better at normalizing discussions about mental health — we talked regularly over Zoom about the importance of seeking professional care, taking mental health days, altering expectations, and giving others grace. Nevertheless, almost all of us suffered from significant mental health challenges caused by isolation, fear, and caregiving responsibilities. I still feel completely burnt out, and I know many of my trainees feel the same way; I worry that they weren't given a fair chance to truly launch their careers. Although mental health resources are stretched incredibly thin at the moment, I hope that the pandemic has created an environment where academic institutions can learn to better support faculty and trainees as they experience mental health challenges.

What is the best advice you've been given? One piece of advice stands out as being critically important for my own career. Dr. Mimi Koehl gave a lecture at my institution when I was just starting out on the tenure track, and she spent some of the lecture discussing her experiences in a peer mentoring group. These are informal groups composed of people at the same career stage that meet regularly to discuss issues that arise in both work and life. As discussed in the book *Every Other Tuesday* by Ellen Daniell, participants seek feedback from the group and often commit to specific tasks and report back to the group. After hearing from Dr. Koehl, a bunch of women faculty and staff who attended the lecture used the format described in the book to set up a peer mentoring group, and it was the single most useful thing I did as a junior faculty member. In the peer mentoring meetings, we admitted to each other that we all felt like imposters all the time, but I could see the other women in the group were amazing non-imposter scientists, which made it easier to accept that I, too, was not a complete imposter. And not only did I get great advice on topics like how to improve my teaching evaluations despite gender bias, but I was able to develop a great network of steadfast friends across my institution (and my new adopted city). These women are now the emergency contacts for my kids at childcare!

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Quick guide

Tentacled snakes

Kenneth C. Catania

What is a tentacled snake and what's interesting about them? When it comes to guile and skill at catching prey, tentacled snakes (*Erpeton tentaculatus*; Figure 1, left) hold a special place in the pantheon of predators. They are fully aquatic, living and breeding in freshwater in Thailand, Cambodia, and South Vietnam and they feed exclusively on fish — hence their nickname — 'The Fishing Snake'. But fish are escape artists, with a unique neural circuit and dedicated command neurons that trigger rapid evasive maneuvers, making them challenging and elusive prey. In fact the sophistication of the fish escape circuit has made them an important model system in the neurosciences (see 'Mauthner cells' Quick Guide). Incredibly, tentacled snakes use the fish escape response to their advantage in two different ways.

How do tentacled snakes catch fish? To understand the snake's diabolical trick, we have to understand the fish escape response (Figure 1, right). Fish have sensitive ears that send powerful excitatory signals to a pair of giant neurons called Mauthner neurons — one located on each side of the brain. When a predator strikes toward a fish, the sounds and water movements usually activate the commanding Mauthner neuron on the side of the attack. Within 1 to 2 milliseconds, the command to flee away from the threat is sent, triggering an irrevocable cascade of neural events that propels the fish away from the sound over the next 20 to 30 milliseconds.

The snake's J-shaped hunting posture is more than just a good way to blend in, it's also a trap tailor made (by evolution) to hack into the fish escape circuit. The snake waits patiently and motionless until a fish swims into the concave area between its head and neck. If the fish is roughly parallel to the snake's jaws, milliseconds before striking, the snake moves a part of its neck on the opposite side of the fish triggering the fish escape response in the wrong direction (Figure 2, upper left). Next, the snake's explosive strike begins toward the fish. But the commanding Mauthner cell has already spoken by giving off a single action potential. There is no turning back and the fish swims toward the strike, often straight into the snake's mouth (Figure 2, lower left).

But what happens if the fish approaches the trap at a right angle to the snake's jaws? In this case the fish cannot be made to swim directly into the snake's mouth. Rather, the escape response will turn the fish either to the right or left of the snake's attack. To solve this problem, the snake still feints with its neck, eliciting an escape response in a predictable direction (Figure 2, upper right). Milliseconds later, the snake launches its strike toward the future location of the fish head, where predator and prey soon meet up, as if in a precisely choreographed

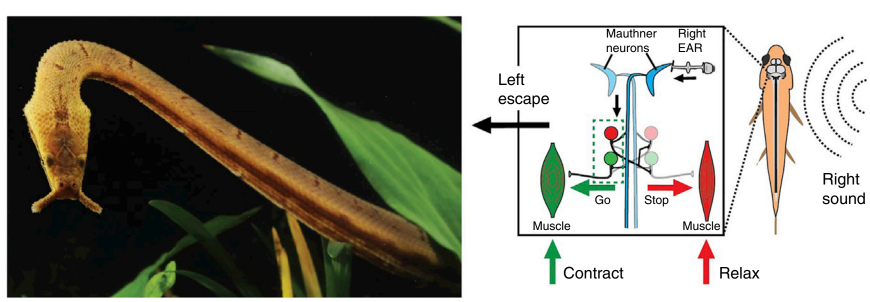

Figure 1. The tentacled snake's challenge.
A tentacled snake waits for a fish in its characteristic J-shaped hunting posture (left). On the right is the (simplified) neural circuit that generates the fish escape response. A sound on the left side usually activates the left Mauthner neuron, which in turn sends a signal (one action potential) across the midline to ultimately activate trunk muscles on the opposite side of the body (green). At the same time, muscles on the same side as the sound (red) are inhibited. As a result, once an escape turn has been initiated the fish cannot change its course. (Figure: © 2010 Kenneth Catania.)

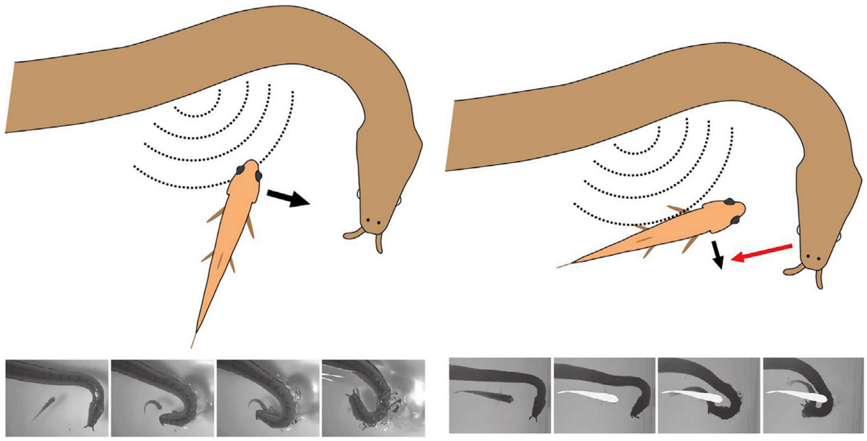

Figure 2. Two different tricks tentacled snakes use to catch fish.
When a fish enters the strike zone parallel to the snake's jaws (left side), the snake generates a water disturbance with its neck muscles, triggering an escape response in the wrong direction. The fish then moves towards the snake's mouth and the snake strikes toward the fish. In the lower left panel, images from video show a fish swimming into the snake's mouth. When a fish enters the strike zone at a right angle to the snake's jaws (right panel), the snake still generates a water disturbance with its neck muscles, triggering an escape response. But in this case the snake aims for the future position of the fish head. The panels on the lower right show a predictive strike. The white mask illustrates the original fish position when the strike began. (Figure: © 2010 Kenneth Catania.)

ballet (Figure 2, lower right). In other words, the snake predicts the future movements of the escaping fish.

Does the snake learn to strike to the future location of a fish, or is the behavior innate? The behavior is innate; newborn tentacled snakes make predictive strikes. The images in the lower right of Figure 2 are from a newborn that had never hunted live fish, yet made predictive strikes. The snake serves as a remarkable example of how closely evolution can tailor a predator to its prey. No doubt the evolution of the snake's strategy depended on the stereotyped form and timing of fish escape responses, and the reliability of the trigger. It takes an escaping fish about 25 milliseconds to bend into a C-shape that kicks off the subsequent swimming. And, it takes about 25 milliseconds for the tentacled snake to reach the fish. Thus in the course of the snake's evolution, these two behaviors have always been pitted, one against the other.

Why haven't fish evolved a defense against tentacled snakes? Tentacled snakes are an example of what Richard Dawkins has called a 'Rare Enemy' that can take advantage of prey behavior that is *usually* adaptive. For fish, with their myriad predators, the best strategy is to swim rapidly away from a perceived threat. It is the unlucky fish that encounters a rare tentacled snake and turns in the wrong direction when attacked. If tentacled snakes become the dominant predator (unlikely), a counter adaptation would be expected. That said, some variability seems to be built into the fish escape response such that they occasionally turn toward a predatory strike and this helps some fish escape from the snake.

What are the tentacles for? The tentacles are scaled appendages with no pores or external sensory organs, but they are densely innervated by two different branches of the trigeminal nerve. Recordings of neuronal activity from the trigeminal fibers show the tentacles to be extremely sensitive mechanoreceptors that respond to slight water movements. Information from the tentacles projects to the snake's optic tectum, together with information from the eyes (Figure 3). The optic tectum is essential for guiding orientation movements, especially in predators tracking prey. Although tentacled snakes have large, sensitive eyes, the tentacles likely provide additional cues to nearby fish location and also allow the snakes to hunt at night and in murky water. Tentacled snakes can catch fish in total darkness (under 940 nm infrared illumination), but their accuracy is much lower than under lighted conditions.

Where can I find out more?

Catania, K.C. (2009). Tentacled snakes turn C-starts to their advantage and predict future prey behavior. Proc. Natl. Acad. Sci. USA *106*, 11183–11187.
Catania, K.C. (2010). Born knowing: tentacled snakes innately predict future prey behavior. PLoS One *5*, e10953.
Catania, K.C., Leitch, D.B., and Gauthier, D. (2010). Function of the appendages in tentacled snakes (Erpeton tentaculatus). J. Exp. Biol. *213*, 359–367.
Catania, K. (2020). Great Adaptations: Star-Nosed Moles, Electric Eels, and Other Tales of Evolution's Mysteries Solved (Princeton: Princeton University Press).
Murphy, J.C. (2010). Secrets of the Snake Charmer: Snakes in the 21st Century (Bloomington: iUniverse).
Sillar, K.T. (2009). Mauthner cells. Curr. Biol. *19*, R353–R355.
Zottoli, S.J., and Faber, D.S. (2000). Review: the Mauthner cell: what has it taught us? The Neuroscientist *6*, 26–38.

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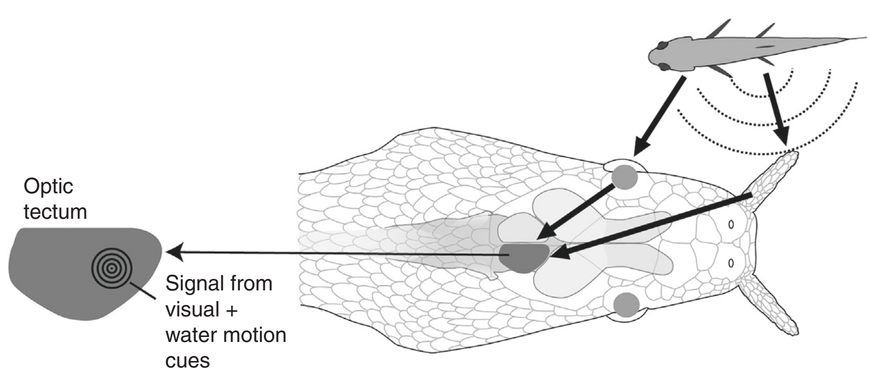

Figure 3. Combining sensory inputs.
Schematic showing the combined information from eyes and tentacles projecting to the snake's optic tectum. (Figure: © 2010 Kenneth Catania.)