SCIENCE

An Ancient Genetic Quirk Could Doom Whales Today

After losing an unnecessary gene millions of years ago, marine mammals are now uniquely vulnerable to pesticides that have only existed for a century.

By Ed Yong

A humpback whale (Kerstin Meyer / Getty)

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Over the past 50 million years, a group of small, hoofed mammals gradually evolved into today's whales and dolphins. In the process, they gained much: a watery, planet-wide habitat and bountiful sources of food. But they lost a lot, too. Surrounded by endless blue, they became color-blind. Immersed in water, their sense of smell disappeared. And for some reason, they lost a gene called PON1.

PON1 helps humans and other mammals process fatty acids and cholesterol, but whales—and other marine mammals like manatees and seals—seem to have lost the need for it. For most of their existence, the gene's absence was inconsequential.

Not anymore.

In the 1940s, humans started intensively studying a new class of chemicals called organophosphates, which attack the nervous systems of animals. Researchers harnessed these substances to create chemical weapons like sarin gas, and insecticides like chlorpyrifos. Today, organophosphates are widely used as pesticides, and they occasionally become environmental pollutants. And as it happens, our main defense against these chemicals is a gene that can break them down—PON1, the same gene that whales have lost.

For millions of years, the loss of PON1 was just another quirk of evolution. Now it's a tragic vulnerability. It means that whales and other marine mammals are uniquely susceptible to toxins that have only existed for a few decades. "It's a bit of a strange coincidence," says Nathan Clark from the University of Pittsburgh.

happens when mammals adapt to a life at sea. Many groups have independently made that transition: Hoofed relatives of deer and hippos gave rise to whales and dolphins; bulky cousins of elephants gave rise to manatees; and meat-eating relations of bears gave rise to seals and sea lions. These changes all happened independently, but the sea-going species all evolved streamlined bodies and flipper-like limbs. And as their physiques converged, so did their genes. Every time mammals adapted to the oceans, hundreds of genes began evolving at a quicker pace, and others at a slower one. And some genes were repeatedly broken.

Clark's colleague Wynn Meyer scanned the genomes of 58 mammals in search of genes that look much the same in land-living species, but have repeatedly accumulated disabling mutations in the marine lineages. She found several, most of which are involved in smell—the sense that marine mammals lack. But sitting at the very top of the list was a gene with no connection to smell at all—PON1. "We definitely weren't expecting that," Meyer says.

PON1 acts as an antioxidant. It breaks down fatty acids that have reacted with oxygen molecules, and that lead to inflammation and heart disease if they're allowed to build up. It's clearly important—so why should mammals lose it every time they evolve for a seagoing existence?

The team doesn't know, but they have a guess, and it involves the deep breaths of diving mammals. "They're packing their bodies full of oxygen and going underwater for up to an hour," Clark says. "They then completely deplete that oxygen before going back up and reperfusing themselves." Whales can tolerate those fluctuations, but humans can't. Even if we didn't suffocate, we'd flood our bodies with unstable oxygen molecules that would royally mess up our cells.

Diving whales and seals adapted to this challenge by mass-producing enzymes that mop up the oxygen molecules before they do much damage. And perhaps, after the conscription of these new biochemical guardians, "PON1 got left by the wayside," Meyer says. "Maybe other proteins took on the job that PON1 used to do." When the gene started to deteriorate, its oceangoing owners didn't notice, because they had other antioxidants at play. "It makes sense from an evolutionary perspective," says José Pablo Vázquez-Medina from UC Berkeley, who was not involved in the study.

Whatever the reason, the result is clear. As far as we know, every mammal that lives on land has a working copy of PON1. But whales, manatees, and seals all independently broke their versions of the gene between 21 and 64 million years ago. Even partially aquatic mammals, like the beaver and sea otter, have lost PON1. And in the modern era of organophosphates, that loss could take a newfound toll.

By coincidence, the same chemical reaction that allows PON1 to break oxidized fatty acids also allows it to break and neutralize several organophosphate pesticides. Indeed, when Clark's colleagues tested blood samples from several aquatic mammals, including bottlenose dolphins, manatees, and beavers, they found that almost all of them completely failed to break down two common organophosphates, chlorpyrifos and diazinon.

No one knows how often susceptible mammals encounter organophosphates in the wild, or what kind of dose would be harmful. These are, quite literally, uncharted waters. In Florida, for example, these pesticides are commonly used, and they can easily drain from farms into the nearby waterways where manatees live. But at what concentrations? "We need more data on specific pesticide levels in manatees in their various habitats," says Margaret Hunter from the U.S. Geological Survey, who studies these animals.

Clark says that it would be easy for environmental agencies to find out: The same simple blood tests that are used to monitor agricultural workers who apply the pesticides can be applied to other mammals. But until now, no one saw a need for such tests. Clark's team was specifically told by a colleague, in an email, that no one monitors for these chemicals in the blood of marine mammals since they're "pretty much metabolized in mammals quickly, and unless delivered in whopping doses are unlikely to pose a threat." The Environmental Protection Agency recently expressed similar views in its assessment of the risks that organophosphates pose to endangered species.

"People have the impression that mammals are only susceptible to these pesticides at high levels, but marine mammals might be susceptible at low levels," Meyer says. "We need data on how much these compounds are getting into the environment and accumulating in the animals."

ABOUT THE AUTHOR

Ed Yong

Ed Yong is a former staff writer at *The Atlantic*. He won the Pulitzer Prize for Explanatory Reporting for his coverage of the COVID-19 pandemic.