From Stress to Joy

> The fish's face is one of its notoriously weak features. Even allowing for the fact that it was the first real face ever attempted, little more can be said for it than that the mouth, nose, eyes, and forehead—if such it can be called—are in the proper order. It is of no use for frowning or smiling; if the fish could do these things, it would receive a great deal more sympathy than it does.
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> —Brian Curtis, *The Life Story of the Fish*

A woman shared with me a tale of two fishes. In late 2009 she bought a five-gallon tank and three small goldfishes, an oranda, a black moor, and a ryukin/fantail. Like many novice aquarists, Lori knew little about how to care for fishes, and she purchased and lost several goldfishes over the ensuing months. But the original fantail and black moor continued to survive. Lori named the fantail "Seabiscuit" and her husband named the black moor "Blackie."

Lori came home for lunch one day and found, to her horror, Blackie trapped inside a decorative pagoda she had placed in the tank as extra stimulation for her fishes. Struggling to get out, Blackie was bumping repeatedly against the walls and windows of his plastic prison. He looked weak.

Meanwhile, Seabiscuit was darting frantically at Blackie in what Lori took to be an effort to free him from the pagoda. Seabiscuit repeatedly charged at Blackie as though trying to budge him loose. Gingerly, Lori reached for the pagoda, and as gently as possible managed to work Blackie loose with her fingers. He was in poor shape. He had rubbed off all the scales and velvety finish on one side, and his right eye was swollen and raw. He hung listlessly at the bottom of the tank, barely moving. Lori didn't think he would survive.

For the next few days Seabiscuit stayed protectively by Blackie's side, and the little black moor recovered. His eye healed, and a new set of scales gradually grew back on his damaged side.

From that point on, Lori noticed a distinct change in the relationship between Blackie and Seabiscuit, and in her own view of them: "Prior to the pagoda incident, Seabiscuit had been bossy, often chasing Blackie aggressively, but this behavior stopped. I began to perceive fishes as individuals with feelings and personalities."

She moved them into a twenty-gallon tank with a big filter and minimal furnishings. Blackie died in June 2015, age six, apparently due to a faulty filter. Seabiscuit is "hanging in there," with a newer goldfish companion named Too Much, who was rescued from a school carnival.

A separate account, published in a South African newspaper twenty-five years earlier, has uncanny parallels to Lori's. It involved a severely deformed black moor goldfish named—you guessed it—Blackie, who could barely swim. When Blackie was transferred into a tank containing a larger oranda goldfish named Big Red, Big Red took an immediate interest in his disabled tankmate. He also began to provide assistance by placing himself just beneath Blackie. Together they would swim around the tank as a tandem, Big Red providing the propulsion that aided Blackie's mobility and access to food after it was sprinkled on the surface. The pet store owner attributed Big Red's behavior to compassion.

Emotional Hardware

Stories like Lori's and the South African pet store owner's don't carry much scientific weight because they are isolated, anecdotal observations, and behaviors and the emotions that underlie them are notoriously difficult to interpret. For instance, how are we to know that Seabiscuit wasn't attacking Blackie in the pagoda out of fear or stress? For me, the lasting change in the two fishes' relationship afterward is the more telling observation. It suggests that Blackie's mishap was a significant event, and that it brought them closer.

Putting anecdotes aside, what does the science say about fish emotions? A good place to start is the hardware in fishes' brains and bodies.

Emotions involve relatively old brain circuits conserved through evolution and shared by all vertebrates. As we saw in the previous section, you don't need a big brain with a neocortex to feel petrified or pissed off. A growing cadre of experts believes emotions originated alongside consciousness. Reacting is sometimes better than thinking. Imagine you are a early marine creature suddenly confronted by a predator. If you have to think to yourself, "Gee, I better get out of here," you will soon be someone's meal. It is more useful to immediately flee in terror and leave the thinking for later.

Emotions are closely linked to hormones—compounds produced by our glands that affect physiology and behavior. How the brain produces hormonal patterns—the so-called neuroendocrine response—is known to be virtually identical in bony fishes and in mammals. The inference is that these patterns might play out similarly in the conscious, emotional realm—that is, the psychoneuroendocrinology of these two groups might also be similar.

Oxytocin provides an example of these parallels. Also known as the "love drug," oxytocin is associated with bonding, orgasm, labor contractions, nursing, and the feeling of falling in love. Researchers from McMaster University in Hamilton, Canada, have discovered that the fish version of this same hormone, *isotocin*, also regulates behavior in different social settings. When adult male daffodil cichlids were injected with either isotocin or a saline solution, the saline-treated controls showed no discernible behavioral changes. In contrast, isotocin-treated fishes became more emotional. They were more aggressive toward a larger perceived rival when placed in a simulated competition over territory. Surprisingly, mid-ranking cichlids injected with isotocin showed submissive behavior toward other members of their shoal. The authors speculate that the submissive response ensures these highly social fishes—which are cooperative child-rearers—remain a cohesive, more stable group. It may not be love (as far as we know), but it is a nice and friendly response.

Another way to investigate fish emotions is to look for parallels with mammals and birds by subjecting their brains to similar insults and comparing the results. One target of such comparisons is the amygdala—a pair of almond-shaped structures making up part of the brain's ancient limbic system. In mammals, the amygdala helps drive emotional reactions, memory, and decision making. The medial pallium of a fish's brain appears to perform the role of the amygdala. When this region is either disabled (by cutting off its nerve supply) or electrically stimulated, changes in aggression occur that mirror those seen in land-dwelling animals subjected to analogous treatment. Studies on goldfishes have also shown that the medial pallium is involved in an emotional response to a fearful stimulus.

How do fishes show fear? For instance, how do they react when attacked by a predator? They respond as we might expect them to if they are feeling afraid. In addition to breathing faster and releasing alarm pheromones, they show classical behaviors shown by land animals when scared: they may flee, freeze, try to look bigger, or change color. For some time afterward they also stop feeding, and avoid the area where the attack occurred.

Might a fish become more relaxed when exposed to drugs that have an anxiety-melting effect on us? Oxazepam is one such drug—used extensively by human patients for the treatment of anxiety and insomnia, and for the control of alcohol withdrawal symptoms. When researchers led by Jonatan Klaminder at Umeå University in Sweden caught wild Eurasian perches and exposed them to oxazepam, the fishes were more active and showed better chances of survival. Increased activity might seem a surprising response to a drug that relaxes people, but the fishes' response is actually consistent with a relaxing effect: tranquil fishes are less afraid to explore their surroundings. In this state, the treated fishes spent less time clustered with their allies and more time foraging, which might also explain their improved survival rate in a captive setting free of predators.

Being relaxed is all well and good if you're in a safe environment, but fear evolved for good reason: it motivates us to flee and hide from danger. Fishes are capable social learners, readily learning to fear something simply by observing the reactions of others of their kind. For example, naive fathead minnows who were initially unafraid of unfamiliar predators swimming on the other side of a glass barrier soon learned to avoid those predators by watching the fearful reactions of experienced minnows.

Fathead minnows also learn to avoid predators when exposed to schreckstoff from other fathead minnows (recall the fishes' alarm pheromone from our discussion of smell). Do they treat these odor-based clues to lurking danger as seriously as they do visual clues? Apparently not. Scientists from the University of Saskatchewan trained fishes that an unfamiliar odor was "safe" because it never led to negative consequences. In fact, the odor was from pike, a dangerous predator of minnows, but the minnows used in this study were collected from a pond where pikes do not occur, and so were presumed ignorant of pike odor and its implications. A group of control minnows received the same training regimen, only with blank water (no pike odor). On testing day, minnows from both training groups were exposed individually to pike odor paired with either (1) fathead minnow schreckstoff, or (2) a knowledgeable and therefore frightened "model" fathead minnow responding to the risky pike odor. Minnows who had no prior exposure to pike odor responded equivalently to the alarm pheromone or the fright reaction of a model minnow. However, minnows taught to believe that pike odor was "safe" showed little response to the alarm pheromone, whereas they showed characteristic fear behavior (moving and foraging less, taking shelter) in response to their fellow fearful fathead.

So, for a fathead minnow, at least, the sight of fear is more persuasive than the smell of fear. The study also supports the idea that, when it comes to predation risk, minnows trust other minnows more than themselves. It is better to heed a threat that turns out to be benign than to ignore a threat that turns out to be real. Or, as the old saying goes: Better safe than sorry.

Stress Relief

Being able to remove oneself from fearful situations is not only important to survival, it favors long-term health. It is well known from unsettling studies of rats, dogs, monkeys, and other species—and indeed, from human victims of war and other prolonged hardships—that unrelieved stress can lead to all sorts of problems, including anxiety, depression, and lowered immunity.

One of our bodies' responses to stress is to release cortisol. This so-called stress hormone acts to regulate stress, and it performs this function in other vertebrates, including fishes.

A team of scientists from the Max Planck Institute of Neurobiology and the University of California studied genetically manipulated zebrafishes with a cortisol deficit. These fishes suffered from consistently high levels of stress, and they showed signs of depression in behavioral tests. When normal zebrafishes are placed in new surroundings they act withdrawn and swim around hesitantly in the first few minutes. But curiosity soon prevails and they begin to investigate their new tank. In contrast, the mutant fishes showed great difficulty becoming accustomed to their new situation, and they had a particularly strong reaction to being alone: they sank to the bottom of the tank and stayed completely still.

The fishes' behavior returned to normal when either of two drugs—diazepam (Valium), an antianxiety drug, or fluoxetine (Prozac), an antidepressant—was added to the water. Social interactions, consisting of visual interaction with other zebrafishes through the aquarium wall, also helped alleviate depressive behavior in the mutant individuals.

If fishes can be vulnerable to depression and anxiety, might they also take an active role in relieving it? Do fishes seek ways to chill out? A 2011 headline, "Calm Down, Dear, I'll Rub Your Fins," describes such a thing. Surmising that the caresses that reef fishes receive from cleanerfishes might heighten pleasure and relieve stress, a research team led by Marta Soares at the Higher Institute of Applied Psychology (ISPA) in Lisbon designed an experiment to test the idea.

They caught thirty-two striated surgeonfishes from a region of Australia's Great Barrier Reef. Once they were accustomed to captivity, the fishes were randomly assigned to either a stressed or nonstressed group. The unfortunate ones assigned to the stressed group were confined for thirty minutes in a bucket with water just deep enough to cover their bodies. This treatment had the intended effect of significantly raising their blood cortisol—a standard measure of stress. Then, stressed and unstressed fishes were individually placed for two one-hour sessions in a separate tank with a handmade, look-alike model of a cleanerfish. The shape and colors of the model closely mimicked a cleaner wrasse, a reef fish that makes a living by providing a cleaning service to customers such as surgeonfishes. In half of the tanks the model was stationary; in the other half, the model was mechanically rigged to move in a gentle sweeping motion.

Stressed surgeonfishes were drawn to the mobile model like kids to candy. They swam over to the false cleanerfish and leaned their bodies right up against it. But they did this only if it was the one that could stroke them. They averaged fifteen separate visits to the mobile model, compared to zero visits to the stationary model. The strokes from the model also brought stress relief, as measured by cortisol levels that dropped when fishes (from both stressed and unstressed groups) had access to a moving cleanerfish model compared to stationary models. Cortisol also dropped in proportion to the time spent in contact with the moving models.

With the characteristic reserve of a scientist, Marta Soares concluded: "We know that fish experience pain, [so] maybe fish have pleasure, too."

Despite the cutesy tone of the media report about fishes rubbing each other's fins, this is not science lite. It unveils important implications about social living, and having a quality of life. It supports the idea that pleasure motivates fishes to visit cleanerfishes, because the moving models were not removing parasites or anything else, yet the surgeonfishes still went to them repeatedly.

Pleasure evolved to reward "good" behaviors that promote flourishing of the individual and perpetuation of its genes; hence, the good feelings we know that come from eating food, playing, staying comfortable, and having sex. Until recently it was considered unscientific to even speculate on how fishes might be feeling emotionally. For this reason most of the discussion has been restricted to the physiology of so-called reward systems. An elegantly simple scientific definition of a reward is anything for which an animal will work.

In mammals, the dopamine system is a key player in the physiology of reward. When rats play, their brains release large amounts of dopamine and opiates, and when they (or we) are given drugs that block the receptors for these chemicals, they lose their attraction for sweet foods they normally enjoy. Fishes also have a dopamine system. If you give a goldfish a compound that stimulates the release of dopamine from his brain—such as amphetamine or apomorphine—the goldfish engages in rewarding behavior: he wants more of the compound. Goldfishes plied with amphetamine prefer to swim in a chamber treated with amphetamine, whereas goldfishes exposed to pentobarbital, a pleasure-squasher, learn to avoid it. Amphetamine produces a rewarding effect in monkeys, rats, and humans, and this happens by increasing the availability of dopamine receptors in the central reward system. Since the goldfish brain has cells containing dopamine, the same mechanism is thought to be responsible for amphetamine's rewarding effects on goldfishes. Like some mammals, fishes are prone to abusing amphetamine and cocaine, unable to resist them when they are freely available. But in the case of those surgeonfishes sidling up to mobile cleanerfish models to get stroked, there is no addiction—just a fish responding to a desire for a pleasurable, therapeutic massage.*

Games Fishes Play

If you've won a prize, made a basket from the three-point zone, or seen a toddler squealing with delight while being playfully chased by a parent, then you know joy. One type of behavior that is joy-inducing is play. Play is useful, especially to young animals who need to develop physical strength and coordination, and to learn important survival and social skills. Play also has a psychological element: it is fun. Scientists have been exploring animal play for a good while; the German philosopher Karl Groos published *The Play of Animals* in 1898.

Animal play is not easily studied. It is a spontaneous activity and the participants generally need to be feeling relaxed or happy to engage in it. Most observations of animal play are serendipitous.

That is no barrier to Gordon M. Burghardt, an ethologist at the University of Tennessee with a striking physical resemblance to Charles Darwin. In a career spanning nearly six decades and hundreds of scientific papers, Burghardt has not shied away from provocative topics, and that includes animal play where you might not expect to find it—or, what he describes on his website as "play behavior in 'non-playing' taxa."

In 2005 Burghardt published the most comprehensive exploration of animal play to date. The cover of *The Genesis of Animal Play* features a tropical fish, a captive male white-spotted cichlid, pushing a submersible thermometer with his nose. Burghardt and two colleagues, Vladimir Dinets and James B. Murphy, have since published a study of three male white-spotted cichlids interacting with this thermometer—a 4.5-inch glass tube with a weight at the bottom causing it to float vertically. Over the course of twelve sessions, the team recorded more than 1,400 instances of the thermometer being nudged by the three fishes, who were placed individually in the tank for each session.

Each fish had his own style. Fish 1 mainly “attacked” the top of the thermometer, causing it to wobble before returning to a vertical position. Fish 2 also liked to swirl around the thermometer, making contacts as he went. Fish 3 batted the object either from the bottom, the midsection, or the top. His hits were the most intense, causing the thermometer to bob about the tank and sometimes get stuck in a corner. Collisions between thermometer and the glass walls were loud enough to be heard from the adjoining room.

Is it play? According to Burghardt, it is play if:

1. it does not achieve any clear survival purpose, such as mating, feeding, or fighting;
2. it is voluntary, spontaneous, or rewarding;
3. it differs from typical functional behaviors (sexual, territorial, predatory, defensive, foraging) in form, target, or timing;
4. it is repeated but not neurotic; and
5. it takes place only in the absence of stressors, such as hunger, disease, crowding, or predation.

The cichlids’ behavior fit all of these criteria. White-spotted cichlids are not predatory, and the attacks they made on the thermometer did not resemble normal feeding behavior. The availability or absence of food had no consistent effect on their cavorting with the thermometer. The possibility of sexual behavior was also ruled out. The cichlids’ interactions with the thermometer resembled their quick jabs at rivals, but were more repetitive —rather like a boxer practicing on a bag—and were engaged in only when the fishes were alone, unstressed, and perhaps understimulated.

Given that the observation tank had other objects in it, including sticks, vegetation, and pebbles, why were these fishes especially attracted to the thermometer? The authors surmise that it might have been the reactive quality of an object that bounces back after being knocked, just like those old life-size inflatable clown toys weighted at the bottom to spring back upright whenever you hit them. Ethologists try to assume the animal’s own perspective. Burghardt interprets the bouncing back as “a simulated counterattack by an opponent that was never successful.”

This is an example of object play. When two individuals interact playfully, biologists call it social play. Here’s an example, courtesy of a former animal shelter worker based in Virginia. She had once shared a house with her husband, several cats, and a banded cichlid kept alone in a tank. The fish developed a sport with the cats, who would occasionally tiptoe over the bookshelves to drink from “his” aquarium. The territorial cichlid would lie in wait for the appearance of one of these furry invaders, hiding under the cover of some reeds in the corner of his tank. Experience had taught the cats to peer into the depths for any sign of an ambush, but the fish knew that and stayed quiet as a mouse. Only when the cat’s tongue descended did he burst into action, propelling himself up through the reeds like a torpedo, hell-bent on taking a chunk out of that raspy organ. If she sensed the underwater eruption, the cat might get her first lap in before tongue and fish met.

In time, the participants in this cat-and-fish game of wits showed signs that it was a welcome diversion from their quiet indoor lives. No blood was ever drawn on either side, but the cats would sometimes come right back—with a cocked head and sly eyes—to play the game again.

That is not just social play, it is interspecies social play.

A third variation on play is solitary play. In 2006, a German speech therapist named Alexandra Reichle witnessed an example of solitary play during a visit to an art exhibition at the House of Art in Stuttgart. She describes the exhibit, titled *Kunst Lebt* (Art Lives), as a fantastic mixture with hidden treasures from all museums of the country. It included a large aquarium (an exhibit from the State Museum of Natural History in Karlsruhe) of about 130 cubic feet holding an exquisite collection of colorful and exotic fishes.

As a fish lover, Alexandra spent a long time watching the goings-on behind the glass. She soon discovered a small, graceful, almond-shaped fish dressed in plush mauve with yellow and electric-blue highlights. (She later identified it as a purple queen anthias, a native of Asian seas.) This one seemed to have a destination. She would swim in one direction along the bottom, then, on reaching the end of the tank, she swerved upward and swam to the surface. Arriving there, she was met by the current of a water pump, pushing the little traveler like a rocket back to the other side. There, she descended back to the bottom and started her circuit all over. Reichle shared with me, “The funny thing is, I would call myself rather a pessimistic person and the first thing I would think is that this is a stereotypy (a functionless, repetitive, neurotic behavior) due to the confinement. But this little fish actually seemed to have a lot of fun.”

I asked her why she thought it was fun. “While most of the other fishes were just swimming about with no particular destination, this one looked so determined to have fun. I wanted to tell the others to follow her and enjoy her wild ride on the man-made current.”

It is not an isolated account. Burghardt has watched marine fishes in a very tall columnar aquarium repeatedly “riding” bubbles from an air stone at the bottom of the tank to the top. He thinks that this might be fun for the fishes, as it would be for us.

Jumping for Joy?

If bubble riding is fun for a fish, might they also jump for joy? If you’ve spent any amount of time boating, fishing, or bird-watching at lakes and rivers, you have most likely seen fishes jumping out of the water. I have seen it many times. The law of averages dictates that it usually happens when I’m looking in another direction, and my eyes arrive at the action just in time to see a splash. Occasionally, I’m lucky enough to see the fish itself, and I’ve seen foot-long fishes and tiny inch-long ones leaping body lengths clear of the water.

Certainly, fishes will exit water in desperate attempts to escape predators. Dolphins exploit the behavior, forming a circle and catching the panicked fishes in midair. But just as we may sprint from fun or from fear, different emotions might motivate fishes to jump. Mobula rays aren’t motivated by fear when they hurl their large bodies (up to a seventeen-foot wingspan and a ton in weight) skyward in leaps of up to ten feet before splashing down with a loud slap. There are ten recognized species of mobula rays and their aerial stunts have earned them the nickname “flying mobulas.” They do it in schools of hundreds. Most of their leaps are calculated to land them on their bellies, but sometimes they do a forward somersault, landing on their backs. Males seem to be the initiators, so some speculate that there might be a courtship role. Other scientists think it might be a parasite removal strategy. Whatever its function, I posit that the rays are enjoying themselves.

While kayaking in the crystal waters of Florida's Chassahowitzka National Wildlife Refuge, I watched several schools of fifty or more mullets moving in graceful formation. Mullets are as beautiful as they are common here. Their cream-colored tail margins and rear fins, and the yellow-tinged border between their metallic backs and white bellies were most evident when they leaped from the water, a behavior mullets are known for. Most of the time I saw one or two successive leaps by a fish, but one made a series of seven. Each jump was about a foot clear of the water and two to three feet in length.

There are eighty species of mullets worldwide, and nobody knows for sure why they leap. They usually land on their sides, prompting theories that they are trying to displace skin parasites. Another idea is that they do it to inhale oxygen. The so-called *aerial respiration hypothesis* is supported by the fact that mullets leap more when the water is lower in oxygen, but is undermined by the likelihood that jumping costs more energy than is gained by gulping air.

Might these fishes also be leaping for fun—a sort of fish play? Gordon M. Burghardt published accounts of a dozen types of fishes leaping and somersaulting repeatedly, sometimes over floating objects—sticks, reeds, sunning turtles, even a dead fish!—for no clear reason other than entertainment.

So far, nobody has subjected this intriguing possibility to scientific experiment. Maybe someone ought to catch a few smart fishes, put them in a lush tank with all the amenities (including romantic music and a mechanical cleanerfish model), then give them floating objects to jump over.

Half a Bathing Suit

Let me share with you a little story of a feeling we all know well. It's the feeling we get when we pass an accident scene, are handed a wrapped gift, or overhear an argument in a restaurant. It's what we call curiosity.

A scientist from Alaska told me about an encounter with curious fishes during a honeymoon swim at a vacant beach in Jamaica. She and her husband were snorkeling along a reef. An excellent swimmer, the husband discovered to his dismay that his bride was unable to dive below the surface. After his efforts to instruct her on how to dive failed, he tried a more drastic ploy:

> With considerable effort, he pulled half of my swimsuit off of me, then swam down and hooked it to a coral branch about fifteen feet below. Surely I would have motivation to retrieve it, he told me with a laugh.
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> Not a nudist by nature, I was quite upset even though we were apparently alone. I tried repeatedly to dive down to get it, but to no avail. All of this frantic activity had an unexpected effect on the local reef fishes. Rather than retreating, they began to gather around us. Then I noticed that Bob was also affected, um, in a very personal way. He swam over to me, and made every effort to fulfill his manly urges. Alas, my own buoyancy prevented any successful conclusion to such efforts. We were amazed, however, at the reaction of the fish. Tiny little blue fish, angelfish, a rainbow of colors, shapes and sizes of reef life, formed a complete circle around us, facing us, watching. Their bodies and tails quivered, causing them to look like a unified, shimmering mass.

The husband finally took pity on her and retrieved the swimsuit. As the passion of the moment subsided, the fishes lost interest and the circle dispersed. That two humans who were making a fumbling attempt to perform an act that puts us all on the same plane were surrounded by shoals of attentive fishes continues to intrigue her; she still wonders what the fishes were thinking, and whether they were feeling the energy generated by the humans’ amorous venture.

Given fishes’ sensitivity to sensory cues in their aqueous medium, several theories might explain what made voyeurs out of these fishes. As visually oriented creatures, our first inclination is to assume they were drawn to the young lovers’ movements. But perhaps there was something about the electrical field or the body chemistry of the two humans that aroused their curiosity. Then again, maybe it wasn’t benign curiosity the fishes were feeling, but unease as they monitored the intentions of a pair of potential predators. That, too, might be viewed as curiosity, especially as these were not familiar intruders.

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When a fish takes notice of us, we enter the conscious world of another being. There is something exhilarating about that. For sure, studying fish emotions is a challenging scientific endeavor. But as we have seen, there are techniques to probe fish feelings, and the accumulating evidence indicates a range of emotions in at least some fishes, including fear, stress, playfulness, joy, and curiosity.

Exploring how and what fishes think is less fraught with challenges than trying to study what they feel. As we’ll see, the field of fish cognition has a lot to show for it.