Not
Just Your
Garden-Variety

SEA SLUGS

garden slugs will not win any beauty contests; however, sea slugs are a different sort—aamong nature’s most beautiful works. And, in the eyes of marine ecologists, their beauty is much more than skin deep.

In the Marine Research Division at Scripps, graduate student Patrick Krug is examining the chemical ecology of sea slugs (nudibranchs) under the guidance of marine chemist Dr. John Faulkner. Krug, standing nearly seven feet tall, is a tower of energy. During

BY JOE HLEBICA
PEOPLE CAN WALK THROUGH HERE FOREVER AND NEVER SEE A SINGLE NUDIBRANCH, BUT IF YOU LOOK CLOSELY, YOU CAN FIND HUNDREDS.
a conversation in the laboratory, he enthusiastically reports on his recent good luck collecting specimens.

“A collector from the aquarium hung a mop from the end of Scripps pier in order to pick up the young crabs that hide in the mop's threads. This is what I found crawling among his catch.”

Krug leans over his desk and gestures with a pencil toward a square dish containing a variety of nudibranchs, none of which is more than a fraction of an inch long.

Crawling within the branches of a small clump of bryozoans (small encrusting animals) are a half dozen orange-striped black nudibranchs. A white nudibranch with black spots slides along the glass above a piece of white sponge. A second dish contains several tiny white sea slugs with wavy red projections on their backs. As they feed on a feathery cluster of brown hydroids, which resemble tiny anemones, Krug explains how sea slugs manage to survive in a hostile environment where most creatures are both prey and predator.

“Animals and plants that spend their lives attached to the bottom must protect themselves from hungry predators. Sponges and bryozoans produce toxic chemicals, mak-
ing themselves poisonous. Corals and sea anemones have stinging cells that zap anything that tries to bite them. Although most predators won’t touch these defended organisms, sea slugs are adapted so that they can. In fact, many sea slugs are so specialized they feed exclusively on a single species of defended animal.

“In an environment as big as the ocean, finding the one species of sponge that you prefer isn’t easy; especially if you’re only a quarter of an inch long,” Krug points out.

“Though it’s hard to imagine how they do this, the secret lies with their larvae.”

Sea slugs lay egg cases, often in beautiful coils or colored ribbons, packed with countless microscopic eggs. The eggs develop into tiny larvae, which swim around in the ocean for about a month. When they eventually bump into a food item that the adult form will eat, the larvae recognize a chemical cue and metamorphose into the juvenile form.

According to Krug, “No matter where a sponge is found, you can usually find a sea slug that dines on it too, even on a mop hanging off the end of a pier. I’m trying to identify the chemicals that tell the larva ‘Hey, this is what you’re going to eat when you grow up—stick around!’”

He places a petri dish under the microscope on his bench. “You can see what the larvae look like here. They have a shell and a pair of retractable velar lobes that look like Mickey Mouse ears.”

In Faulkner’s laboratory, chemists use sophisticated techniques to determine the structures of the molecules made by sponges and other marine animals, in order to better understand their role in the chemical ecology of the intertidal region.

Mary Kay Harper, a sponge taxonomist and research associate working with Dr. Faulkner, elaborates on the subject.

“Though each type of sponge produces unique defense chemicals, nudibranchs have developed the ability to eat sponges without being poisoned. As a matter of fact, most nudibranchs can store the toxic chemicals produced by sponges. Any fish that attempts to eat such a nudibranch ends up with a dose of repulsive sponge chemicals instead. That’s why so many nudibranchs are spectacularly colored; their coloration makes it easier for fishes to learn that they taste awful.”

Some nudibranchs slightly modify the chemicals they get from their food in order to make them even more distasteful to predators. Other sea slugs even make their own chemicals from scratch.

In the ocean, the web of interrelated species is at least as complex as any newly determined chemical structure. According to Harper, “The closer you look at the web of interrelationships, the more complicated things get.”

It’s 5:40 a.m. and, shortly following a gray midsummer dawn, a very low tide has uncovered a broad reef adjacent to La Jolla Cove near Scripps. Harper nods her head toward another group of tide-pool explorers. “People can walk through here forever and never see a single nudibranch, but if you look closely, you can find hundreds.”

Krug has already collected a few specimens and, tipping his bucket to offer a look inside, he identifies them. With new species being described all the time, many nudibranchs lack common names.

“These little guys are Diaconia picta. They’re arinacea nudibranchs and eat hydroids. The little red one is the aeolid nudibranch
Flabellina trilineata, also a hydroid eater. It was one of the sea slugs I found on the pier mop."

Acolid nudibranchs have variously shaped tentacle-like organs called cerata on their backs (see illustration page 4). Cerata, which in some species look like dazzlingly colored fur coats, serve both for respiration and defense. Acolids feed on sea anemones, hydrodroids, and corals—all animals that defend themselves with stinging cells. Not only are the nudibranchs immune to the stings—which can kill small fishes—but they again manage to turn this defensive mechanism to their own advantage. The digestive system of the sea slug sorts out the stinging cells as they are eaten, and passes them along into the cerata, where they remain functional. "If a fish tries to eat a Dirona plecta, it gets a mouthful of borrowed stinging cells," Krug explains.

"Aplysopsis enteromorphae is found in the high-intertidal, in places like Dike Rock just north of the Scripps pier. It lives in shallow depressions on boulders at the high-tide line, which is much higher than you'd think any of these animals could survive, but that's where its food is found. It eats the alga Enteromorpha, which grows like fine green hair in tide pools. It's a sacoglossan—a kind of sea slug specialized to slurp out the contents of filamentous algae. Its digestive system performs another amazing trick. It sorts out the chloroplasts—those parts of the plant cell that carry out photosynthesis—and places them in its own body wall. The chloroplasts continue to photosynthesize, manufacturing sugars, which the sea

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from Marine Organisms

In addition to the understanding of natural relationships gained from their chemical studies, scientists in John Faulkner's laboratory gather data on natural compounds with important applications in other areas. Many of the compounds isolated from marine organisms were previously unknown to science and are of great potential value as medicinal drugs or probes for biomedical research.

For instance, explains Mary Kay Harper, a research associate in Faulkner's laboratory, "There's a compound called zonarol we're interested in that was isolated in a local brown algae. Dr. Vivek Malhotra of the UCSD Biology Department is studying compounds that will help in understanding processes in the Golgi body, an organelle inside living cells that stores secretory products, which are active in cellular secretion. Zonarol has some of the characteristics of such compounds."

A specialist in the taxonomy of sponges, Harper recently took a break from work in the laboratory to describe her own research on two local sponges.

"What distinguishes these sponges is that one has a skeleton made of keratin fibers, and the other's skeleton is made of spicules. You can actually feel the difference in their textures. If it's squishy, it's fibrous. If it's denser and more malleable, it has spicules."

In order to make individual identifications of such sponges, Harper must examine tissue samples under a microscope. When magnified thousands of times, the spicules appear as slender, crystalline rods, and bear certain characteristics that can be used to distinguish one species from another.

About one sample she explained, "Orange sponges like this are probably the most common in the local intertidal zone. I'm going to extract compounds from this one and send them to Osteoarthritis Sciences, Inc., of Cambridge, Massachusetts. We've sent them various extracts from numerous organisms from all around the world. We plan to do more in-depth chemical analyses on the ones that show promise and then purify the active components."

Researchers at Osteoarthritis Sciences, Inc. conduct a chemical assay in which they look for certain chemical reactions that they know to occur in tissues affected by osteoarthritis. It is known that at the onset of cartilage breakdown from the disease, an enzyme is released. According to Harper, the company's researchers are looking for inhibitors to the degenerative process.

With a little luck, she may find that her sponge sample contains just such a compound. ©
slug then absorbs. Some tropical sacoglossans can stop eating altogether and just survive by sunbathing.”

As he talks, Krug adds to his collection. “This is a cool one called *Antipella barbarensis*. It has these thick cerata that come to sharp points that are tipped with bright orange and blue. This one with markings like a leopard is a dorid, *Jorunna paridus*.” Dorid nudibranchs usually have a single tuft of gills on the back (see illustration page 4). “I began work on their chemistry using two specimens I found here last year, but couldn’t get enough material to work with. I should be able to complete that project with the ones I’m finding here today.”

He uncaps a small plastic bottle. “In here is my prize, *Sclerodoris tanya*, a nudibranch whose chemistry I’ve been working on for the last year. Smell it?” The animal has a strangely pleasant aroma. “It contains a compound that is actually very floral smelling when you purify it, and its chemicals appear to be the sort that certain nudibranchs make for themselves—ones they do not get from their diet. It’s a really gorgeous animal that’s named after someone’s cat.” (According to the field guide *Pacific Coast Nudibranchs*, the dorid’s namesake was a Siamese named Tanya.)

“This dorid is really cool because it has a ‘lunar surface’ that’s covered with pits and protuberances.” Krug describes the rough, brown-and-gray body that gives this dorid a drab appearance. “No one knows what it eats. It’s usually found on algae, or cruising just beneath the surface of the water.” He refers to the remarkable ability of nudibranchs to crawl upside down across the liquid ‘ceiling’ of the water’s undersurface.

He points out another specimen in his bucket. “Unlike *Tanya*, the diet of this one, *Mexichromis porterae*, is known, and it eats only the local sponge *Dysidea ambilina*. Dr. Faulkner worked out the chemistry of that relationship about 10 years ago.”

According to Krug, the most common local nudibranch is the white-spotted sea goddess (*Doriopsilla albopunctata*). Referring to the variety of adaptations found among these creatures, Krug states admiringly, “The array of tricks performed by this one relatively small group of animals is pretty spectacular.”