1 The Message from the Mud

Making Meaning Out of Microbes in Monterey Bay

Call me distracted, divided, but as I head to sea this Friday in March 2003, I already wonder how I will render my oceangoing experience into text. I am not alone. The marine biologists swaying back and forth around me are also preoccupied with representations to come, with setting sampling and recording devices in place to aid in piecing together a portrait of the waters we will visit today. We are all a bit groggy in the morning fog, just finding our feet on the drizzly deck of the *Point Lobos*, a small oceanographic vessel operated by the Monterey Bay Aquarium Research Institute (MBARI). The ship is gliding out of Moss Landing, California, a tiny coastal hamlet between Santa Cruz and Monterey. The town is harbor to fishing boats with names like *Desperado* and *Baits Motel*, home to antique stores cluttered with compasses and harpoons, and hub to marine research devoted to mapping both the undersea Monterey Canyon and the genes of its resident marine life. I have joined the *Lobos* to conduct anthropological fieldwork about and alongside marine biological fieldwork.

This will be a one-day expedition to scout for microscopic ocean life crucial to the balance of the biosphere. The chief scientist on board, marine biologist Pete Girguis, briefed me a few days ago over a preparatory calamari lunch. He told me we would be looking for deep-sea microbes that eat methane, a potent greenhouse gas. Residing in muddy methane-rich zones of the seafloor known as "cold seeps," these microbes are often found in sediment beneath vesicomyid clams and vestimentiferan tubeworms, themselves thriving in intimate relation with bacteria that live off compounds poisonous to most creatures. The goal of our trip today is to dredge up sediment from the bottom of Monterey Canyon, muck heavy with methane-metabolizing organisms, so that, as Pete puts it, he and his colleagues can decode "the message from the mud." This message, stowed in the cells and genes of methanotrophic (methane-eating) microbes, will eventually offer these scientists insights into how such teensy creatures may be linked to global biogeochemical processes, those interconnected biological, geological, and chemical cycles that sustain the Earth system. It will tell a story about how the smallest scales of marine biology affect the largest lattices of life.

In assembling the materials and equipment that will make the message from the mud intelligible, these scientists work with a variety of media: seawater, cameras, computers, deep-diving robots, petri dishes, DNA libraries. By *media,* I mean substances, channels, or instruments through which forms of action are propagated. These marine biologists engage with *mediation*—watery, televisual, digital, biotechnological—at every step in their journey, from data collection to analysis. As I follow Pete and company from sampling sludge to sequencing genes, from their Monterey Bay boat to their Moss Landing lab—the trajectory I trace in this chapter—I will see the scientific sea manifest as a media ecology, a complex of material, meaningful relations among researchers and their objects of study, relationships structured by techniques of perception and communication.[1] I will learn, too, that the message from the mud depends not only on the media through which it is transmitted and translated but on who is reading and with what sorts of interpretative habits. MBARI researchers' exegeses of marine microbial texts are animated by environmental and ethical imaginations that have the ocean oscillating between the immersively immediate and the disorientatingly different, an alien medium intimately yet opaquely implicated in human affairs. For some of these secular scientists the microbial sea, made up of out-of-the-ordinary life forms with lessons for humans, even materializes as a quasi-spiritual medium.

THE RESEARCH VESSEL AND THE ROBOT

As we slowly swerve away from shore, the seven crewmembers of *Lobos* hustle across well-worn paths, securing swinging doors and tying necessary knots down the length of our 110-foot ship. Though *Lobos* usually carries some six people in the science party, today we are only four. Pete, coordinating the cruise, works as a postdoctoral fellow under MBARI microbial biologist Ed DeLong, whose work in environmental marine genomics, the sequencing of DNA from ocean water, is getting wide notice. In his early thirties, Pete is an amiable bear of a man who sets everyone at ease with his generous humor and quiet ability to cajole heterogeneous collections of oceangoing apparatus into coordinated action. A graduate student from nearby UC Santa Cruz whom I will call Adam wears a wool cap, windbreaker, and khaki pants that mark him as an outdoorsy type; he has signed on to participate in sampling and will be interested in extracting genetic material from the mud we collect. Nadine, dressed in a ship-smart slicker, is an assistant to an MBARI marine geologist and has been charged with learning about the ship's global positioning system.

We are just getting out to sea when the drugs begin to take hold. Nadine tells me she has taken meclizine. Adam has downed six Dramamine and four Vivarin. Pete promises that he, too, is well prepared, though he jokes that he has steered clear of scopolamine, which makes people hallucinate at sea. I, foolishly, have taken nothing against seasickness. Having ascertained that everyone else is dosed up, I nervously consult my stomach and listen with half an ear as Adam tells me about his fascination with genetics: "It's all the same. You can't tell bacterial and human DNA apart at first glance."

Perry Shoemake, deckhand on *Lobos,* approaches and asks us to sign waiver forms. We all hiccup over the phrase "including death." But, steeled by an odd conviviality prompted by this amusingly bureaucratic reminder of our mortality, we sign. After we ponder our deaths at sea, Perry, relaxed and reassuring, gives us a briefing on life—or, more exactly, on life jackets and lifeboats. Life, apparently, is about floating. And floating at sea, Perry says, is often about throwing up. He shows us the "place to yak," an area on the port side of the boat, a location, he instructs us, not monitored by the ship's cameras.

The boat is studded with surveillance for two reasons. One is safety—to make sure scientists do not wash into the sea. The other is to transmit images to the Monterey Bay Aquarium, a major tourist destination just down the coast dedicated to making the oceans ever more visible to ever more publics. The fish tanks at the Aquarium invite patrons to "come closer and see." The ship's cameras allow patrons to come closer and see us.

But the most important cameras on *Point Lobos* are not attached directly to the ship itself. They are built into the massive, 2.5-ton robot sitting on deck. This is *Ventana,* a remotely operated vehicle (ROV) that can be dispatched into deep water off the side of the ship (figure 4). True to its name, *Ventana,* Spanish for "window," offers a framed glimpse into the deep, a once-removed promise of transparency, an encounter with the sea alternating between immediacy and distance. *Ventana* receives commands through a stream of fiber optic cables running from the ship through what researchers call an umbilical cord connecting the robot to the *Lobos* onboard command center. This tether allows the ROV to travel down to

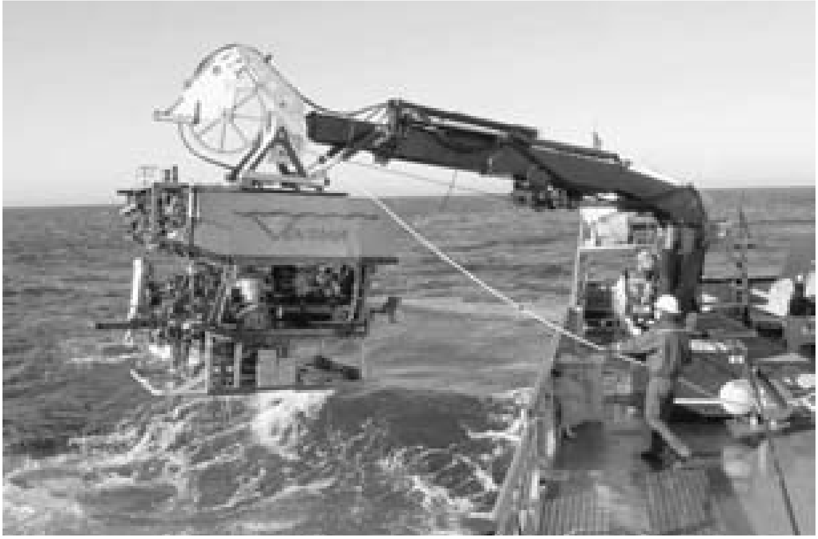


FIGURE 4. ROV *Ventana,* launching. Photo by Kim Fulton-Bennett ©2004 MBARI. Reproduced with permission.

1,500 meters, a zone of enormous pressure and heavy darkness, which *Ventana* can illuminate with full-spectrum and incandescent lamps. The images *Ventana* captures from the depths are transmitted up to the ship's control room, where they can be monitored in real time and, if desired, telemetered via microwave to shore and uploaded to the Internet, where a curious, clicking public can surf into a digitized deep.[2] The robot is outfitted, too, with remotely operated manipulator arms and a suction sampler, for collecting things like clams and tubeworms.

Ventana encapsulates a technological history of deep-sea sensing. During the first oceanographic voyages, in the nineteenth century, ships such as Britain's HMS *Challenger* drew their knowledge of the abyss from dredging—bringing up objects from the bottom of the sea using buckets attached to piano wire. *Ventana*'s metal manipulators will later today deliver up coarse mud, sediment not too different from that curiously caressed (and sometimes tasted) by Victorian naturalists on *Challenger.* Sonar (SOund NAvigation Ranging), an invention of the early twentieth century created to detect submarines, also finds its place on *Ventana,* an aid to steering the robot. Sonar affords a dimensional portrait of the deep unavailable through the patchwork deployment of sounding lines. In her history of wire and acoustic sounding, Sabine Höhler argues that sounding with sound marked an arc toward visual representations of the deep: "Oceanographic research commencing in the mid-19th century could not rely on the direct observation of its object, but had to create its images of ocean depth through remote investigation. Depth became a matter of scientific definitions, systematic measurements, and graphic representations. In the course of a century, the *opaque* ocean of the 1850s was densely depicted in physical terms and transformed into a technically and scientifically *sound* oceanic volume."[3]

Piggybacking on innovations in underwater photography pioneered by the likes of Jacques Cousteau, ROVs now afford optical access to bits of this oceanic volume. The sensory trajectory through which the deep sea has been scientifically apprehended has traveled from the tactile, to the auditory, to the visual, with the submarine world becoming at once more intelligible and more fantastic. As I look into *Ventana*'s prominent zoom lens, attached to a Sony HDC-750A high-definition camera, I am reminded of the earliest exploits of William Beebe, inventor of the bathysphere. Crouched in his metal ball in the 1930s off the coast of Bermuda, Beebe looked out of his tiny portal and, speaking through a telephone wire run to the surface, delivered some of the first vivid descriptions of the abyss, later translated into watercolors by his associate Else Bostelmann. Rhapsodizing about the realm below, Beebe wrote: "The only other place comparable to these marvelous nether regions, must surely be naked space itself, out far beyond atmosphere, between the stars . . . where the blackness of space, the shining planets, comets, suns, and stars must really be closely akin to the world of life as it appears to the eyes of an awed human being, in the open sea half a mile down."[4]

This analogy to the cosmos has gathered gravity with *Ventana*, which, with its adaptations to extreme pressure and temperature, is sharply sculpted by space-age technology.[5] In trading telephones for telepresence and watercolors for the World Wide Web, the half-million-dollar *Ventana* also allows the ocean to be plugged directly into that peculiarly contemporary technoscientific medium, cyberspace.

The use of computer technology to sound the sea is a central goal of MBARI. Computer entrepreneur David Packard, of Hewlett-Packard, nurtured an interest in marine technology and founded the institute in 1987. The $60 million Aquarium, inaugurated in 1984, was inspired by Packard's daughters, both marine biologists; Julie Packard has long been executive director. MBARI was chartered to satisfy David Packard's more technical, research-oriented leanings. Known for his skill in winning military contracts for his company, Packard served in the 1970s as deputy secretary of defense under President Nixon, managing far-flung U.S. naval forces. By the time he left this position, he had gathered a store of knowledge about classified national marine technology. When the cold war ended, this intelligence, coupled with his wealth, put Packard in a unique position to move military technologies into the private sector as well as to commission custom-built devices like *Ventana.* MBARI has become a key player in developing robotic and telepresence techniques to research ocean ecosystems. In recent years, MBARI scientists have also been drawn to genomics, sequencing DNA from sea creatures like those we hope to gather today.

Ventana has been outfitted by operations technician Mark Talkovic with a bank of plastic cylinders that will be pushed into the seafloor to collect cross sections of methane-infused ooze. Looking for signs of life at the bottom of the ocean turns out to be a relatively recent possibility, not just technologically but epistemologically. In the early nineteenth century, naturalists thought the deep to be devoid of life, in part because of a prevailing belief that seawater was compressible—that, as James Hamilton-Paterson puts it in his remarkable book, *The Great Deep,* "seawater grew more and more solid until a point was reached beyond which a sinking object would sink no farther. Thus, somewhere in the middle regions of the great abyss, there existed 'floors' on which objects gathered according to their weight. Cannon, anchors and barrels of nails would sink lower than wooden ships, which in turn would lie beneath drowned sailors, who themselves lay at slightly different levels from one another, depending on their relative stoutness, the clothes they were wearing, and, quite possibly, the weight of their sins."[6] The ocean in which *Ventana* descends is no longer the thickening realm of the eerily lifeless. Nowadays, it is a medium layered with living things all the way down.

As I look at *Ventana*'s plastic cylinders, called pushcores, Adam tells me about marine mud. Among the DeLong lab's many interests, he explains, is a process called anaerobic methane oxidation, the metabolic breakdown of methane without the aid of oxygen. Microbes called methanogens—so named because they generate methane as a byproduct of their energy metabolism—are well known; they live in such comfortable environs as cow stomachs. Less understood are close relatives of these creatures that use methane as a source of carbon and energy. This process represents a kind of chemosynthesis, the production of organic materials without, as in photosynthesis, the need for light as an energy supply. Adam and Pete want to get hold of genetic material from microorganisms flourishing in the sunless settings of cold seeps to see if these creatures are capable of making enzymes that could address the question of whether methane-eating microbes are involved in Monterey anaerobic methane oxidation, and whether methanotrophy is a form of methanogenesis in reverse.[7] This is something the DeLong lab has been investigating since 1999. A key piece of the metabolic puzzle comes from work by outgoing MBARI postdoc Victoria Orphan, who provided evidence that anaerobic methane oxidation might unfold in multispecies microbial collectives, with methanotrophs oxidizing methane to carbon dioxide in coordination with microbes reducing sulfate.[8] Adam points out that methane oxidation is environmentally important because almost 75 percent of methane emanating from seep and other methane systems may be consumed by these "bugs," prevented from entering the atmosphere as a greenhouse gas.[9] If it were not, he laughs, we humans would be in "deep shit," smothered in methane.

Stopping himself abruptly, Adam points to starboard: "Look, there's a whale!"

I miss it.

We head inside to study a wall map of Monterey Canyon, on which serpentine lines representing the canyon's branches snake out from a shore-based origin point at Moss Landing (figure 5). This sonar atlas of a sucked-up sea delivers a parched blueprint of a topography invisible to an airborne eye. It is an apt symbol of the transparency promised by remote sensing and digital imaging. Still frustrated by my missed whale, my eye wanders up to a bend where, I am informed, a remarkable biotic feature sits at the bottom of the bay, 3,000 meters down. This is a "whale fall," the sunken carcass of a giant cetacean. Whale flesh and skeletons can become hosts to riotous ecologies. A dead whale delivers a dose of nutrients to the bottom of the sea more potent than the steady fall of "marine snow," bits of organic detritus that continually drift down to the deep. A whale fall is given its first going-over by scavengers such as sharks, after which invertebrate worms settle on the bones. The decomposition of whalebone lipids produces sulfides off which symbiotic microbes residing within these worms thrive. Some scientists think cold-water enzymes breaking down fats within whalebones might be good ingredients for cleaning detergents—a twenty-first-century descendant of the whale oil of *Moby-Dick*'s day.

We arrive at our dive site, just 12 nautical miles out of Moss Landing, at 36.78° N, 122.08° W. Monterey Canyon, deeper than the Grand Canyon, escorts deep water close to shore, one reason MBARI is sited where it is. When I step out onto deck, Perry and Mark are readying *Ventana* for deployment. Suddenly the full heft of the robot is over the rails. It begins to sink. Adam, Nadine, and I head back inside to watch a television tuned to *Ventana*'s channel. Marine snow rushes up from the bottom to the top of the screen, telling us that *Ventana* is descending. We begin our hour-long

FIGURE 5. X marks the spot of the *Point Lobos* destination, March 7, 2003. Map by Norm Maher. ©1998 MBARI. Reproduced with permission.

wait until the robot reaches the methane-saturated ecologies in which Pete is interested. The color of the water on the monitor begins to change as wavelengths of light taper off, from light blue, to deep azure, and finally to black. Descriptions of the deep as dark and *therefore* mysterious, full of secrets, unknown, draw on a reservoir of meanings that associates sight and light with knowledge; indeed, the word *theory* derives from the ancient Greek for "to look on" and "to contemplate." No surprise, then, that seeing through the opaque ocean has become the governing goal of oceanography, the grail of techniques of remote sensing.

The emplacement of the medium of ROV TV in the medium of water suggests a maxim for media studies. Like seawater, media such as radio, television, and computers are not merely material, not merely delivery systems for messages, but in our very conceptions of their substance and form come suffused with meaning. Just as the opacity of seawater has been historically associated with mystery (and just as the once-assumed compressibility of seawater suggested irretrievability), so, for example, the fractured presence promised by television partakes of prior associations of sight with both distance and immediacy. Marshall McLuhan once suggested that "the medium is the message"[10]—that is, that media extend and modulate our sensorium, that "the effects of technology do not occur at the level of opinions or concepts, but alter sense ratios or patterns of perception."[11] But, though sense ratios or patterns of perception do indeed morph with media, opinions and concepts cannot be so easily centrifuged out of the swirl of materiality and meaning that make media. Franz Boas, a founder of American anthropology, famously wrote his dissertation—in physics and geography—on the color of seawater, which he later argued depended not only on scientific measurements but on angles of vision, frames of reference, modes of assigning meaning, and the whole suite of habits and beliefs he would later call *culture*.[12] In the wake of Boas, cultures came to be understood as social media saturating action and perception: forms of life.

I head outside and squint to see if I can make out Moss Landing, my most recent frame of reference.

MOSS LANDING

Moss Landing draws together various histories, and a maritime anthropologist will detect the outlines of many seas in this town from which I embarked upon my research. Never much larger than its present population of three hundred, Moss Landing was founded in the 1860s by a Captain Charles Moss, from New England, in partnership with Cato Vierra, a Portuguese whaler. Together, the two built a port for shipping barley from nearby Salinas. Centuries before, this had been Ohlone land, and then, with the establishment of Jesuit and Franciscan missions, an outpost of New Spain. By the time the Boston Brahmin author of *Two Years Before the Mast*, Richard Henry Dana Jr., anchored at Monterey in 1835 during a stint slumming it as a sailor, this area was part of Mexico. When Moss and Vierra arrived, twelve years after the United States bought California from Mexico, they found the harbor occupied by a visionary Frenchman, Paul Lezere, who nurtured a failed dream for a futuristic seaside metropolis to be named the City of St. Paul. Moss's Landing (as it was first called) operated until 1874, when the transcontinental railroad reached nearby Watsonville and barge traffic ceased. In the 1920s the town saw resurgence as a whaling station in the twilight days of the industrial hunting of these mammals, and from the 1930s it was a sardine cannery site, until the fishery collapsed. During World War II, Moss Landing was home to an African American battalion stationed to defend the coast against Japanese submarines—a reminder of the wartime sea, a zone not just of myth and mystery but also of strategy and state secrets.

Moss Landing has been a haven for commercial fishers—though in the age of corporate fishing their small-crew endeavors have suffered tremendously.[13] The town shifted toward nautical nostalgia in the 1970s, with antique stores moving up from Monterey's Cannery Row.[14] Ecotourism has arrived, and whale-watching boats now share the harbor with fishing vessels. Moss Landing has become a destination for kayakers and surfers, eager to immerse themselves in the wilderness attraction of the Monterey Bay National Marine Sanctuary. With the founding of California State University's Moss Landing Marine Laboratories in 1965 and, later, of MBARI, Moss Landing has become a center of marine research.

My settling as an anthropologist into Moss Landing began during afternoons at the Haute Enchilada, a Mexican folk art café stuffed with pottery collected by owner Kim Solano. Here, I held my first conversations with marine scientists and chatted with local fishermen, antique dealers, and migrant workers employed in nearby artichoke fields. Most of the farm hands I met were Mexican, living in the area temporarily, wiring money to Jalisco and Michoacán. Advertisements on public buses I took around Monterey County announced cheap calls to Mexico, promising a more quotidian telepresence than that offered by deep-diving robots like the somewhat romantically named *Ventana*. Fishermen, mostly Anglo, held forth at the café about their diminishing catch—and sometimes about MBARI, which they associated with government agencies dishing out regulations, although MBARI does nothing of the sort. A few complained about the cost of cleaning their boat hulls, keeping their crafts clear of hitchhiking pests from other ports—a problem to which biologists called attention with pamphlets profiling Monterey Bay's "Least Wanted Aquatic Invaders," the area's "alien species." Tensions between fishermen and scientists became apparent to me when I strayed into Moss Landing's fishermen's bar, The Bear Flag, with Adam, who was teased about his pristine surfstore-logoed sweatshirt and short pants.[15]

Commercial fishermen feel themselves squeezed out not just by scientists but also by a growing number of modest pleasure craft and houseboats claiming places on the piers. I learned about the live-aboard community when I ended up boat sitting for a retired construction worker I met at the Haute Enchilada, J. P., a 73-year-old man whose glass eye and prosthetic leg bespoke an adventurous, if accident-ridden, past. J. P. had been drawn to life on a boat because he could live inexpensively in a harbor where monthly slip fees were low. I lived for a few months aboard J. P.'s Chris Craft, decked out inside like a groovy 1970s Volkswagen bus, complete with a shag carpet and a jumble of Native American curios celebrating J. P.'s one-eighth Yukot ancestry. My stay on the boat tuned me into a different sea, that of people on the margins of middle-class life, living at an ocean's edge they associated with self-sufficiency. Some crewmembers from *Lobos* lived in this harbor. J. P.'s generosity in allowing me to live rent free in his boat suited my circumstances; I had just moved to California from Manhattan and was living on New York state unemployment while I waited to hear about grant and job applications. Shuttling back and forth between the harbor and MBARI helped me see how thick Moss Landing was with various ways of encountering the sea.

SENSING AN EXTREME MARINE WORLD

Ventana arrives at the seafloor and now floats just off the bottom, a thousand meters below *Lobos*. The science party congregates in the ROV control room, a wedge-shaped chamber squeezed into the front of the ship, on the lowest deck. In the dim light we can discern the inside-out shape of the bow. Once upon a time, when this ship was an oilfield supply vessel named *Lolita Chouest*, this room, the forecastle, housed sleeping quarters. Where sailors once sunk into seesaw sleep, scientists now remotely ride *Ventana* into the deep, revealed to them in a stream of images delivered to the banks of video monitors that crowd this dark room.

This array of computer and video screens is overwhelming, a torrent of sense data that feels like a direct feed from what Kant once called the *mathematical sublime*, that domain of difficult-to-get-your-head-around measures and magnitudes.[16] Arranged into columns, shoulder to shoulder, are Hewlett-Packard computer monitors showing sonar from *Ventana*, real-time diagrams of the ROV's thrusters and fuel tanks, and scrolling profiles of oxygen, temperature, and salinity levels at the depths through which *Ventana* has traveled. Video screens range amid these monitors. Some present exterior views of the ship. The starboard-side video, taken from a camera on the bow, is unsettling; if the ship is pitching (an up-and-down movement from bow to stern), this screen presents us with the inverse of what our guts feel. One screen offers a glimpse into the auditorium at the Monterey Bay Aquarium, where we see a podium from which docents lecturing to visitors can contact *Lobos* for the latest cruise news.

The central images in the control room, the ones we are here to see, are those affording looks through *Ventana*'s lenses. Though *Ventana* carries several cameras, we are most interested in the forward view, presented on several screens, at many sizes. The most prominent is adjacent to a VCR, next to a monitor hosting a video annotation system called VICKI, for Video Information Capture with Knowledge Inferencing. Next to this is a monitor displaying "frame-grabs" from ROV video; frames are captured when a researcher clicks an icon in the annotation display. On this trip, I am that researcher.

Pete has stationed me in a chair in front of VICKI. He hands me a timer to remind me when to change videotapes. As I look around the room, each screen sways to its own rhythm, providing a view of, well, everything at once. Pete sits to my left, in front of a keyboard from which he controls *Ventana*'s cameras and lights. The two ROV pilots (members of the ship's crew) sit in the leftmost two chairs, outfitted with joysticks for steering, or, as they prefer to say, flying the ROV.[17] The pilots also control two robot arms with which *Ventana* can grasp instruments and pick stuff up. Nadine sits in back, studying the navigation console. We all wear headsets, allowing us to speak with one another over the hum of the boat. Pete addresses me: "Stefan, go ahead and snap as many frame grabs as you want of the pushcores going in, coming out, whatever looks good." A CD player percolates a gentle reggae. The room is a sensory scramble, a layering of ocular, auditory, and corporeal disorientations: a multimedia experience, a dip into the *media sublime,* an overpowering flow of mediated sense data (figure 6).[18] To get our bearings in this milieu, we project our presences into *Ventana,* whose cameras are to be our steady eyes.

We see a clam bed, a sign that *Ventana* is near a methane seep. Pete moves his fingers over a mouse pad to control the camera. We are searching for peculiar colorations of mud, signs of distinctive metabolism. Pete instructs ROV pilot D. J. Osborne on where to position *Ventana.* D. J., slowly transposing his bodily motion, a fragment of his presence, into the robot deep below, tries to be mindful of the clams.

D. J.: If I sit down here, I can try not to disturb them.

PETE: They're pretty happy. They're gigantic! [*Looking at camera controls, realizing things are not what they seem*] Oh! We're *zoomed in.*

FIGURE 6. Oceanic sublime meets mathematical, media sublime. ROV control room on the *Point Lobos.* ©MBARI. Reproduced with permission.

In "Seeing in Depth," anthropologist Charles Goodwin argues that on oceanographic research vessels "perception is something that is instantiated in situated social practices, rather than in the individual brain," and he maintains that an "architecture for perception" is built into such ships, with oceangoing scientists and crew enacting "not simply a division of labour, but a division of perception."[19] Just so, Pete and the ROV pilots behave as different parts of a distributed body, adjusting to each other's perceptions and prosthetics. One pilot is hands, another, wings. Pete serves as the guiding gray matter. I act as a bit of memory, though, like everyone else, I am also part of a compound eye, grafted to screens of data which, as Goodwin would have it, "provide not just a window into the sea, but the resources required to move other inscription devices within it, including some of the machines that are producing these very representations."[20]

Classical sociologies of relations between scientists and ship's crew comment upon the different expertise these parties have, on how class hierarchies are often reinforced through divisions between "mental" and "manual" labor.[21] Though there are mechanical aspects of managing *Ventana* scientists would be ill prepared to undertake, operations in the ROV control room put scientists and crew into tighter relations of interdependence than typify much sea science. Scientists have to know how the robot works in order to think about sampling, and pilots have to be able to intuit what scientists might find interesting. Together, they enact what Edwin Hutchins, in his ethnography of navigation on board a navy ship, called "cognition in the wild," converting and communicating information through a cascade of representations channeled through analog and digital media and propagated through different people's embodied expertise.[22] Still, scientists are understood to direct the action:

PETE: Tubeworms! We landed right on them. Can I zoom in a little bit? Look at all of those! Let's do a flyby. Is it easy to get some of those tubeworms?

D. J: We can't guarantee that we'll be back to the tubeworms, so let's do it now.

PETE: Stop here. Come wide. Zoom in. There's one right next to your wrist there.

Pete means the wrist of *Ventana*'s claw, not the pilot's closer-to-hand hand. The substitution is telling, a sign of presence transported. The ROV control system uses software similar to that of the Sony PlayStation, making joystick controls transparent to those, like younger ROV pilots, who have played first-person video games.

In her sociological account of deep-sea research, Chandra Mukerji argues that with such familiar techniques, benthic environments "begin to become less natural environments than areas that have characteristics of both the natural world and the social world of science. The expression of signatory techniques through the manipulation of equipment gives scientists a way to assert their culture, and not become overwhelmed by the scale of the ocean."[23]

In the language of flying that accompanies the operation of the ROV, we might hear a further assertion of the cultural command Mukerji describes. To be sure, this way of speaking, along with the notion that the ROV offers an extension of self, signals that people on *Lobos* construe their activity as exploring. But to imagine scientists on *Lobos* hungering after some exterior, transcendent position would be to miss the more intimate relations they develop to their subjects of study, relations for which the medium—water, video—is vital to the message. On *Lobos,* the sensation is not of detachment from nature but of a pleasurable, technological immersion *in* it—an experience of being "in the field" at once immediate and hypermediated. Media theorists Jay David Bolter and Richard Grusin offer that "our culture wants both to multiply its media and to erase all traces of mediation; ideally, it wants to erase its media in the very act of multiplying them."[24] Yes, but the world of *Lobos* also overflows this ideal. On board, awareness of visual mediation—of the always-negotiated social and technical boundaries of the interface—adds to and creates the sublime shudder

FIGURE 7. VICKI frame grab of *Ventana*'s vantage point as the ROV arm grasps a tubeworm. ©2003 MBARI. Reproduced with permission.

of encountering an alien world. The experience of a simultaneously immediate and hypermediated ocean emerges from a grappling dynamic between surfaces of flesh and machines that Haraway, following phenomenologist Maurice Merleau-Ponty, calls "infolding."[25] The technologically enabled origami of infolding sees elements of culture and nature, ROV and ocean, trading places, delivering an alternation between remote and intimate sensing, a rising and falling immersion in a multimedia ocean.[26]

After a few foiled attempts at wresting tubeworms from their moorings—"Did we lose that little guy?"—D. J. fastens the ROV arm onto a likely candidate. I am still next to Pete, in front of VICKI, and he instructs me to take frame grabs of the tubeworms we have now found near a methane seep (figure 7). These tubeworms are noteworthy because living inside their tissues are microbes that metabolize sulfide. This indicates that we might be near sulfate-reducing microbes, which, as Adam told me, some microbiologists suspect join with methanotrophs to accomplish anaerobic methane oxidation.

We are far from the sunny, humanly familiar ocean here. In fact, one biologist at MBARI argued to me that, rather than demonstrating that the sea is a zone of ecological harmony, sites like methane seeps should lead us to see it as a giant refuse heap; life exists here not because the medium is friendly to life but because life is so adaptable, can make its way in the most noxious environments. I am not sure this attitude is fair to tubeworms and their symbionts, though it is true that they have been persistently associated with the creepy, unearthly, even extraterrestrial—a chain of association more sensational than logical (one could argue that anaerobic methane oxidation is the most "earthy" process there is). But the alien connection is prevalent, particularly among scientists who see these critters as analogs for extraterrestrials. Pete tells me some enthusiastic artists have plopped tubeworms into fanciful seascapes of alien planets, a graft that makes little sense, since if metazoans evolved on other worlds it is unlikely they would resemble earth creatures.

Science fiction turns out to have been one of Pete's inspirations for becoming a deep-sea biologist. He tells me of having been a kid riveted by the television show *Star Trek,* by the idea of traveling and doing science in three dimensions (fittingly, the starship *Enterprise* and *Lobos* each employ viewscreens to convey images of an unfamiliar, exterior realm). As a teenager, Pete was also fascinated by deep-sea documentaries and took a keen interest in the migration of whales, reinforced by family trips to Sea World. He particularly enjoyed *Star Trek IV,* in which the crew of the *Enterprise* travels back in time to twentieth-century Earth to save the whales (specimens of which they find at a fictional "Cetacean Institute," portrayed in the film by the Monterey Bay Aquarium). Just as seventeenth-century European travelers to seaside Holland were trained by Dutch seascape paintings in how to see the sea, so Pete's eyes have been prepared for the deep by ecologically themed media entertainment and science fiction.[27] Not surprisingly, the environmentalist message of *Star Trek IV* is of a piece with MBARI's mission to understand the local waters of the central California coast. The message from the mud, I am coming to understand, is likely to be an ecological message, perhaps a message of warning to humans about fossil fuel use, agricultural intensification, and waste disposal. As at the Aquarium, which features primarily local sealife, "the old tropes of 'nature' as outside culture" are, as Eva Hayward puts it in her study of this site, "transplanted with ecological epistemologies of conservation."[28] In this ecological linkage between life forms and forms of life—famously articulated in the 1950s by Rachel Carson, whose books on Earth's endangered seas are easy to find at the Aquarium—we humans are nestled within ecosystems to which we have ethical responsibilities.

Pete says he was drawn to *Star Trek* because the scientists were not always perfect; they made mistakes.[29] Having been brought up in an Egyptian American Coptic family that urged caution about adopting the tenets of Darwinian evolution, he was aware of the need to be prudent about the limits of science. At the same time, Pete was taught respect for empirical ways of knowing; his mother had been a support engineer for some Apollo missions to the moon.

By now, a whole bush of tubeworms has been plucked free of its moorings—a process I have been uneasily documenting with frame grabs (does yanking up benthic life under incandescent light really constitute environmentally friendly science?). Later, I will visit the MBARI video lab, where such images are annotated. Thousands of tapes have been made using *Ventana* since 1988, in assorted formats. The three women who work in the video lab—a windowless, temperature-controlled room on shore—review footage and mark which creatures show up when. One of the video librarians, who holds a master's degree in invertebrate zoology, tells me their database has become unruly as organisms have changed names in response to genetically inspired rewritings of old classifications. Another calls bemused attention to the gendered division of land-and-sea labor that sees women like herself running between kids and nine-to-five work while a male ship's crew delivers ROV videos peppered with sometimes off-color jokes about the shapes of underwater formations.

We travel farther with the ROV. We see bamboo coral. Another pushcore is pressed into the mud, capturing a clam. "This guy comes back with us!" says Pete.[30] I glance at my monitor and see a digital count of Greenwich Mean Time, tweaked to display numerals melting, Dalíesque, into their successors. Surrealist invention is allowed to flower in the corners of our computer screens, but an aesthetic of realism is sternly enforced for the screens delivering images from *Ventana*. We are meant to be watching a sort of real-time documentary about extraordinary things, not, say, a high-definition version of the bizarre works of Jean Painlevé and Geneviève Hamon, twentieth-century French filmmakers famous for their far-out movies of sea creatures, in which the viewer is constantly reminded of how much cinematic prodding it takes to make human eyes get their bearings in the refracting realm of the sea.[31] Still, looking at, through, and into water requires some tangling with *theory underwater,* recognizing that ways of seeing, schemes of explanation, are always informed, performed, and deformed by their medium. Pete continues in movie director mode, panning and tilting amid the ship's pitch, rock, and roll.

I realize that my stomach is rolling. I get up to find some air and no sooner do I step outside, onto deck, than vomit leaps out of my stomach into my ballooned mouth. The video timer goes off in my pocket. I race to the yak zone. Other people in the science party have gotten sick, too, in spite of the drugs. Adam remarks that it is hard to do science under these conditions; you're either sleepy or sick. *Lobos* is notorious for making people ill. A poem about the ship penned by an MBARIan ends,

> But I am experiencing technical difficulties:
> My heave compensator has failed,
> Compiler's in error, signals drowning in noise,
> Standard output is over the rail.[32]

When I reenter the control room, Adam has kindly changed videotapes and taken my place at VICKI. After a while, operations are finished and the ROV begins its ascent to the surface.

I ask ROV pilot Knute Brekke how he maneuvers *Ventana.*[33] He demonstrates the robot arms. The left one has several joints, named with words suggesting an amalgam of the mechanical (swing), bodily (shoulder, elbow, wrist, grip), and nautical (pitch and yaw). The right arm boasts hydraulics capable of lifting 500 pounds. I play with a *Ventana* arm as the robot rises to the surface. It is an experience of disconnection; there is no force feedback through the joystick. This reinforces a sense of weightless, outer-space-like travel. This is telecommunication without teletactility, a gap that makes explicit the work required to realize telepresence, immediacy from afar (other ROVs *do* have force feedback, narrowing the sensory gap).

Knute tells me he is sometimes up till midnight before a dive day, fixing hardware on the robot. I ask about an anecdote I heard back on shore from an MBARI software engineer. Normally, *Lobos* finds out where *Ventana* is through pinging a sonar signal off of it. Location information is fed to shore, where programmers receiving data points use a formula to construct a best-fit line for a day's ROV path. The pilots, though, have not found the sonar as fine tuned as they like; they want to know more about speed. They reoutfitted the ROV with a Doppler velocity log, measuring movement relative to seafloor (rather than in "absolute" space). Though this has been accurate about how fast the ROV is going, it has been less so about where it is. When Doppler data were first fed to shore, software engineers became confused about the ROV's line of flight, not knowing of the pilots' modifications. Knute says that computer folk sometimes confuse people at sea, too—as when they upgrade ship software from shore. Cursors move around on ship screens as though the boat is haunted.

It is a difference of perspective, of who is authorized to exercise remote power. My interview with shoreside software engineer John Graybeal a week earlier centered on how he thought about the sea as he put together a database for *Lobos.* The ocean on the screen was for him about projection, conceptualization. When he considered the ocean through the medium of his database, he said, "I don't think of it as a wet thing. It's a construct that places constraints on what we do. It's not the same ocean that we go to when we step outside and go to the beach." He said he "couldn't imagine someone solving a chess problem if they were up to their neck in water. *The ocean is not of us.* You can't live there." But the problem of giving form to information, which Lev Manovich in *The Language of New Media* describes as the task of software, is a problem which, for the ROV pilots at least, *does* require being "up to their neck in water."[34] It cannot sidestep the wetness of the ocean medium; deconvolving Doppler data, for example, requires practical knowledge of the materiality of seawater. On ship, oceanic data management is less of a chess problem than, perhaps, an exercise in underwater basket weaving, a material practice of manipulating form in a saturating medium, an activity more challenging than its folkloric association with easy college classes would suggest.

A call from the Aquarium interrupts my ROV tutorial. Through our shipboard monitor of the Aquarium auditorium, Knute and I see stock footage of the very control room in which we sit. I squint at the image of the docent on our screen and hear her tell her audience, in a tinny television voice, "Nothing is larger or more important than the ocean. We get food, minerals, and pharmaceuticals from it. And with the ROVs, we can enter this alien world. None of this would be possible without MBARI's research vessels. The scientists are on the boat right now! They can beam images to us live. If I go live to the boat, we see . . . not much. *Point Lobos,* are you there?"

Knute says yes.

"What did you do today?"

Knute explains about clams and tubeworms and cold seeps. The docent thanks him and proceeds, on the fly, with the help of a vast video menu, to explain what these are. She tells her audience that hydrogen sulfide smells like rotten eggs, that methane smells like what comes out of a cow when it farts.

Ventana is up. It does smell. Adam labels the mud-filled pushcores and transfers them into a holding box. Still scouting for whales on the horizon, I make out the shore and recall a whale-monitoring program run by the Moss Landing Marine Laboratories (MLML), the other research center in Moss Landing. If MBARI is high-tech and focused on the future, MLML is more modestly budgeted and attaches itself to more traditionally conservationist undertakings. One of MLML's projects has been the attempt to monitor the migration of whales using sea lions outfitted with cameras. During a conversation with the director of this program, whose offices are in a small trailer, I caught sight of a somewhat forlorn fiberglass model of a whale, to be used for training sea lion cinematographers. The sea lions, though they are much more at home in the water than robots, get nothing like the funding of the more technologically spectacular *Ventana*.[35]

We all end up on the *Lobos* bridge. Pete asks the captain about the ship's future. There is talk of decommissioning *Lobos*, transforming it into a craft that can maintain elements of MBARI's next big technological undertaking—a distributed ocean observatory, a network of remote sensing buoys providing continual Internet access to data from the sea. I later hear a talk at MBARI about how such networks would allow scientists to sit at home gathering oceanographic data. No need for seasickness pills, yak sites, or, indeed, fieldwork; what counts as presence in the field—presence upon which representations will be based—is transforming. The *Lobos* might do maintenance on nodes and cables in such a system (and *Ventana* might shift from a glamorous tool for immersive exploration to an everyday repair device). A crewmember jokes that without scientists on board they could do some proper salmon fishing.

Weeks later, on shore, I speak with Chris Scholin, an MBARI biologist working on a remote sensing module called an environmental sample processor, or ESP, an apparatus that might become part of an ocean observatory. The device is designed to test seawater for genetic signatures associated with ecologically interesting microbes or unwanted organisms. These might be invasive alien species or blooms of harmful algae, phytoplankton which, in too great quantities, he tells me, can have negative impacts on humans and wildlife as well as on local economies. Scholin says that genetic probes for such organisms would need to be augmented by further information in order to assess properly the hazards any samples may suggest; after all, one could find lots of genes from dead organisms. Closing a beach on the basis of false positives could be costly. But he is optimistic about "putting the oceans online," getting data from in situ, real-time sensors, using these to do long-term ecological monitoring, watching for changing abundances of dinoflagellates and other organisms like bacteria and viruses, which could offer clues about environmental change.[36] Scholin says that the ESP might someday be like *Star Trek*'s tricorder, a hand-held device that sniffs out signs of life. ESP, of course, is a perfect name for a tool that promises to jump beyond human sensing, to an expanded remote sensing that allows people to assay the ocean without going there. Extending associations between oceans and outer space, projected marine observatories have acronyms like MARS (Monterey Accelerated Research System), NEPTUNE (NorthEast Pacific Time-series

Undersea Networked Experiments; see chapter 6), and VENUS (Victoria Experimental Network Under the Sea). The vision feels science-fictional, floating in the future.

In these computerized days, the oceans are coming to be viewed through the robot cameras of entities like *Ventana* and their online interfaces. Understanding today's scientific sea means engaging with this media ecology. It also requires following how this system interacts with the medium of seawater, a churn of already in-place meaning and materiality. If "the medium is the message," or, as McLuhan later put it, "the medium is the *massage*"[37] (to draw attention to the sensual effects of media), media are already massaged by prior meanings. The media-mathematical sublime delivered by the online ocean at once tames, amplifies, and scrambles the old-fashioned seagoing sublime.

As Pete's message from the mud moves from sea to shore, media remain central to its fashioning. With the application of gene sequencing to consortia of marine microbes, the ocean is becoming something to be textually scanned, deciphered, read, at ever-higher resolutions. If there is a sensory itinerary toward accessing the previously unseen in marine biology, it should be no surprise to see a growing focus on harder-to-find, harder-to-discern life forms. Such a trajectory not only tracks the miniaturization new techniques have enabled but also sketches a story about the dwindling scale of life forms in the sea in the age of overfishing.[38]

READING THE GENETIC SEA

Just off the boat, I join Pete and Adam in archiving mud, which will be kept on ice until Adam can extract nucleic acids from it. Donning plastic gloves, Pete treats a few samples with RNA*later,* a product that prevents the degradation of messenger RNA, the substance that mediates—"translates"—between DNA and the proteins it specifies. Pete is curious to know whether he and Adam might be able to retrieve RNA from the mud, though DNA is the easier substance to work with and the favored material for the DeLong lab. We joke that RNA*later,* manufactured by Ambion, "The RNA Company," is ill named, suggesting not preservation but eradication—which Adam glosses, surfer style, as "RNA! Later, dude!" Pete remarks that when he touches mud with his ungloved hands—not permitted at the moment, since we do not want to contaminate samples—he finds it makes his skin smooth. He jokes that he should start a cosmetics company with the slogan, "It comes from the bottom of the sea!"—a phrase he repeats the next day at a port-tasting party held at a postdoc's apartment in Santa Cruz. The ensuing laughter prompts discussion of the chemical qualities of the wine, upon which people studying chemosynthesis are well qualified to comment. As if to confirm this observation, weeks later I meet a marine chemist from UC Santa Cruz, Phil Crews, who has started his own boutique winery.

The port tasting is a going-away party for one of the postdocs—an occasion for celebration but also a moment suffused with a certain exhausted melancholy. Present at the gathering are three marine biologist couples in the thick of trying to square their committed relationships with job offers from geographically distant universities. It is a problem that visits more and more academics in this age of scholarly temp work, and it is something these oceanographers have in common with this anthropologist. My fiancée lives in Pasadena and we see each other only occasionally, though her one-year job teaching anthropology in Claremont has made my fieldwork geographically—and, to begin, financially—feasible. Familiar to me, too, is the way marine biologists' negotiations between the personal and professional demand that they constantly articulate their research to a variety of possible employers—that they have flexible identities while building recognizable expertise. Pete and company's decoding of the message from the mud must be carefully managed, parceled out in strategic publications, tactically divided between postdocs on the job market, graduate students needing a push into a new project, and, of course, lab leaders like DeLong. Such dynamics are replicated across MBARI, which hosts some fifteen laboratories—in geology, chemistry, biology, and ocean engineering—each with its own principal investigator and a few postdoctoral fellows.

What will be the aim of extracting nucleic acids from the mud? Pete tells me the best outcome will be the construction of a genetic library representing the diversity of genes found in microbes in the cold seep environment. Such libraries allow comparison with microbial life in other ecosystems. Researchers in DeLong's lab concern themselves, we might say, not so much with mapping the sea as with mapping the DNA of sea creatures.

The lab is at the forefront of attempts to characterize the genetic profile not just of single organisms but also of whole environments.[39] Environmental marine microbial genomics seeks to describe sea-going microbes by sequencing the genes of entire communities of these creatures—from such diverse environments as deep-sea mud, hydrothermal vent systems, and surface waters.[40] It constitutes a radically new approach not just in marine biology but also in microbiology. The earliest days of microbiology depended almost exclusively upon microscopes, first turned to analytic advantage by Antonie van Leeuwenhoek in seventeenth-century Holland to peer at "animalcules" swarming in a drop of water. Two hundred years later, Louis Pasteur and Robert Koch isolated individual microbial strains for study by growing them in petri dish "cultures," a technique modified for use at sea in the 1940s by Claude ZoBell to cultivate microbes capable of metabolizing at high pressure.[41] "Culturing" entails concocting a nutrient medium congenial to organisms' dietary needs, simulating their environment so they can grow in the lab.[42] But it has proven notoriously difficult to manufacture laboratory cultures that replicate the conditions encountered by most marine microbes in their natural habitats, typified by complex ecological networks; the vast majority of microbes remain uncultured.[43] Biologists like DeLong have found ways around this impasse, even turning this obstacle into an asset. Nowadays, gene sequencing permits marine microbiologists to dispense entirely with the need to zero in on individual microbes—or even on populations of discrete cells. Volumes of water can be filtered directly for the genes they harbor, which in turn can be sequenced and read as signatures of microbial marine life.[44]

This is not merely a technologically innovative genre of genomics; it represents a theoretically novel mode of parsing the biotic world. This is a genomics beyond organisms, a practice that implicitly queries whether individuals are the only evolutionarily meaningful units. As DeLong explained in a 2003 interview in the *New York Times*, "A milliliter of seawater, in a genetic sense, has more complexity than the human genome."[45] In the view of DeLong and others, the microbial ocean can profitably be seen as a sea of genes.[46] Scientists at MBARI store, summarize, and analyze fragments of this sea in gene libraries.

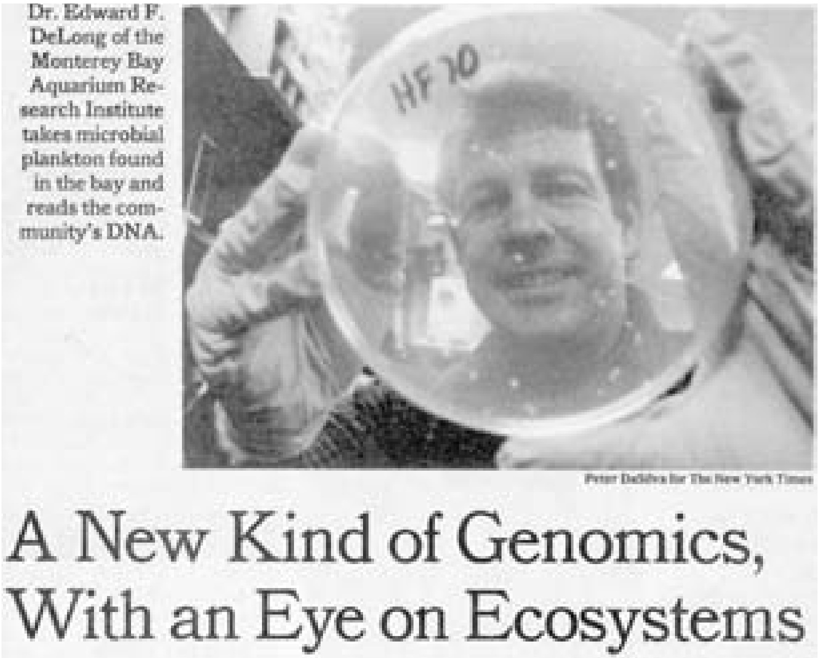
How are libraries compiled? A few days after our cruise, Pete escorts me upstairs at MBARI, where he hands me to Steven Hallam, another postdoc in the DeLong lab, who promises to walk me through the process. Steven, a spry, jocular fellow in his early thirties, catches on to my anthropological attitude from the moment we meet, joking about the fetish objects of molecular biology: the centrifuges, which spin biological substances into component parts; the gene amplifiers, which "xerox" DNA; and the sequencers, which read the nucleotide stutters of the genetic text—strings of adenine, thymine, cytosine, and guanine, abbreviated A, T, C, and G. All the machines have pet names, he tells me, rattling off monikers like Harvey, Lola, and Eve—this last the designation of a device purchased from a company whose sales reps had recently dressed up as Raelians, the religious group that claimed the offshore cloning of a human in late 2002, whom they named Eve. Steven tells me that the most important machines in the lab do not carry names; these are machines so commonplace as to be almost invisible: freezers. These are where DNA libraries are stored. Steven opens a refrigerator-sized vault maintained at a subarctic –80°C, housing shelves stocked with small rectangular, clear plastic trays about the size of CD cases. Each tray, frosted with ice, is stickered on its side with the location and depth from which its contents hail. I see trays labeled "Monterey Bay," "Hawaii," and "Antarctica." Steven pulls out a typical tray, dotted with a twelve by eight grid of holes, each about half a centimeter in diameter. This is a 96-well plate, the basic storage format in this lab (more recent work uses a 384-well configuration). A collection of trays from one location at several depths (e.g., a site in Monterey Bay) constitutes a genetic library for that environment.[47]

What, exactly, is *in* a DNA library, and how does it get there? Steven leads me from the freezer to the lab bench. The first step, he says, is extracting DNA from organisms, a process that dissolves intact cells to release DNA and then eliminates unwanted proteins, lipids, and carbohydrates. This results in the purification of DNA (DNA extraction kits often include an agent for separating DNA that is derived from the fossils of diatoms, microscopic plankton that grow silicon cell walls). After extraction, one must decide what kind of library to make. One might make a *ribosomal library,* using genetic material involved in the production of ribosomes (cellular organelles, made of RNA, where protein is synthesized); such a library, based on genes many scientists consider genealogically stable, provides a possible inventory of taxonomic groups in a sample. One might also make a *functional library,* targeting a specific enzyme in a metabolic pathway to learn about links between cellular dynamics and ecological or biogeochemical processes. A *genomic* or *metagenomic library* represents a snapshot of the full genomic complement of a sample.

For a ribosomal or functional library, the next step is DNA amplification, making copies of a genetic material of interest. One needs DNA in bulk to get experiments going. Amplification is accomplished using the polymerase chain reaction (PCR), which enables the exponential copying of DNA segments. To copy segments from particular organisms, researchers stir into the genetic sample a few off-the-shelf DNA fragments called primers—sequences of genes that match only with specified target sequences. Such mixtures are then placed into a PCR machine like the lab's GeneAmp PCR System 9700 by Applied Biosystems. The system heats up and cools down the genetic mixture, in a repeating cycle, allowing sections of DNA double helices to uncouple—"denature"—and then reassemble—"renature"—into copies of the DNA element specified by the primer. To help this process along, PCR makes use of enzymes that survive at high temperatures. Some of these derive from extremophilic microbes at hydrothermal vents. DeepVent, "isolated from a submarine thermal vent at 2010 meters and able to grow at temperatures as high as 104°C,"[48] is one such extremozyme, and a product about which I learn more later. At the end of an environmental PCR screen, researchers have a heterogeneous mixture of DNA representing a sampled community.

After amplifying a sample, one needs to separate different genetic segments for closer examination. The first step toward this aim is cloning—cutting and pasting—genes into a circular piece of DNA known as a plasmid. The plasmid acts as a "vector" for inserting genes into a bacterial cell, such as *E. coli*, able to host genetic material from other organisms. *E. coli*'s incorporation of external DNA is aided by subjecting the bacterium to high heat and placing it in an incubator such as Forma Scientific's Orbital Shaker, inside which it is brought back down to 37°C, human body temperature. Zipping through the lab, Adam hazards that, as a "shit bug," *E. coli* (which lives in intestines) finds its comfort zone here. Transfer of genetic material into *E. coli* allows researchers to grow substantial quantities of such substances. (Making a genomic or metagenomic library is different; here, the lab uses a fosmid, a plasmid that controls copy number in cells).

What Steven and company are creating, then, are "mermicrobes"—organisms part sea creature and part everyday terrestrial bacterium.[49] When I offer this word to Steven, he grins and says the concern at this stage is to avoid producing chimeras, DNA clones containing gene regions artifactually combined from different organisms during amplification. Like the same-named fire-breathing monster of Greek mythology, such chimeras do not exist in nature; like mermicrobes, they are tangles of the natural and cultural. But, Steven cautions, the creation of such hybrids does not make of this kind of biology a Frankensteinian endeavor. Cloning microbial genes does not immediately scale up to the science-fiction-style cloning controversies that make the cover of *Time*—though, as I puzzle over plasmids, Pete joins Steven, shakes his head, and remarks that he shies away from telling more religious family members that his job entails cloning; they have been known to scold him for toying with creation. This is a sharp acknowledgement of ideological rifts in today's North American public culture about the proper relation between the objects of life science and the subjects of social life, between life forms like stem cells and forms of life like scientific research. If Pete and Steven see genes as manipulable



Dr. Edward F. DeLong of the Monterey Bay Aquarium Research Institute takes microbial plankton found in the bay and reads the community's DNA.

Peter DaSilva for The New York Times

A New Kind of Genomics, With an Eye on Ecosystems

FIGURE 8. Ed DeLong, looking through a dish of cloned colonies. Reproduced with permission of Peter DaSilva Photography.

bits of life, they do not therefore think genes in the lab *stand for* life as a moral whole; that status is reserved for organisms (and, for Steven, as becomes clear, for ecosystems as well).

Once genes have been cloned into *E. coli,* the bacteria are placed into a bed of agar, a gelatinous substance derived from seaweed (originally named *agar-agar* in Malay; *Gracilaria lichenoides* in the scientific lexicon). The bed sits a few millimeters deep in a circular petri dish, permitting clumps of *E. coli*—"colonies," in lab language—to form on the agar, dotting the plate with tiny, pale flesh-colored circles. Figure 8 shows DeLong looking through a circular plate specked with colonies of clones. The plate is labeled HF 70, which stands for Hawaii Ocean Time-series, Fosmid library, 70 meters down. I cannot help but compare this picture to DeLong's slide of Leonardo's Man against planet Earth; here again, a human has a whole world in his hands.

This petri dish of cloned colonies is the raw form of a genetic library, a form of what science studies scholar Eugene Thacker calls *biomedia,* "the technical recontextualization of biological components and processes."[50] The biological components at issue here, lengths of marine microbial DNA, have been placed in the context of *E. coli* to make them available en masse, as colonies, for scientific inspection. Once colonies are grown in media, they are transferred into slots on a 96-well plate. They are then dosed with antibiotics that permit only those clones that have taken up the plasmid vector to replicate. Steven tells me this is artificial selection at the molecular level. With a nod to Darwin, he offers, "We're doing this because this is how nature does it, and we haven't found a way to do it better." Commenting ironically on the conversion and regeneration of organic material in play here, he adds a religious joke: "Only the born-again will grow."

The joke points toward a key concern among these marine microbiologists: they are seeking to find meaning in the microbial life they study. Talk of the message from the mud—the extraction of information from sludge—should make this clear. The recontextualization at the center of Thacker's definition of biomedia alerts us to how meaning does not preexist interpretation; rather, the readjustment of context is that which *makes* meaning. Laboratories, after all, are devices for creating significance, for separating figure from ground, for adjusting what counts as text and context.[51] Steven's irreverent one-liner about the born-again is an ironic commentary on how difficult—and sometimes facile—the making of meaning might be. Scientists' quips about methane, *E. coli*, and shit—important associates and associations with mud—bespeak anxieties about how meaning might be made of messy things.[52] At the same time, such comments express a wonder and confidence that even the most chaotic substance can be made to signify. The language of *message* also suggests a communicative relationship between sender and receiver—a relation that unfolds in time, in which methanotrophic microbes are rhetorically positioned as delivering to scientists an ancient and alien wisdom from the deep history of Earth. While reinforcing scientists' sense of wonder, such messages are not, in the main, imagined through earnest spiritual rhetoric. The majority of the microbiologists I met were firm secularists, even agnostics and atheists. In searching for meaning in microbes, they trust rational approaches to reveal surprising relations—like those between biodiversity and biogeochemistry—though they also consider such connections to have social consequence, even ethical import.

With a range of associations from sullied to morally significant, methanogenic and methanotrophic microbes exhibit something of the flavor that anthropologists have assigned to the taboo. In Edmund Leach's 1964 "Anthropological Aspects of Language: Animal Categories and Verbal Abuse," we read: "Quite apart from the fact that all scientific enquiry is devoted to 'discovering' those parts of the environment that lie on the borders of what is 'already known,' we have the phenomenon, which is variously described by anthropologists and psychologists, in which whatever is taboo is a focus not only of special interest but also of anxiety. Whatever is taboo is sacred, valuable, important, powerful, dangerous, untouchable, filthy, unmentionable."[53]

So far, microbes have been described as bearers of important messages, as in need of protection from contamination, as versatile, as possibly chimerical, as invasive, as smelly, and as shit bugs. If not strictly taboo, microbes are certainly objects of interest and anxiety; their relations to humans matter to these scientists. And they come to matter precisely through their manifestation as media—as symbolic intermediaries between human selves and an oceanic other, as material things whose functions can be investigated as biomedia.

Microbes, then, become media for thinking about the world beyond the lab. For many of these ecologically minded and politically liberal scientists, deep-sea life forms are important for environmentalist forms of life. One of the microbiologists at the port party, a graduate student from a nearby university, e-mailed me an extended reflection on her search for meaning in marine microbes. Her words illustrate the connections at stake for many of these scientists:

> When I began to learn about marine ecology, ecosystems, cells, and genes, I was enraptured by the bizarreness of hydrothermal vents, by the mysteries and promises those still-freshly-discovered habitats embodied—and I began to learn about the roles microbial actors played. Marine microbes are the linchpins not only of marine food webs, and thus ocean life, but indeed the linchpins of global biogeochemistry, global ecology. They are the "spark of life"; not only do they hold clues to the first sparks of life, and the accretion of those sparks into the mighty flame we now behold around us, but they remain the great Spark. They fuel the biosphere, they transform waste into nutrients, they adapt. I've never been religious, but my heart just sings to contemplate the miracle of this planet's complexity, how much sense it makes, how beneath every layer there's another and yet we can piece together the workings and learn new emergent principles. And yet, what dire immediacy in this pursuit, today. So many beautiful creatures, wrought by millennia of evolution, being snuffed out in today's cataclysmically changing world. I feel the calling to help mediate the gulf of what we don't know about the workings of the oceans, and what the public doesn't know they should even care about. I want to learn how these communities control our biosphere, in hopes that we can grasp, as a species, what the likely paths can be before us, so we can make an informed decision among them and walk into our future with our eyes open.

This student's words reveal sentiments of wonder and a respect for nature, a view of humans as reliant upon (though often ignorant of) this order, and a rational optimism that scientific explanations of life forms can broker forms of life responsible to the future well-being of all life. This position follows a long tradition in American science of considering biology to hold civic lessons for researchers and their publics.[54] The marine microbiologist becomes a medium for propagating information about the subvisible realm of microbes to the human-eyed world.

When I walk into the lab the next day, Chris Preston, a research technician in Ed's lab, greets me. She is "picking colonies," plucking small clumps of *E. coli* out of gummy agar with a toothpick and transferring each colony into a hole on a 96-well plate. Each tiny well contains a liquid growth medium called Luria-Bertani broth. The work, Chris sighs, is numbingly dull, and in bigger labs robots do it. She sits me down at the bench and gives me pointers for taking over, and for the next hour I busy myself picking colonies. As I poke the little dots of *E. coli,* placing each in a well of its own, I am not sure if I am transfixed or completely bored out of my brain. My gaze wanders to a haiku written on the lab whiteboard:

> picking colonies
> meditation or boring?
> just buy the robot

Steven sprints by and informs me that he favors listening to minimalist composer Philip Glass while doing this work. Chris has put on Norwegian techno. People in the lab shuttle around, in attitudes of distracted concentration, waiting for various processes to finish, staring into the middle distance, considering what they must do next. I, too, have invisible materials in my head, such as fragments of argument from sociologist of science Karin Knorr-Cetina's *Epistemic Cultures.* Of lab work in molecular biology, Knorr-Cetina writes, "Scientists act like ensembles of sense and memory organs and manipulation routines into which intelligence has been inscribed; they tend to treat themselves more like intelligent materials than silent thinking machines."[55] The techno music gives such intelligence an enabling soundtrack, immersing researchers in a mundane media sublime, a flow. Such activity may support Knorr-Cetina's claim that, "if anything is indeed irrelevant to the conduct of research in molecular biology, it is the sensory body *as a primary research tool.*"[56] But while messaging mud and swaying to the sounds of the Orbital Shaker are, yes, not primary research protocols, they *do* allow researchers to fasten their bodies to their work. Nonetheless, it is true that the parameters within which these scientists must embody repetitive routines can become confining and tiring. Occasionally, someone groans that they need a break and wishes it were warm enough to use MBARI's beachside volleyball court.

Steven, now installed next to me, transfers small volumes between wells on different plates and goes through lots of disposable pipettes. He complains about the trash molecular biology generates; it is scandalous, he says, that here we are doing science about ecology while generating this toxic material that will head straight to landfills. I turn back to the *E. coli* I am stabbing and, reading the legend on the petri dish, realize it contains gene fragments from Hawaiian waters. I try to connect a visual of blue water with the gel before me and find it impossible. I see each well as a Russian doll, containing a unique colony containing a unique plasmid containing unique DNA. At the end of my toothpicks, I have completed one plate in a genomic DNA library.

DNA libraries are understood as collections of information encoded in catalogued packages. If *Ventana* promises oceanic transparency, genetic libraries promise legibility. In play here is not so much the uncanny oscillation between immediacy and hypermediacy that produces the intimate and alien ocean for ROV users but rather a sense that the unfamiliar will yield to decipherment, which may lead to unexpected knowledge. The library analogy is persuasive to scientists in part because of the linguistic metaphor of the genetic code, a set of correspondences between nucleotide bases and amino acids. The textual metaphor might also suggest that different plates are volumes in series that treat of microbes from different places. Each plate, after all, has a call number, like a library book. But DNA is not a language—it has neither grammar nor semantics—and so the analogy of these plates with books containing text is inexact at that level.[57] The libraries are anyway read more hypertextually, with meaning read out in relation, pragmatically, not written in beforehand. The libraries have much in common with *Gould's Book of Fish*, that volume described in Richard Flanagan's novel of the same name, a liquid book that spawns new chapters every time it is opened.[58]

These wet databases of fragmented life, of life as media technique, are different from the jars of dead fish MBARI maintains in an air-conditioned room downstairs, a place humorously known as the Necropiscatorium. This assortment of squids, jellyfish, and other creatures has some of the romance of a nineteenth-century natural history museum.[59] The collection, however, is falling into disuse. "Only a few people care anymore," says Steven. "We are losing sight of the organism." People today are more interested in gene libraries, because of the multiple stories they can tell in concert with bioinformatics programs—because of their potency as biomedia, organic stuff that can be reformatted into novel configurations. In "Unpacking My Library," Walter Benjamin writes that "not only books but also copies of books have their fates."[60] So, too, with DNA libraries.

Back upstairs, Steven instructs me that when one completes a 96-well plate labeled something like MB10—a legend that stands for "Monterey Bay, 10 meters down"—one might compare it to other plates or libraries, looking for similarities across environments. With a genome library one could head back to the PCR machine and, using a specific DNA primer, see if already known genes appear in an unanalyzed library. An example: In 2000, the DeLong lab discovered a complex of genes in Monterey Bay near-surface marine bacteria specifying the production of a light-absorbing pigment, rhodopsin, not previously known to exist in oceanic microbes and of signal importance for comprehending how energy from the sun is cycled by the sea.[61] Creating primers complementary to genes involved in rhodopsin production enabled DeLong's team to use PCR to see if rhodopsins were present in genomes from other environments, like Hawaiian waters. DeLong discovered rhodopsins at different ocean depths, spectrally tuned to distinct frequencies of light. This finding has enormous significance for understanding the rates at which ocean plankton can turn light into life—processes which, in parallel with such activities as microbial methane munching, are instrumental in keeping Earth habitable for aerobic light lovers like us.

I run into Adam, pipetting small volumes of microbes from one plate to another. He laughs, "It's an act of faith that there's anything in these tubes!" In some ways, there is nothing particular about the ocean driving the way this lab science is done. It is, much of it, standard molecular biology.

Chris disagrees, though clarifying that the oceanic particularity requires expertise to discern. She tells me that in trying to figure out what might be unique about a library from Hawai'i, for example, she consults the log of the ship on which samples were collected, looking through records of salinity, temperature, and the like. She shows me a website from which she can retrieve such data and comments on the constant need to think of context. Sometimes, she tells me, if she is looking at a microbe living near the surface, she will think back to surfing or scuba diving, trying to remember temperature and light shifts. Meditating on further connections between the lab and the sea, she tells me a chilling fact about ocean samples: when trying to determine whether particular marine microbes gather their carbon from near the bottom or higher up in the water column, some labs look at the concentration of carbon-14 in their bodies. Because of twentieth-century nuclear testing in the South Pacific, surface waters around the world are enriched in "bomb carbon," which because of the ocean's slow circulation has not yet reached its deepest regions. Steven interrupts us to say, with a mixture of outrage, world weariness, and scientific detachment, that such information can be crucial for "doing forensic science on the living ocean."[62]

The frequencies of war hum in the background of our work now, too. Everyone I talk to hates the Iraq war, but no one knows what to do, short of showing up at protests. Most people in the lab dislike President Bush, who, distrusting climate science, by implication dismisses the value of these aspiring scientists' vocations and probably the relevance of any message from the mud the lab might decrypt. Whereas the technologies of the cold war generated much of MBARI's instrumentarium, marine scientists here are not much preoccupied with a vision of science in the national interest. They are committed to a moral economy of following questions where they lead—a position enabled in part by the ample funding of the Packard Foundation, which gives them steady salaries that shield them from constant grant writing (even as MBARI operates with an industrial model that keeps inquiries from wandering too far from the objectives of the institute, which demand that science always be done with an eye toward using new oceanographic technologies).

Another echo of war arrives in the form of an e-mail from MBARI's long-range research vessel, the *Western Flyer,* now in Mexico's Gulf of California.[63] Everyone on board is reading *The Log of the Sea of Cortez,* a book written by John Steinbeck about a voyage he took to the Gulf with Ed Ricketts, during World War II, to collect invertebrates. Remarking on the scrambled sensibility that came from being at sea while life on land slid into war, Steinbeck wrote, "Our radio was full of static and the world was going to hell."[64] As if to cement MBARI scientists' feeling that they are stuck in a perverse repetition of history—and politically paralyzed at sea, like Steinbeck—the institute's ship takes its name from the very vessel Steinbeck and Ricketts chartered to Mexico. What has changed between the eras of Ed Ricketts and Ed DeLong, of course, is the speed at which warfare and science now unfold, when information is produced far faster than meaning, when intelligence about a suspicious warehouse in the desert or an anomalous gene sequence in *E. coli* outpaces the ability of experts to decipher plausible functions.

If making gene libraries provides a first step to reconstructing genetically enabled microbial processes, a proper reading requires gene sequencing—spelling out the bases constituting DNA. The DeLong lab has a modest sequencer the postdocs have named Lola, after the German movie *Run Lola Run,* a film that features three alternative endings for the same story. I ask Steven whether "Lola" was chosen because sequences never come out the same way twice. He chuckles enigmatically. More pertinent is that Lola runs too slowly—it takes six hours to sequence a 96-well plate. MBARI sends most materials out to be sequenced at the Institute for Genomic Research, the entity behind the shotgun sequencing that propelled the Human Genome Project toward completion. Shotgun sequencing works by shredding multiple copies of the same organismic DNA, which are then sequenced by armies of speedy robots. Using bioinformatic software, computers churn through all these overlapping sequences and reassemble them into something researchers hope looks a lot like the actual, correct, sequence. When such sequences are sent back to MBARI, people like Pete, Steven, Adam, and Chris move into the realm of computational comparison, matching their sequences with those at other labs and building relationship trees for consortia of microbes, trying to find out how they are related. At this juncture, marine biology goes digital—of which much more in the next chapter.

LOVELOCK MEETS LOVECRAFT

We have still not heard the message from the mud. Adam continues to toil to get genetic material out of sediment we collected with *Lobos,* sorting it into neatly named types, a difficult task since, as Pete points out, "whatever message we read will come from *everybody* hanging around in the mud—microbes, protists, even worms, should we have accidentally ground one up." But Pete remains enthusiastic about using nucleic acids to learn about methane metabolism, though he tells me he is wary of thinking about microbial matters only bioinformatically; organic stuff often drops out, he says, in the digital domain. He compares digital gene sequences to CDs and organisms to full-bodied analog LPs and, warming to his comparison, says, "Hey, I still like my old vinyl records."

Pete points me to a poster detailing results the DeLong lab will present later in the year. I scan the poster, titled "Construction and Analysis of Shotgun and Fosmid Genomic Libraries of Anaerobic Methane-oxidizing Archaea from Deep-sea Methane Seeps," reviewing, in technical language, some of what I have seen at MBARI. The poster reports on work undertaken with DNA libraries made well before my *Lobos* trip, though on similar samples. What, then, is the message of the mud? What have these scientists read from such libraries as they have compiled? Steven says there is a parable in the poster, on which he is first author. He will tell me over lunch.

When we meet up at the Haute Enchilada, Steven reports that during his undergraduate studies at Sarah Lawrence he was impressed with the work of Teilhard de Chardin (1881–1955), a Jesuit paleontologist keen to riddle through the relation of religion to science. I learn that Steven's father is a Methodist minister and that Steven has long been a student of spirituality and alternative epistemologies, convinced that science is just one—albeit, compelling—way of knowing among others. Steven has been ruminating on an account of anaerobic methane oxidation that proffers a moral about the dangers of seeing the sea as infinitely flexible, endlessly able to absorb human insults like toxic waste or the sinking of carbon dioxide into the deep to keep it out of the atmosphere (a practice in which the Bush administration expressed interest a few years previous). He begins with a quick sketch of atmospheric chemist James Lovelock's Gaia hypothesis, the notion that Earth is a homeostatic system, delicately tuned to and by the life forms it supports. Gaia, he points out, for all its associations with romantic visions of natural balance, could care less about the well-being of humans; indeed, we may produce the very feedback systems that lead to our own demise. Inspired by our recent visit to the unforgettably odd Necropiscatorium, Steven brings up H. P. Lovecraft, an early twentieth-century fantasist famous for his ornamented horror stories about aliens and his panic about the biological degeneration of Western civilization. Fusing Lovelock and Lovecraft, Steven offers the following fever dream—in the spirit of Lovecraft's weird accounts of "the unsampled secrets of an elder and utterly alien earth"[65]—a sort of psychedelic rereading of the anaerobic methane oxidation paper:

> Once upon a time, when the Earth was young, there was very little oxygen in the atmosphere. Instead, the atmosphere was mostly composed of methane and carbon dioxide and the oceans were warm and shallow. Life evolved to thrive under these greenhouse conditions. Methanogenic microbes feeding on carbon dioxide and other simple carbon compounds produced vast quantities of methane and this methane was in turn consumed by methane-oxidizing microbes found primarily beneath the ocean's surface. In cooperation with sulfate-reducing organisms, the methane-oxidizing microbes built towering reef cities formed from mineralized carbonate and filled them over countless generations with their collective brood.
>
> And affairs continued in this tranquil equilibrium for one and a half billion years, until the genesis of oxygenic-phototrophic metabolisms and the oxidation of the atmosphere. Life forms able to adapt to elevated

> oxygen levels thrived and radiated. Meanwhile, those content with living in anoxic places were pushed to marginal zones, to extreme environments—subterranean worlds and still waters, mud flats, and seafloor spreading centers. The great reef cities fell into ruin and were subsumed into submarine strata, a cryptic but lingering record of the lives of these ancient organisms. Despite this catastrophic reversal of fortune, these ancient ones held onto the edges of their once great empire and there they waited.
>
> And here's the moral of this conjectural tale: They knew, these ancient ones knew, to the very core of their genomic fiber, that it would all be okay, because through their DNA they had bequeathed the knowledge and the drive to return and rebuild. Because it turns out that all of the anthropogenic processes connected to climate change—fuel emissions, deforestation, cattle grazing—may well have the result of bringing back the ancient atmosphere. You see, these ancient organisms are patient. And here are the ironies—a good story always has ironies—they have no imperial ambitions, they have adapted to live and lurk in the marginal zones. But when the madness of humanity resurrects the ancient atmosphere they will be ready and willing to return, to rebuild their ancient dwellings beneath the sea and continue their eldritch cycling of methane. And the primordial balance will return. Until the next big catastrophe.

Steven's generative fusion of Lovelock and Lovecraft discloses an ocean alien to human purposes, purposes themselves perhaps unwittingly alien to their own scaffoldings.[66] Steven tells me he wishes we humans had something like an ocean ethic, an ethos that could detour us away from funneling everything through the marketplace or technocratic politics. A deep-sea biologist from MBARI, Kurt Buck, walks by. He asks Kim, behind the counter of the Haute Enchilada, if he can get some used vegetable oil to experiment with as a biofriendly fuel. Steven says to me, "I would argue that the lesson to be learned is how to compose our lives and our societies based on the properties of Earth systems under study and the properties and interactions of organisms living in balance within these systems."

It is a good start that MBARI funds vanpools from Santa Cruz, I observe, though mordantly funny that the institute is built on the beach, which after a century of climate change could all be under water. Steven wants a more spiritual sensibility to animate our engagement with the ocean, though he also says, "But I am not a priest for Gaia. Gaia doesn't need priests. Gaia needs scientists." It seems to me that what Steven desires is a sophisticated "gaiasociality," a way of weaving biogeochemical knowledge and political commitments responsibly together. The task is huge. Steven has to get back to publishing, to doing the science he trusts.

Steven's fantastic fable will not soon appear in the pages of a scientific journal. If MBARI scientists were to deliver a moral from the message from the mud, it would more likely come in the shape of a sober policy recommendation, from an elder statesperson like DeLong. As a postdoc, Steven is being professionalized, and his story is infused with questions about the meaning of his career and the creatures to which he has devoted his work. The paper that Steven eventually publishes in *Science,* "Reverse Methanogenesis: Testing the Hypothesis with Environmental Genomics," begins by pointing out that "microbial methane consumption in anoxic sediments significantly impacts the global environment by reducing the flux of greenhouse gases from ocean to atmosphere"[67] and, after arguing that a better characterization of microbial metabolism is on the way, leaves it at that, as well the paper might, since the study does not reach into methods and theory from climate science.

Although Steven's Lovecraft-Lovelock account is wryly satirical about human shortsightedness, it has a serious strand. Alienated from the ocean, humanity may be destined to damage it. And ancient life forms, with ways alien to contemporary oxygen-addicted humans, may inherit the earth.[68] This story of evolution, devolution, and revolution coils together narratives of the conjoined origins of self and alien in the sea. The ocean becomes a spiritual medium, delivering messages from apparitions of an ancient world to listeners living today—just as the media of telephone, radio, and television were once believed to carry transmissions from ghostly denizens of alien realms.[69]

Mixing the horror of Lovecraft with the romantic rationalism of Lovelock produces a volatile concoction. I hear in the tale the twin impulses that Haraway locates in the American millenarian imagination: "Apocalypse, in the sense of the final destruction of man's home world, and comedy, in the sense both of the humorous and of the ultimate harmonious resolution of all conflict through progress, are bedfellows in the soap opera of technoscience."[70] In the froth of Steven's science fiction is a struggle to make meaning out of microbiology, to tell a story that will compel humans to slog out of their own mud, our own mess. It is a call to tune in to the alien medium of the ocean, revealed through a media ecology of ROVs, DNA libraries, and bioinformatics programs. If the alien ocean is a medium refractory to human apprehension and presence—dense in its darkness, crushing in its pressure, suffocating in its substance—it is also host to creatures whose very otherness is crucial to human life support. Steven's is a story about time and limits—about deep time and contemporary emergency. The relation between humans and microbes is structured by their shifting positions on this timeline. Anthropologist Johannes Fabian, in *Time and the Other,* writes that "time, much like language or money, is a carrier of significance, a form through which we define the content of relations between the Self and the Other."[71] The ocean Steven describes is ancient, enduring, and often alien to human origin stories and destinies. He is not alone in describing this sea.