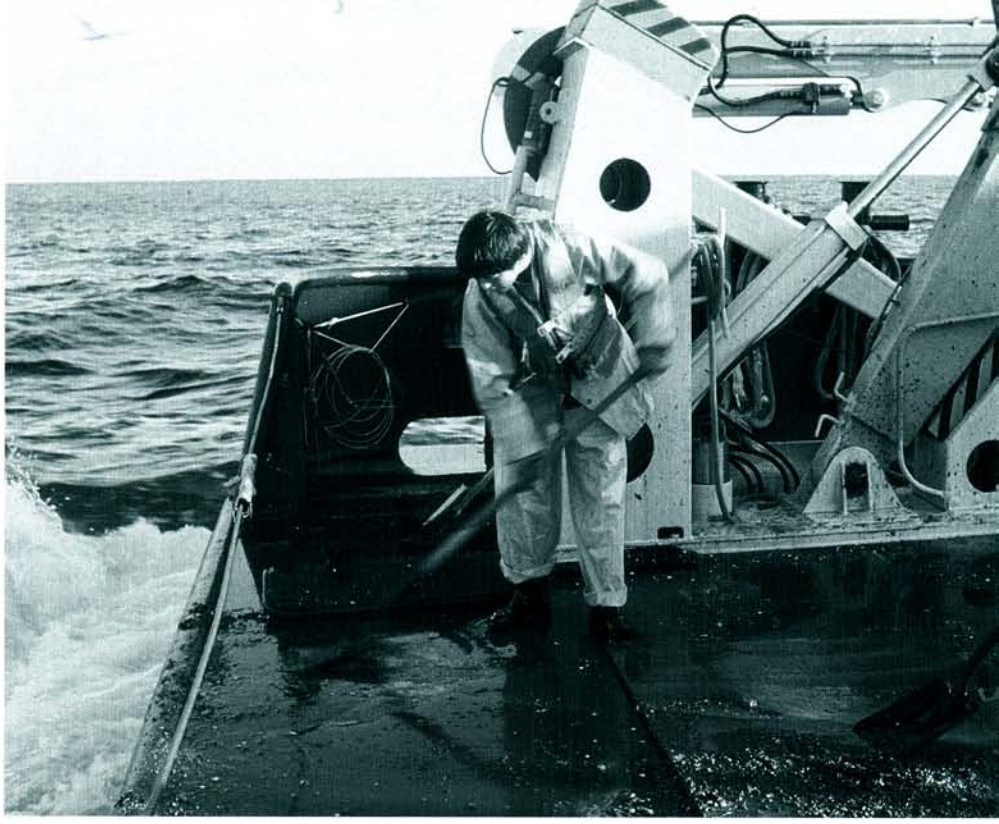
Moving south to Santa Monica Bay, the ship reaches the second station after dinner. Debbie Hughes, a third-year graduate student in Felbeck's laboratory, leads the first team for a four-hour shift of collecting. The animal being sought is *Solemya reidi*. Unlike *Lucinoma*, which has a reduced digestive system, *Solemya* is completely gutless and lives along the openings and within the sludge of sewage treatment plants. Felbeck is especially interested in these small bivalves because they thrive in an environment that most marine animals find intolerable.

Collecting *Solemya* is a bit trickier, and much more malodorous, than the first venture. A large metal sampler, known as a Van Veen grab, is attached to heavy wire and lowered over the fantail. Maneuvering this instrument, which will scoop up approximately 3 cubic feet of bottom sediment, is potentially dangerous and requires agility and concentration from the entire team. A good haul brings aboard black, sticky mud smelling of rotten eggs. The team, with bodies concealed in yellow rain slickers and hands protected by elbow-high rubber gloves, digs into the black muck searching for clams of deep red adorned with gold stripes.

"Aren't they beautiful," exclaims Hughes as she cleans off an inch-long clam and drops it into a bucket of seawater.

The first few grabs are very successful, each providing more than a dozen clams. But it will be a long night as they work to collect more than 120 specimens. Between the increasing swell, decreasing air temperature, and constant stench, a few students are threatened with sea sickness; but with the thought of a warm bunk only a few hours away, nausea is avoided. By 1:30 a.m. the second team has finished and the clams are securely housed in giant buckets of the noxious muck. Back at Scripps the clams and sludge will be transferred to

In a flurry of activity all hands, gloved or not, are needed to comb through the sediments and retrieve the *Lucinoma* clams. Fortunately these sediments, from the Santa Barbara channel, do not exhibit the odor or sticky consistency characteristic of the mud to be collected near the sewage outfall.



Everyone takes turns at the chore of shoveling the "picked-through" sediment off the fantail; this time graduate student Melinda Duplessis is on duty.

2-feet-deep tubs lined with calcium sulfate and seaweed. This lining causes sulfur bacteria to grow quickly, providing the *Solemya* symbionts with the sulfide they need as energy.

Felbeck first became interested in *Solemya* in 1981 after reading a paper describing a gutless clam found in a paper mill outfall, an area characterized by very high sulfide concentrations. He was already studying giant tube worms and immediately thought that if these clams were gutless and thrived in sulfide-rich environments, like the tube worm, maybe they existed in other exotic locales.

"We found the first specimens near the San Diego sewage outfall, tested them, and this started the ball rolling. Subsequently, we found symbionts in association with undeveloped or poorly developed digestive systems in a number of bivalves and other animals.

"Normal clams have digestive systems," explains Felbeck, "but in these sulfide rich environments they have reduced digestive systems because they rely on the bacteria to supply them with nutrients. This way they don't have to work for anything; they don't have to have a source of particulate food; and they don't have to look for a parcel of tissue to eat. The symbionts do all that."

Felbeck is so interested in the basic science behind the relationship between carbon-fixing bacteria symbionts and their different hosts that twice he has spent a month on a football field-sized island off Belize studying gutless nematodes that live between grains of sand.

A 72-hour cruise in southern California waters is quite different from a month of exclusion on a Central American island, but it supplies Felbeck with his necessary specimens and serves as the perfect testing ground for undergraduate and graduate students considering careers as seagoing scientists.

"We always have lots of undergraduates as volunteers on these cruises, especially on the short cruises, but also on the longer ones we usually take one or so. On the shorter cruises we use a lot of muscle, to sort through the trawl, and to drag the trawl. That is a very good way to introduce students to marine science, real marine science on a ship. There are always takers."