LISTENING TO WHALES

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The class bell rings, as usual. But then the lights are switched off. A deep blue light spills on the ceiling overhead, rippling like waves. Images appear on the front screen: whales underwater. Eerie sounds emerge. Wailing? Keening mourners? Water sounds. Low guttural rolls. Short squeaking moans. Long stuttering glissandos. Almost melodic. More images: a whale lofting out of the ocean, then its immense form crashing seaward again, with an explosive spray of water. The sounds continue, strange but soothing. These must be whales? Nothing on the board to copy in your notes. No hints from the teacher. Somewhat uncertain, you sit back to take it in. The haunting, almost mystical sounds wash over you and penetrate through you. After a while, you recognize a series of sounds you heard before. The strange becomes more familiar. The undulating light above is almost hypnotic. The sounds in the darkness lull you into thoughtfulness. You revel in the pleasant atmospheric sound. Eventually, the sounds taper into silence. The class bell rings again. Has it been a whole period? What was the teacher thinking? *Is this going to be on the test?*

Your teacher, smiling gently, expresses a hope that you have enjoyed the experience and learned something valuable from it. As you leave, one student shakes his head ruefully ("Loony!"). You wonder. Readjusting to the familiar cacophony and hectic change of classes seems difficult. You reflect: why was that sound so haunting?

No, this will not be on the test. So perhaps it is not a proper biology lesson? If it is not listed on the state curriculum, is the class time even justified? Here, I wish to challenge the sacred bovine that what matters in biology education is only – or even *mostly* – the content. Aesthetics matter, too. And they matter most importantly, I contend, not merely for humanistic reasons, but because they are integral to scientific practice.

○ Discovering Whale Songs

The story of interpreting whale sounds is typical, perhaps, of scientific discoveries in general (Rothenberg, 2008; Ludwikowski, 2014). It began in the 1950s. Apprehensive of Soviet aggression, the United States established secret bases to monitor the ocean, to listen for enemy submarines. In Bermuda, engineer Frank Watlington helped develop the new technology for underwater microphones, or hydrophones. With one hydrophone sunk at a depth of 700 m, he heard something new and puzzling – the eerie sounds described above. He recorded them. Local fishermen said they came from whales. For the Navy, the sounds were an annoying distraction. For Watlington, they were captivating. He shared the recordings with friends. He played them at a neighborhood square dance. Every spring from 1953 to 1964, during humpback whale migration, he captured the sounds on tape (Neil, 2008).

During that same period Roger Payne had been studying bioacoustics. He had researched how bats echolocate, how barn owls find prey by hearing, and how noctuid moths evade bats. But Payne's career interests were turning to conservation. In 1967, he traveled to Bermuda to see whales. There, a friend introduced him to Watlington, who shared his recordings in the engine room of his research vessel. Payne, too, was entranced by what he later described as the "exuberant, uninterrupted rivers of sound," which he found "utterly beautiful." Payne played the recordings for acquaintances, as well. With growing familiarity, he recognized that sequences of sounds recurred. That appreciation led to formal study. Later, Payne commented:

> The whole business of the scientific method, I've always thought, was a sort of useful myth. In fact, scientists work backwards from the way textbooks describe the way they work. You don't sit down and decide, "okay, this is my materials and these are my methods and this is going to be my experimental set up and this is what I'm hopefully going to find out." What usually happens is that you're slopping around in some sort of half-baked way and suddenly something occurs to you and you realize, "my god, this is fascinating."
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> It's the same with the humpback whales. We heard these sounds totally in a sort of random way, just playing them for friends, sitting down and listening to them again and again, and realized, "my gosh, these things are structured!" (Jackson & Mendoza, 1979)

Payne had also shared a tape with Scott McVay, an early advocate for whale conservation who had also once worked on human communication with dolphins. McVay had access to equipment to visualize the sounds as audio spectrographs, which display frequencies versus time. Limited by his machine, he edited the sounds into short, 2.6-second segments, then slowly transcribed each and assembled them into long rolls (Figure 1). Laid out on his living-room floor, the patterns that Payne had heard became visible. Viewing the spectrographs, one can discern discrete sounds (like complex notes), which

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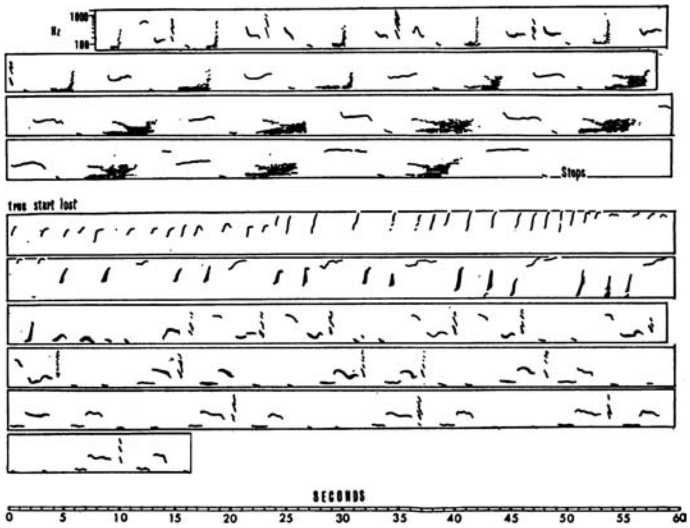

Figure 1. Whale song spectrogram. Note the repeated and subtly changing patterns. (From Payne & McVay, 1971, p. 588. Reprinted with permission from AAAS.)

are combined into short gestures (like melodic phrases). The phrases are repeated in series and (like motifs) sometimes subtly modified, creating longer thematically unified sections. Several themes are threaded together in a consistent order. The whole distinctive sequence, from a few minutes to a half-hour, was repeated many times. That is, there was a clear structure, allowing for some variation (improvisation?). Payne and McVay published their findings in *Science* in 1971, concluding that, on the basis of their rhythm and patterned structure, the humpback sounds could legitimately be conceived biologically as *songs*.

In orienting their scientific readers to the landmark article, Payne and McVay referred to "the humpbacks' most extraordinary feature" – namely, "they emit a series of surprisingly beautiful sounds" (p. 585). "Beautiful," they noted. Beauty, they thus implied, helped motivate, or justify, the scientific analysis, which in turn led to revealing the songs' profound structure.

Meanwhile, Payne had released an album of the songs (Payne, 1970). He played them for musicians, inspiring them to include the sounds in numerous popular songs and in an orchestral symphony. The efforts were designed to help raise awareness of the plight of whales, endangered by human harvest. And they did. The songs had an emotional effect. But characterizing the sounds scientifically as *songs* also helped render whales as complex, social, likely intelligent animals, worthy of conservation. These were not the sort of creatures one hunts for food or lamp oil. Awareness of the songs *as songs* engendered respect. The science, originating from aesthetic experience, thus further enhanced a different kind of appreciation of whales that was important to their conservation.

The humpback songs have continued to inspire research. And each discovery deepens our appreciation of the sophistication of whale behavior. For example, by analyzing the songs from year to year, one finds that the songs change. They do not merely follow some fixed genetic template. Rather, the whales improvise each mating season, elaborating or truncating sounds, or extending or editing motif phrases. At the same time, despite the individual changes, all the whales within a population tend to mimic and conform to one another. The songs thus gradually evolve at a cultural level (Payne & Payne, 1985).

In the 1980s, Katy Payne (Roger's wife) and a coworker also realized that the songs' themes frequently shared similar sounds, sometimes at the end of a phrase, sometimes at the beginning. That is, they rhyme: another indicator of the overall structural integrity of the songs (Guinee & Payne, 1988).

Recently, by monitoring multiple populations across the South Pacific for over a decade, researchers have documented that whales not only adopt new songs locally, but transmit them gradually across whole oceans, and have done so on many successive occasions (Garland et al., 2011). The evidence for song transmission reflects the vast scale of humpback social interactions and their cultural evolution. Again, the science of humpback songs has deepened our appreciation of another species and their potential for social organization and culture, once thought to be uniquely human.

This last study was conducted by a consortium that included Nan Hauser, Director of the Center for Cetacean Research and Conservation, based in the Cook Islands. Perhaps it is no coincidence that as a child, Nan spent summers with her family in Bermuda. There she was introduced to Frank Watlington's whale recordings, just as playful entertainment. Decades later, however, she could report with glee, "Frank Watlington is the reason I do what I do." She has reminisced, "I used to close my eyes and listen to it [a particular recording], and just think, 'Oh my gosh, I just wanna study underwater behavior of whales and record whale song'" (CBS Interactive, 2013). Roger Payne, it seems, was not the only scientist whose research was inspired by the compelling experience of listening to whales.

○ Aesthetics in Science & Science Education

Science teachers are hardly unaware of the role of wonder in education. They avidly collect fascinating facts to pique interest and open the door to learning science. Indeed, when asked, teachers typically identify their foremost practical challenge as trying to motivate today's often disaffected students. To engage them, some educators advocate integrating aesthetics into science education more systematically (Flannery, 1991, 1992, 1993; Girod et al., 2010). Aesthetic perspectives help contextualize scientific concepts and promote more meaningful learning.

But as illustrated in the opening scenario, listening to whales may serve another purpose, quite apart from leveraging attention to conceptual lessons about whales or their conservation. Imagine instead that the intended lesson is the experience itself. Appreciating nature, its organisms, and the world around us. Just as Payne and Hauser did, along with many other scientists.

Here, the educational objective is shaped by understanding how science works. First, the primary focus is on the process of science, not its tidy theoretical products. Second, doing science is not reduced to some static configuration of tests, hypotheses, and evidence. Human agents are essential. Who starts scientific investigations? Why? The recently published *Next Generation Science Standards* (National Research Council, 2013) aptly emphasize learning about scientific practices. And the very first scientific practice is, appropriately enough, asking questions. But little more is said about *why* scientists ask questions, or what turns them from query to active inquiry. What *motivates* scientists? Here, the discovery of whale songs, as much as the history of any scientific achievement, offers insight. Listening to whales mattered to Payne and to Hauser. Charles Darwin and Alfred Russel Wallace each collected beetles long before reflecting on the origin of divergent species. E. O. Wilson had affection for nature and ants well before launching sociobiology. The aesthetics of living things matter in motivating biological research. And so they have a place when teaching about the nature of science.

The goal, of course, is not to herd cohorts of students directly into research on whales, or any other particular field of study. Still, the fundamental cognitive disposition to wonder can be encouraged. One can nurture the ability to appreciate living things, without layers of biological theory or conceptual interpretations. Natural history museums often exhibit extraordinary specimens for their own sake. Many years ago, the Smithsonian displayed selected "Wonders of Nature" – exotic butterflies, elaborately convoluted seashells, iridescent beetles – presenting each in its own case, like precious works of art. The Peabody Museum at Yale (among others), by contrast, displayed their beetles in large patterned arrays, highlighting their impressive diversity of form and color. No rhetoric about sexual selection or refractive surfaces. Aesthetics trumped didactics. So too, at times, for biology classes? Aesthetic experiences open awareness for students, from self-understanding to possible careers in science.

One may surely invite wonder in many ways. From zoo or aquarium visits to field trips to conservatories, simulated tropical rainforests, or local parks or nature centers. Alternatively, one can bring the world into the classroom via a slideshow of the world's most extraordinary organisms (http://arkive.org). One can reflect on preserved human bodies (http://www.bodyworlds.com) or one's own dissections. Wonder matters to science. Indeed, the cultural flourishing of that emotion in the 16th and 17th centuries helped support the emergence of modern science (Sacred Bovines, November, 2007). Whale songs are only one way to foster a deeper appreciation of living things, as a potential prelude to scientific inquiry.

No, this will not be on the test. Indeed, it is hard to imagine any appropriate way to evaluate or grade students on their aesthetic responses. They will not be uniform or universal. Nor will they appear in any standardized cookie-cutter curriculum. Even so, aesthetics are vitally important to motivating and guiding scientific research. And so, too, for teaching science fully.

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