Sippewissett Time Slip

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The salt marshes of Sippewissett, Massachusetts, a few miles north of Woods Hole's Marine Biological Laboratory, host sheets of microbes that detail a history of early Earth. This history is not so much archaeological—revealed by peeling back ever-older layers—as it is analogical: microbial mats similar to these have likely existed on Earth for more than three billion years.

I visited these squishy structures in May 2005 with Lynn Margulis, traipsing with her through the Cape Cod mushscape as part of anthropological fieldwork I was then doing about how contemporary microbiologists have been reimagining the past, present, and future of our ocean planet. I was conducting ethnographic fieldwork, it turns out, about, alongside, and entangled with Margulis's microbiological fieldwork.

The ocean I was in the midst of discerning was one that I have come to call the "alien ocean." That ocean, for today's marine microbiologists, manifests as both a futuristic, science fictiony space of weird and ultimate others—critters living at extremes of temperature, pressure, salinity, and much else—as well as an alluring reminder of our own organismic origins in brine and bacteria. To adapt an old anthropological dualism about the simultaneous newness and everydayness of "other cultures," today's microbial sea is both strange and familiar. It is an echo of the past as well as a place unfolding into unknown futures.

"Strange and familiar" well describes the wet and watery world that Margulis described in her work. She was in Sippewisset pondering additions to her theory of symbiogenesis, the idea that evolutionary novelty emerges from the symbiotic fusion of different sorts of cells and organisms. According to this view, all of today's nucleated, eukaryotic cells evolved through incorporating once free-living prokaryotes—like the oxygen-respiring bacteria that became mitochondria and the cyanobacteria that became chloroplasts, entities that now constitute indispensable organelles in the cells of animals and plants. In Margulis's tale of symbiogenesis, the biologically strange has become the biologically familiar—the familial, even.

As we walked through the marsh, Margulis told me that she was investigating the possibility that structures such as the tiny hairs on the edges of cells, the filamentous threads in mitotic cell division, and the tails of sperm—all known to have common descent—might come from an earlier incorporated ancestor called a spirochete, a swimming, corkscrew-shaped bacterium. Margulis was leading us to the marsh to collect mats of organisms she knew hosted similar spirals stirring from a dormant, rolled-up form; she wanted to detect signs of emergent symbiogenesis, evidence that these wiggly creatures were insinuating themselves into their neighbors' cellular structures.

There were seven of us on this modest expedition into Earth's microbial past: Margulis, some students from Woods Hole, a journalist from *Discover*, my anthropologist spouse, and me. We trailed Margulis's red compact car over dirt roads that string together gray-shingled Cape Cod vacation homes along the marshlands. Private Property and No Trespassing signs did not deter Margulis; she moved in a different time and space continuum than most New England humans. As a key collaborator with James Lovelock on Gaia since the 1970s, her mind tuned in at once to the microscopic and macroscopic, to the subvisible and superorganismic, to the baroque and romantic aspects of the world around us. She tuned in to what we could call a Sippewissett time slip, playing here on the title of Philip K. Dick's *Martian Time-Slip*, a novel that takes place on a Mars that is experiencing all its history simultaneously. Our Sippewissett trip takes place not just in 2005 but also in another time, on an early Earth, in a throwback sea. One might note, too, that "Sippewissett"—a Wampanoag place-name meaning "at the little river"—also indexes the all too ghostly Native American presence in this patch of Cape Cod. This place is a mix of past and present: a time machine, an eddy in the alien ocean.

After parking our caravan of cars—fueled by oil, itself the result of ancient microbial processes Margulis calls "unearned resources"—we hiked out to the intertidal zone, the sort of threshold region Rachel Carson celebrated in her ecological urtext from 1955, *The Edge of the Sea*. Margulis wore knee-length waders and a fleecy hooded pullover and walked determinedly into the mush, grasping a spatula and large spoon, ready to hunt microbes. She was the only one dressed appropriately, though sympathetic to those of us freezing in the drizzle on that unseasonably cold day. Waving us into the marsh, she pointed out grasses that were signs of nearby microbial mats.

She directed us to shallow pools bottomed by multicolored mud. Pointing out that the alternately exposed and submerged character of this site is ideal for mat growth, she dug up a lichen-like sample of microbial mat and instructed us to look at its dripping wet cross section, half an inch thick. Its rainbow layer cake of orange, green, pink, and black was composed of diatoms, cyanobacteria, purple sulfur bacteria, sulfate-reducing anaerobes, and other microbes living in complex interdependency. The mats were ecosystems, with cyanobacteria and purple anoxygenic photosynthetic bacteria as primary producers—"the acme of evolution," she remarked.

"Cyanobacteria can do everything," Margulis said, "except talk." "Everything" means they gather their necessaries from vastly different media: electrons from water, energy from sunlight, and carbon dioxide from the air. They are expertly suited to the earthly elements, the proportions of which, according to the Gaian model, they have themselves had a role in determining.

Margulis was inviting us to look anew at planet Earth, to peer through these mat systems all the way back to the Archean eon, 2,500 million years ago. The mats were portals to another world. They were media transmitting messages from an age when the ocean was otherwise, when Earth was just becoming the planet it is now. Cyanobacterial photosynthesis long ago filled the world with oxygen, pushing into marginal zones such anaerobic creatures as methanotrophs. Ancestors of blue-green bacteria like the ones in microbial mats consigned methanotrophs to environments we now consider extreme—the reason scientists call them and other such nonstandard life-forms extremophiles.

Standing in the marsh with Margulis, we were searching for embodied, living analogues of ancient life. There is ample evidence for mats in Earth's fossil record in the form of stromatolites, rocks left behind by the trapping, binding, and deposition of carbonate (and other sediment, such as sand) by cyanobacterial mats. Some biologists suggest that if bacteria evolved on other planets they would leave behind stromatolite-like formations, which might then be considered signatures of extraterrestrial life. The extraterrestrial analogy was not far from our minds because our trip into the marsh came at the end of a weeklong workshop on astrobiology at Woods Hole's Marine Biological Laboratory. Astrobiology is an area of inquiry devoted to thinking about biological systems—actual ones on Earth and possible ones elsewhere—in a cosmic context.

Astrobiologists want to know how life emerges on worlds in general and in particular; they are curious, for example, whether Mars might host microorganisms akin to those found in extreme environments on Earth. In this scientific venture, microbes in such locations as salt marshes become meaningful as proxies for extraterrestrial life. Scientists read them not just for clues about Earth's past, present, and future but as a means for considering the category of life itself in a more ample, universalistic frame. Margulis's work on comprehending earthly life as transformative of planetary biogeochemistry has been centrally important to astrobiology—a field of inquiry institutionally established by NASA in the late 1990s though in existence in a slightly different version since 1960 as "exobiology."

At the astrobiology workshop, Margulis gave us a compressed, autobiographically organized chronicle of the Gaia hypothesis, which she joined Lovelock in developing in 1970. As she told us, this model originally emerged to look not at Earth but at Mars, to determine whether it might be possible to discern from a distance whether the red planet supported life. In 1965 Lovelock had been invited by NASA to design an experiment for detecting life on Mars. Using his expertise in gas chromatography, he wagered that the best way to look for life remotely would be to search for signs of metabolism in planetary atmospheres. As our workshop organizers, historians Steven Dick and James Strick, put it, Lovelock suggested that "the most obvious activity of living things which offsets entropy [is] that they keep the gas composition of a planetary atmosphere far from equilibrium."[1]

Margulis emphasized that the Gaia hypothesis did not suggest that the planet was some perfect Eden, as many critics have misunderstood it to claim. She pointed this out during our jaunt into the salt marsh: "The ocean is too salty. Does anyone know the pH of the ocean? Most biologists will say 7 because that's neutral and they want to be neutral. But it's not. It's 8 or so. The ocean is too salty." Fishes are often happier, she remarked, in the lower salt concentrations of water provided in aquariums. "Gaia is not God and didn't do anything perfectly." Margulis emphasized that Gaia could care less about humans. She dismissed, as well, the idea that Gaia demanded that Earth be considered an organism: "No organism can consistently eat and live on its own waste." If Gaia sometimes veers toward the romantic—a holistic vision of harmony—it also includes an attention to such baroque complexity as the never fully equilibrated relation between chemistry and biology.

How far can Earth or life be translated into theoretical terms that can float free of particular embodiments? If we follow Margulis on her travels in the salt marsh, the answer might be "not too far." Margulis periodically toted mud from Sippewissett back to her lab in Amherst, where she placed mats in nutritive media to see if spirochetes would materialize and attach themselves to other cells. As she wrote in 2004, "I believe that with much help from colleagues and students, we will soon be able to show that certain free-swimming spirochetes contributed their lithe, snaky, sneaky bodies to become both the ubiquitous mitotic apparatus and the familiar cilia of all cells that make such 'moving hairs.'"[2] For Margulis, living things were—are—forever incorporating one another, engaging not just in lateral gene transfer but also in lateral genome transfer.

But Margulis would not know how such incorporation works unless she actually ran an experiment, tried to jostle spirochetes awake to see what they might do next. In the language of rhetorician Richard Doyle, she worked in the realm of "wetwares," "encounter[s] with flesh as a refrain, a repetition of algorithms or recipes of sufficient complexity that only through instantiation can they be experienced."[3] In other words, Margulis's spirochetes produce a sign of life that needs to be *fed* to be *read*. The semiotics of life needs living things to signify, and those things cannot exist except in contingent, real time—coming into liveliness through such material activities as eating, which always happens in a web whose coordinates are never fully in place prior to their habitation and creation. "Life" is a set of relations of sustenance, operating across scales. There is no Platonic world of "life."

Margulis's biology, then, is a fully theoretical biology that does not permit theory to operate as an abstraction, to rove over or above the bodied enfleshments that are living things. In her 1995 book with Dorion Sagan, she addressed the question "What is life?" by delivering a distinct answer to the question for each of life's five kingdoms: bacteria, protoctists, animals, fungi, and plants—emphasizing neither some underlying logic nor an overarching metaphysics but rather the situated particulars of bacterial, protoctist, fungal, plant, and animal embodiment. Life was not something that could be compressed into the logic of a code but was a process ever overcoming itself in an assortment of bodied manifestations.

Thinking back on Lynn Margulis's leading of our crew into the Sippewissett time slip, then, I might put the lesson this way: life, like the sea, is an alien, a visitor always on its way toward fields of unexpected connection.

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The Cultural Dimensions

of Lynn Margulis's Science

WILLIAM IRWIN THOMPSON

When twentieth-century genetics was added to nineteenth-century natural selection, we were given a grand narrative of how the competition of individuals for survival and reproduction created an ecosystemic marketplace—one disturbed from time to time by catastrophes that knocked out a gene in random mutations caused by an errant cosmic ray or a falling star. A bolide or a supervolcano that darkened the atmosphere for years was presented as a rocky speed bump on the path of the evolution of the biosphere that could cause species within it to crash and become extinct.

Lynn challenged both these ideas of mutation and catastrophe. Mutations, she claimed, generally cause more damage than naturally selectable novelty, and catastrophes, like a horizon, are based on the observer's perspective. The oxygenated atmosphere produced by photosynthesizing cyanobacteria was not a catastrophe for bacteria but simply a change of address. The bacteria are still here, in our guts and at the bottom of lakes.

Or, to speak in the metaphors of my native Celtic animism that Lynn appreciated in my descriptions of her critters as "the little people," the dwarves like to work underground in the mines, but the elves prefer to