PART III

WHAT A FISH FEELS

Your life a sluice of sensation along your sides.

—from “Fish,” by D. H. Lawrence

Pain, Consciousness, and Awareness

Water wetly on fire in the grates of your gills.

—from "Fish," by D. H. Lawrence

Do fishes feel pain? While it may seem obvious to some of us that they do based on their appearance, their behavior, and their membership in the group of vertebrate animals, many people believe otherwise. I am only aware of limited opinion research on this question, such as a survey of North American anglers and other recreational fisheries stakeholders, which found that slightly more believed fishes feel pain than believed they do not, and a survey of New Zealanders that had a similar result.

The question of whether fishes experience pain is of cardinal importance—recall those astronomical numbers of fishes killed by humans, from the prologue. Organisms that can feel pain can suffer, and therefore have an interest in avoiding pain and suffering. Being able to feel pain is not a trifling thing. It requires conscious experience. An organism may move away from a negative stimulus without any experience of pain. It could be a reflexive response in which nerves and muscles cause the body to move without any mental engagement. For example, a heavily sedated human patient in a hospital setting with no capacity to experience pain may nevertheless recoil in response to a potentially harmful stimulus, such as exposure to heat or intense pressure. This is due to the actions of peripheral nerves working independently of the brain. Scientists use the term *nociception* to describe a reflex that in itself involves no awareness or pain. Nociception is the first stage in pain sensing—necessary but not sufficient for the experience of pain. It is only when information from nociceptors is relayed to higher brain centers that it hurts.

There are some good reasons to expect that fishes are sentient. As vertebrates, they have the same basic body plan as mammals, including a backbone, a suite of senses, and a peripheral nervous system governed by a brain. Being able to detect and learn to avoid harmful events is also useful to a fish. Pain alerts animals to potential damage that may lead to impairment or loss of life. Injury or death reduces or eliminates an individual's reproductive potential, which is why natural selection favors the avoidance of these dire outcomes. Pain teaches and motivates animals to avoid a noxious past event.

I have an assignment for you that might provide some insight on the question of whether fishes are consciously aware and thus capable of pain. Go to a public aquarium. Choose a tank. Spend five minutes watching the fishes in there. Look long and hard. Look closely at their eyes. Watch the movements of their fins and their bodies, keeping in mind what you now know about their vision, hearing, smell, and touch. Choose an individual. Does he pay attention to other fishes? Do you see any organization to his movements, or does he appear to be just randomly swimming about as if on autopilot?

If you do this, you will usually see nonrandom patterns of behavior. You'll notice a tendency for fishes to consort with others of their own kind. You will see—especially in larger fishes with more easily watched body parts—that their eyes are not locked into a fixed stare, but swivel in their sockets. If you are especially patient and observant, you'll note idiosyncrasies expressed by individuals. For example, one fish might appear dominant over another, giving chase when the subordinate transgresses some social or physical boundary. Some individuals may be more adventurous, others more shy.

When I was little, I didn't pay much attention when gazing at "fish" in a tank. I wasn't looking at other beings—only at swimming creatures with shapes and colors. Gradually I began to watch fishes more closely, and they became more interesting. Now, when I linger in front of the glass wall that separates two universes of life, I notice that there is pattern and structure to their swimming, and organization to their social lives. Even in a small tank, which is a poor substitute for the complexity of a natural habitat, fishes usually have favored areas to swim or rest in.

Fishes are certainly awake, but are they aware? Being aware involves having experiences, taking notice, remembering things. An aware creature is not merely alive; she has a life. This book contains a lot of science that supports fishes being aware. But sometimes a story conveys it better than any amount of science can. Ana Negrón, a physician friend of mine from Pennsylvania, shared this account with me:

> It was 1989. I was snorkeling leisurely back to the sailboat anchored in the crystal-clear waters off the northeast coast of Puerto Rico when a four-foot-long grouper and I caught sight of each other. He was so close I could almost have reached out and touched him. His entire left side shimmered in the sunlight. I stopped flapping my fins and froze. We both remained immobile, suspended barely a foot under the surface, looking into each other. As I drifted with the current, his large eye moved in its socket, locked to my gaze for perhaps half a minute, which seemed an eternity. I don't remember who moved away first, but as I climbed back on the boat let it be known that a fish and a woman had been aware of each other. Although I have looked into the eyes of whales since, I still feel this fish's presence the strongest.

When I watch what fishes do—swimming through the water, chasing one another, coming to one end of an aquarium to be fed—my common sense emphatically tells me that they are conscious, feeling creatures. It goes against my deepest intuition to think otherwise. But common sense and intuition do not a science make. Let's see what the science says about sentience in fishes.

The Fish Sentience Debate

Two key players in the fish-feel-pain camp are the fish biologists Victoria Braithwaite at Pennsylvania State University and Lynne Sneddon at the University of Liverpool. James Rose, a professor emeritus at the University of Wyoming, denies that fishes feel pain. In 2012 Rose and six colleagues—each with impressive academic credentials—published a paper titled "Can Fish Really Feel Pain?" in the journal *Fish and Fisheries.* The crux of their argument is their belief that fishes are unconscious (meaning unaware of anything, unable to feel, think, even see), and because pain is a purely conscious experience, fishes therefore cannot experience pain. The basis of their claim is what I call *corticocentrism*—the claim that to "possess a humanlike capacity for pain" one must have a neocortex, the cauliflower-like portion of the brain that features ridges and in-foldings. *Neocortex* translates from its Latin roots to mean "new bark," denoting the new layer of gray matter that is thought to be the most recently evolved part of the vertebrate brain. Only the brains of mammals have it.

If the neocortex is the seat of consciousness, and only mammals have one, it follows that all nonmammals lack consciousness. But there is a major snag here. Birds lack a neocortex, yet the evidence for consciousness in birds is virtually universally accepted. The cognitive feats of birds include tool manufacture; remembering for months the locations of thousands of buried objects; categorizing objects according to combined characteristics (such as color and shape); recognizing a neighbor's voice over successive years; using names to call one's chicks back to the nest at sunset; inventive play, such as sliding down snowbanks or car windows; and clever mischief, such as stealing sandwiches and ice-cream cones from unsuspecting tourists. So impressive are the conscious acts of birds that the nomenclature of the proverbial "birdbrain" was overhauled in 2005 to reflect the parallel evolutionary pathway that the avian paleocortex (old bark) has taken—allowing birds to function cognitively at comparable levels with mammals. Birds lay waste to the idea that a creature needs a neocortex to be aware, have experiences, and do clever things. Or feel pain.

If any animal without a neocortex is nevertheless conscious, it disproves the notion that a neocortex is required for consciousness. As such, it is no basis for a claim that fishes are unconscious. "There are many ways to get to a complex awareness," says the neuroscientist Lori Marino of Emory University. "To suggest that fishes cannot feel pain because they don't have sufficient neuroanatomy is like arguing that balloons cannot fly because they don't have wings."

Or that humans cannot swim because they don't have fins.

The fishes' answer to the mammalian cortex is the *pallium*, which is noted for its astonishing diversity and complexity. And while there is less computational power in the average fish pallium than in the average primate neocortex, it is increasingly apparent that the pallium serves functions for fishes that the neocortex does for mammals and the paleocortex for birds. We'll explore these capacities ahead, but for now, let me just mention learning, memory, individual recognition, play, tool use, cooperation, and account keeping.

Returning to the Hook

Let's address the situation in which a fish gets repeatedly hooked in quick succession. "Stories abound of bass that are caught and released, only to turn around and be taken again the same or next day, sometimes more than once," writes fish biologist Keith A. Jones in a book for bass anglers. Some fishermen claim, understandably, that this suggests the experience of being hooked is not traumatic for the fish. Otherwise, why would they so quickly strike bait again? (We might as soon ask why a fish would return repeatedly to the hand of a fisherman to be petted if it couldn't feel anything.)

But "hook shyness" is also a term familiar to most fishermen. There are studies in which long periods of time elapsed before fishes resumed normal activity following capture by hook and line. Carps and pikes avoided bait for up to three years after being hooked just once. A series of tests on largemouth basses showed that they, too, quickly learned to avoid hooks and remained hook-shy for six months.

There are also studies in which fishes resumed what appeared to be normal behavior within minutes of being subjected to invasive procedures such as surgery to implant transponders to track their movements in the wild. I fail to see how this should cast doubt on fish pain. A very hungry fish who is in pain does not cease to be hungry, so the motivation to feed may override the inhibiting effects of traumatic pain.

In a 2014 interview, Culum Brown, who researches fish cognition and behavior in the Department of Biological Sciences at Macquarie University, in Sydney, responded to the repeat-hooking phenomenon:

> They need to eat. There is too much uncertainty in the world to let a meal go by. Many will strike even when they are completely full.… People will often say to me, “but I keep catching the same fish.” Well yeah, if you were starving and someone kept putting a hook in your hamburger (say 1 in every 10 had a hook) what would you do? You keep eating hamburgers because if you don’t you starve to death.

Pain Studies in Trouts

The matter of hook shyness proves little, and scientists and philosophers will likely continue to debate animal consciousness for a long time to come. For probing fish sentience, we would do better to look at scientific studies on fish pain. A substantial body of research exists on the subject, of which I can provide only a small sample in a book of this scope. Among the most meticulous experiments are those performed on rainbow trouts—a representative bony fish—by Braithwaite and Sneddon. Their findings are summarized in Braithwaite’s book *Do Fish Feel Pain?*

The first step in examining the capacity for pain in fishes is to see if they are equipped for it. What sorts of nervous tissue do fishes have, and does it function as we would expect in a sensate animal?

To find out, trouts were deeply and terminally anesthetized (they were knocked out for the duration of the experiment and then killed with an overdose of the anesthetic at the end) and their facial nerves surgically exposed. The trigeminal nerve—the largest of the cranial nerves, which is found in all vertebrates and is responsible for sensation in the face and motor functions such as biting and chewing—was examined and found to contain both A-delta and C fibers. In humans and other mammals these fibers are associated with two types of pain sensation: A-delta fibers signal the sharp initial pain of an injury, whereas C fibers signal the duller, throbbing pain that follows. Interestingly, the researchers found that C fibers were present in a much lower proportion in trouts (about 4 percent) than has been found in other vertebrates studied (50 to 60 percent). This suggests that, in trouts at least, persistent pain following initial injury could be less severe. But the proportion skew may mean little, for, as Lynne Sneddon has pointed out, trout A-delta fibers act in the same way as mammalian C fibers, reacting to a variety of noxious stimuli.

Next, the research team wanted to find out whether noxious stimuli delivered to the trout's skin would activate the trigeminal nerve. This was done by stimulating the trigeminal ganglion, a region where the three sensory branches of the trigeminal nerve converge. Microelectrodes were guided into individual nerve cell bodies in the ganglion, then three kinds of stimuli were applied to receptor areas on the head and face: touch, heat, and chemical (weak acetic acid). All three generated rapid bursts of activity in the trigeminal nerve as registered by electrical signals in the electrodes. Some nerve receptors responded to all three stimulus types, others to one or two. This provided an important clue to the scientists that trouts are equipped to respond to different types of potentially painful events: mechanical injury (like cutting or stabbing), burning, and chemical damage (from acid).

Being equipped to experience pain is a solid foundation for the conclusion that an organism is sentient, but it is not the final word. Even in the face of the evidence accumulated so far, it could still be that the neurons, ganglions, and brains of fishes can only register a negative stimulus in a reflexive way, without any actual sensation of pain.

In the next phase of the experiments, trouts were subjected to one of four treatments: after being netted, then briefly anesthetized, they were either (1) injected in the mouth (just under the skin) with bee venom, (2) injected with vinegar, (3) injected with a neutral saline solution, or (4) similarly handled but not injected. Manipulations 3 and 4 allowed the researchers to cancel out the effects of being handled and injected with a needle. The trouts were then returned to their home tank to be watched from behind a black curtain to avoid disturbing them further. The scientists measured gill beat rates—how quickly the gill covers are opened and closed—a measure known from earlier studies to be a good indicator of distress in fishes.

All of the trouts were clearly distressed by the treatment they received, but not equally across treatments. In the two control groups, gill beats rose from an original resting rate of about 50 beats per minute (bpm) to about 70 bpm. The gill beat rate rose to about 90 bpm in the bee venom and vinegar groups.

All of the trouts had been trained to swim to a ring to be fed whenever a light went on, but following their respective treatments, none approached the ring, even though they had not been fed for a day. (This contrasts with anecdotal observations of hooked fishes returning to the bait following release.) Instead, they rested on their pectoral and tail fins at the bottom of the tank. Some fishes from the bee and vinegar groups also rocked from side to side, and made occasional darting movements. Some of the vinegar-treated fishes also rubbed their snouts against the tank walls or gravel, as if trying to relieve a sting or an itch.

Toward the end of the first hour, control fishes' gill beats returned to normal. By comparison, gill beats of fishes from the bee venom and vinegar groups were still 70 bpm or more at 2 hours after injection, and they didn't return to normal until 3½ hours later. In addition, at 1 hour post-injection, control fishes began to show alertness when the light came on, although they still did not approach the food ring. One hour and 20 minutes after injection, fishes from both control groups were approaching the food ring and taking pellets as they sank through the water. It took nearly three times as long before the bee venom– and vinegar-treated fishes started showing interest in the food ring.

The trouts' negative reactions to the insults were dramatically reduced by the use of a painkiller, morphine. Morphine belongs to a family of drugs called opioids, and fishes are known to have an opioid-responsive system. Their behavior in response to it here is consistent with their experience of relief of pain by the drug.

In separate experiments being conducted at about the same time, the ichthyologist Lilia Chervova at Moscow State University was documenting that nociceptors—the nervous tissue sensitive to noxious stimuli—are widely distributed across the bodies of trouts, cods, and carps. She found that the most sensitivity was located around the eyes, nostrils, tail, and the pectoral and dorsal fins—parts of the body that, like our faces and hands, do most of the sensing and manipulation of objects. Chervova also found that the drug tramadol suppressed sensitivity to electric shocks in a dose-dependent manner: more drug, faster pain relief.

The experiments by Braithwaite, Sneddon, and Chervova are strongly suggestive that fishes are *feeling* pain and not merely responding reflexively to a negative stimulus. But there was still another test worth trying, one that would involve a change in complex behavior requiring higher-order cognitive processes. Recognizing and focusing attention on an unfamiliar object seemed just the ticket, and that is what Sneddon, Braithwaite, and Michael Gentle decided to focus on.

Like most fishes, trouts recognize and actively avoid objects that have been newly introduced into their environment. Knowing this, the researchers built a tower of red LEGO blocks and put it into the fishes' home tanks. When they returned the "control" fishes to their home tanks after they had been handled and injected with saline into their lips, these fishes actively avoided the tower, whereas fishes injected with vinegar regularly wandered near the tower. The vinegar appeared to impair trouts' ability to perform a higher-order cognitive behavior—awareness and avoidance of a novel object. The research team conjectured that the pain of vinegar so distracted the afflicted trouts that they were unable to perform normal survival behaviors.

In an attempt to further verify this "distraction" hypothesis, fishes in both treatment groups were injected with morphine following the injection of saline or vinegar. This time, fishes in both treatment groups—saline-then-morphine, or vinegar-then-morphine—avoided the LEGO tower.

Other Studies of Fish Sentience

The experiments I've summarized are not the final word on the matter of fish pain. There are other angles to assessing how fishes respond to what we regard as painful. One of the expectations of a consciously experienced pain as opposed to an unconscious, reflexive reaction to nasty stimuli is a variable or nuanced response. One way to test for this is to vary the intensity of the stimulus. For example, paradise fishes responded to low-level electric shocks by swimming about more actively, as if trying to find an escape route. In contrast, higher-intensity shocks led to retreat from the shock source, and defensive behaviors.

A different approach is to vary the behavioral state of a fish at the time of the stimulus. In a study using 132 zebrafishes, responses to an injection of acetic acid into the tail varied according to whether or not the fishes were frightened before the injection. When injected only, zebrafishes swam erratically and beat their tails in a peculiar manner that did not produce propulsion. However, when they were pre-exposed to the alarm pheromone of another zebrafish, they behaved as zebrafishes normally do when confronted with something new or scary: they either froze in one place or swam near the bottom. They did not swim erratically or beat their tails. The difference suggests that the fishes' fear suppressed or overrode their pain—a phenomenon well known in humans and other mammals. It is an adaptive response because fleeing a dangerous situation that could end in death takes priority over stopping to tend to a wound.

Lynne Sneddon used what I consider to be a most convincing way to examine pain in zebrafishes: she asked if they were willing to pay a cost to get pain relief. Like most captive animals, fishes like stimulation. For instance, zebrafishes prefer to swim in an enriched chamber with vegetation and objects to explore rather than in a barren chamber in the same tank. When Sneddon injected zebrafishes with acetic acid, this preference didn't change; nor did it change for other zebrafishes injected with saline water (which causes only brief pain). However, if a painkiller was dissolved in the barren, unpreferred chamber of the tank, the fishes injected with the acid chose to swim in the unfavorable, barren chamber. The saline-injected fishes remained in the enriched side of the tank. Thus, zebrafishes will pay a cost in return for gaining some relief from their pain.

When Janicke Nordgreen from the Norwegian School of Veterinary Science and Joseph Garner, now at Stanford University, presented a different method for evaluating pain in goldfishes, it yielded a surprising result. They attached small foil heaters to sixteen goldfishes and slowly increased the temperature. (I was somewhat relieved to read that the apparatus was fitted with sensors and safeguards that shut off the heaters to prevent severe burns.) Half of the goldfishes were injected with morphine; the others received saline. The authors believed that if goldfishes feel the pain of heat, then the morphine-treated fishes would be able to withstand higher temperatures before reacting to it.

Not so. Both groups of fishes showed an appropriate pain response: they began to "wriggle," and it happened at about the same temperature. However, checking on the goldfishes thirty minutes or more after they had been returned to their home tanks, the researchers noticed that those from each group were exhibiting different behaviors. Morphine-treated fishes swam about as they normally would, whereas the saline-treated ones showed more escape responses, including so-called "C-starts" (moving the head and tail toward the same side of the body, forming a "C"), swimming, and tail-flicking (flicking the tail without sideways movements of the head or trunk region).

Garner and Nordgreen's study is evidence that a fish can feel both initial, sharp pain and the lasting pain that follows. The response can be likened to our reaction to putting our hand on a hot stove. First, we have an immediate, reflexive response: we involuntarily jerk our hand away from the heat without pausing to think about it. It is only a second or so later that we feel the true brunt of the pain. Then we may endure hours or days of discomfort while our bodies protect the offended limb and remind us not to do it again! This result suggests to me that goldfishes might have more of those C fibers—the ones associated with lasting, throbbing pain—that trouts were found to have in short supply.

Toward Scientific Consensus

The weight of evidence for fish pain is strong enough today that it has the support of venerable institutions—among them, the American Veterinary Medical Association, whose 2013 Guidelines for the Euthanasia of Animals state:

> Suggestions that finfish [fish that are not shellfish] responses to pain merely represent simple reflexes have been refuted by studies demonstrating forebrain and midbrain electrical activity in response to stimulation and differing with type of nociceptor stimulation. Learning and memory consolidation in trials where finfish are taught to avoid noxious stimuli have moved the issue of finfish cognition and sentience forward to the point where the preponderance of accumulated evidence supports the position that finfish should be accorded the same considerations as terrestrial vertebrates in regard to relief from pain.

In 2012 an august group of scientists met at Cambridge University to discuss the current scientific understanding of animal consciousness. After a day of discussion, a Declaration on Consciousness was drafted and signed. Among its conclusions:

> Neural circuits supporting behavioral/electrophysiological states of attentiveness, sleep and decision making appear to have arisen in evolution as early as the invertebrate radiation, being evident in insects and cephalopod mollusks (e.g., octopus).

Translation: consciousness needn't require having a backbone. Furthermore:

> The neural substrates of emotions do not appear to be confined to cortical structures. In fact, subcortical neural networks aroused during affective states in humans are also critically important for generating emotional behaviors in animals.

Translation: emotions also derive from parts of the brain outside the cortex. And:

> The absence of a neocortex does not appear to preclude an organism from experiencing affective states.

Translation: you don't need a big, convoluted humanlike brain to feel excited about food or scared of predators.

* * *

Now you may be thinking: Bravo, you clever scientists, for coming up with a new way to demonstrate that you are the last ones to recognize what common sense already told us is patently obvious. As the psychologist and author Gay Bradshaw declared: "This is not news, it's Science 101." But it also speaks to the challenge of accepting a phenomenon (consciousness) that is fundamentally private, and to the historical reluctance of science to fully embrace it in anything other than a human.

Fishes show the hallmarks of pain both physiologically and behaviorally. They possess the specialized nerve fibers that mammals and birds use to detect noxious stimuli. They can learn to avoid electric shocks and anglers' hooks. They are cognitively impaired when subjected to nasty insults to their bodies, and this impairment can be reversed if they are provided with pain relief.

Does this close the book on the debate over pain and consciousness in fishes? Not likely. There may always be those who use the crutch of uncertainty to assert that fishes are pain-free. Even if the evidence for the few fish species studied is accepted as true pain, one can still claim that we just don't know for the myriad other fish species fortunate not to have been subjected to scalpels, syringes, or small foil heaters.

Not only is scientific consensus squarely behind consciousness and pain in fishes, consciousness probably evolved first in fishes. Why? Because fishes were the first vertebrates, because they had been evolving for well over 100 million years before the ancestors of today's mammals and birds set foot on land, and because those ancestors would have greatly benefited from having some modicum of wherewithal by the time they started colonizing such dramatically new terrain. Also, it is likely that fishes' ancestors evolved consciousness because fishes today have abilities that are consistent with their being conscious and sentient. As we will discover, fishes use their brains to achieve some quite useful outcomes.