All organisms, particularly those that lack vision and hearing, rely on chemical cues to locate food and potential mates, avoid predators, or suppress competitors. Chemical signals constitute a language through which diverse organisms interact, and deciphering the language could deepen researchers’ understanding of ecological communities. Mark Hay, a marine ecologist at the Georgia Institute of Technology, has pioneered the study of chemical signaling in marine ecosystems, such as coral reefs. Through a combination of field and laboratory research, he has shown how chemical cues and signals mediate interactions between seaweeds, corals, and herbivores, and help shape their populations. Hay’s work also has implications for coral reef conservation. In recognition of his accomplishments, the National Academy of Sciences awarded Hay the 2018 Gilbert Morgan Smith Medal for excellence in research on algae. PNAS spoke with Hay about the work that led to his award.

PNAS: What led you to study chemical signals in marine ecosystems?

Hay: I was looking at how plants on coral reefs evolved to deal with attack by herbivores. As an example, we find many seaweeds that occur only on reef flats and don’t occur on the deeper reef slope where herbivores are more common. We could move seaweeds between these different habitats and show that some of them that didn’t normally occur on the slope could grow there really well, but they got eaten so fast that they went locally extinct. Then we looked at the seaweeds the fish wouldn’t eat and asked, “If they’re not eating these, how come?” I realized that it must be a chemical trait. So, I paired up with chemists who were interested in what certain novel compounds they were finding did in nature.

I was very good at conducting field experiments and figuring out what these compounds did in nature, but wasn’t very good at the chemistry. When we joined up, each of us had been building expertise that the other needed; our collaborative interactions produced an explosion of productivity. We worked out ways to extract the chemistry from the seaweeds that the fish avoided and put it on ones they normally liked. Then we could put those seaweeds back out in the field and see, if species A, which the fish don’t like, traded chemistry with species B, which they do like, would the fish avoid species B? And they do—often, very strongly.

PNAS: What are some examples of ways in which chemical signals affect marine organisms’ behavior?

Hay: Chemical cuing is heavily involved in mating at scales ranging from attraction of sperm to eggs, on up to males tracking females using chemical cues emitted by the female. These cues can be very strong. If a golf ball or rock is treated with crab pheromones, male crabs will carry, protect, and mate with these items (1). In Fiji, we showed that a particular seaweed is a potent killer of corals (2). However, we would find it close to certain corals that are particularly susceptible to it, but it didn’t look like much was happening. The coral has symbiotic goby fishes that live among its branches. When we put this seaweed against that coral, the coral recognizes the seaweed chemically; it sends a 9-1-1 chemical call to the gobies, they come out and graze that seaweed just enough so that it doesn’t touch the coral and can’t transfer toxic compounds over to it (3). We can move the chemistry from seaweed to string, put the string against the coral, and the coral sends out that same signal to tell the fish to come to protect it, and the fish come over and try to attack the string.

PNAS: How can understanding chemical signaling improve our ability to protect coral reefs?

Hay: Just like biomedical researchers learn the chemistry of the body and develop medicines, I’m hoping that over time we can use this as a way to develop “cures” for environmental collapse. I don’t anticipate that we’ll drop a pill in the water and the reefs will get better; I anticipate that we can learn how to effect
small changes that have a huge impact versus large changes that have minimal impact.

We’ve recently shown that when seaweeds degrade a reef too far, they give off a “smell of death,” and then coral larvae and fish larvae won’t recruit to that reef (4). Meaning, if we let reefs degrade too far they go into a death spiral, because the fish and the corals you need to recruit to make them recover won’t go there. In Fiji, where we’ve been working, there are 29 species of grazing fish that are common, but only four of those are really important in removing nuisance seaweeds.

PNAS: You have recently explored interactions between climate and chemical signaling. How might chemical signaling be affected by climate change?

Hay: All of these chemical signals have evolved to work well within a certain physiochemical setting, and we’re changing that setting. For example, we know that under today’s conditions, recruiting juvenile fishes smell and avoid predators. If we crank the pH down to conditions that are expected 50–100 years from now, they start being attracted to predators rather than avoiding predators. They run around a little more than they should, they get a little further from structure, they’re a little too bold, and they all get eaten. So, climate change has the potential to short-circuit some of the chemical advantages that have been selected over eons because we’re changing the background against which they work.

PNAS: What was your reaction upon learning that you had won the Gilbert Morgan Smith Medal?

Hay: I was very honored to be recognized by the [National Academy of Sciences] and to be included within such a prestigious group of exceptional scientists.