Microbial Muse: Drawing on Microbes for Inspiration

Through music, graphic design, poetry, photography, and metabolic alchemy, microbiology elicits distinctive artistic creativity

Peter Brannen

Visit systems biologist Peter Larsen at the Argonne National Laboratory in Illinois and you can expect to find a pile of CDs on his desk and a Pandora station tuned to the masters of improvisation. You might recognize John Coltrane, Thelonious Monk, Charlie Parker, or Miles Davis, or it could be less familiar offerings such as coccolithophores and nitrogen. Larsen looks for relationships between microbial populations and their environment.

Faced with ever-larger data sets, he hit upon a novel if unusual method for making big data sets tractable to humans interpreting them. “There’s only so much that a person can do to see patterns in these outrageously huge data sets,” Larsen says. “And on the other hand there’s only so much that a computer can do to see patterns in them.” Jazz is his solution.

The L4 station buoy floats near Plymouth, England, along the western end of the English Channel. For nearly a century, scientists have monitored these waters for oceanographic changes. In recent years, the station began sampling microbial populations in the surrounding waters. These populations, which worldwide are responsible for 97% cent of primary production in oceans— cycling vast amounts of carbon and other nutrients through their seasonal blooms— provide a key to understanding how energy and nutrients move around the planet, especially in response to a warmer, more acidic world.

The vastness of data collected at the L4, including yearly changes in temperature, sunlight, nitrate, chlorophyll, phosphorous, and acidity, as well as samples for DNA sequencing, is staggering. In Larsen’s song, “Fifty Degrees North, Four Degrees West,” parts of this massive data set are captured as a driving, off-kilter musical arrangement in which the microbial community responds sonically to changes in the ocean.

“You are in the key of sunshine and phosphorus,” Larsen says, explaining how those data are rendered in song. “So what you’re hearing is a chord progression based on the amount of sunlight at the surface of the ocean and the measured amount of phosphorus in the water.”

Seasonal variations of sunlight and phosphorus set the bass line beat, a regular, throbbing motif, while the microbes are the improvisers, responding to and constrained by these or other seasonal variations. In the musical score, data points are represented as notes for different instruments—piano, trumpet, xylophone, and steel drum— each of them representing different taxa of microbes, their growth behavior turned into sounds that wander uneasily over the beat. Larsen says this inspiration struck when he realized that fluctuations in microbial populations were framed by the physical parameters of their environment the same way a melody in jazz flirts playfully with a particular chord progression. “These relationships in jazz reminded me very much of the kind of relationships you see in natural systems,” he says.

SUMMARY

- Data-based musical scores are being evaluated as a way of analyzing marine microbial populations in constant flux.
- Micrographs of phytoplankton inspired a graphic designer to produce a montage of etchings, while serving as a microbiologist’s muse for poetry.
- Partly masked ultraviolet (UV) light enables bacteria to grow pointedly, forming portraits on petri plates.
- Extremophiles turn toxic gold salts into gold, which is used deftly for making portraits of these microorganisms.

Microbial Bebop

http://www.youtube.com/watch?v=pl3-MSSpuos

http://www.youtube.com/watch?v=Nk5lLVF4CWQ

http://www.youtube.com/watch?v=IRb3-J2ABYA

http://www.youtube.com/watch?v=EwZJj2k61ns

Bloom

http://www.whoi.edu/oceanus/feature/a-poem

Bacteriographs

http://sciencetothepowerofart.com/

The Great Work of the Metal Lover

http://adamwbrown.net/projects-2/the-great-work-of-the-metal-lover/

These data "tunes" are, above all, strange, and Larsen is uncertain whether there is any music like it. "If I'm in an extraordinarily generous mood it does have an avant-garde improvisational feel to it, but I think it is probably a mistake to say that what we are hearing is the same thing as music." Music, he is quick to add, is a product of the human condition, an effort to turn feeling into sound. "This is turning data into a sound. This is not music. This is a music-inspired process."

This unmusical quality is palpable in the arrangements, which sound occasionally inspired but often wander into unnerving dissonance, and rarely offer the sort of harmonic resolution so satisfying to the human ear. Nevertheless, jazz programs at several nearby universities have expressed interest in sheet music for Larsen's microbial bebop.

Larsen says that while the music itself is not likely to provide breakthroughs in analyzing microbial populations, or replace computer algorithms that sift through the terabytes of information looking for patterns, it makes the previously staggering data sets at least a little more accessible to the human researcher.

"Generating these sounds is probably never going to replace the bar graphs for analyzing data," he says. "But I do very strongly believe that the process of thinking about the data and approaching it in a new way absolutely does lead to additional insight. But, for the most part, the music itself is, I think, its own end."

Images of Phytoplankton Inspire Etchings and Poetry in "M'Ocean"

While Larsen was inspired to create music based on data describing marine microbes, poetry is the muse for marine biologist Elizabeth Halliday from the Woods Hole Oceanographic Institution in Woods Hole, Mass. A month-long research cruise surveying phytoplankton blooms in the Ross Sea off Antarctica fired her poetic impulses. "We were taking pictures of what we were seeing through the microscope, doing DNA studies and a few small-batch experiments looking at predation on the bloom," she says. "It was really an amazing and inspiring experience."

Gazing at phytoplankton through her microscope, Halliday came to be enchanted with their brilliantly intricate and endlessly beautiful world. Scientific journals, Halliday says, fail to convey the full wonder and beauty of, say, diatoms, which along with other types of phytoplankton, are responsible for producing much of the oxygen in our atmosphere.

"Oh they're gorgeous," she says. "I think they're absolutely beautiful, and you might not think that some little single-celled algae from the ocean would be. People are always surprised to see the beautiful structure of their glass skeletons. From the perspective of a scientist, I see beauty in my research all the time, and it's really hard to convey that beauty to a broader audience."

Last year Halliday was given a venue to express that beauty, thanks to the Synergy project, which pairs scientists with artists to bridge the gap between the disciplines and to make otherwise obscure research findings accessible to the wider public. Halliday described a session of "speed dating" between the scientists and artists in which she and graphic designer Janine Wong paired off to bring the inherent beauty of the specimens displayed on Halliday's microscope slides to vivid artistic life.

Wong used micrographs from specimens collected on an Antarctic cruise to produce copper plate etchings. She then overlaid those etchings on atmospheric backdrops to evoke the stages of phytoplankton blooms that can be viewed from space. Halliday's own verse accompanied these works in the book *Bloom*, pages of which were displayed through June 2013 at the Museum of Science in Boston (Fig. 1). In it, Halliday describes organisms "sculpted of silica, structures

FIGURE 1

Elizabeth Halliday of the Woods Hole Oceanographic Institution (WHOI) in Woods Hole, Mass., collaborated with Janine Wong, a graphic designer and book artist, to create *Bloom*, a book inspired by the ocean's voluminous seasonal phytoplankton blooms. *Bloom* included prints made by Wong, inspired by photographs of phytoplankton; diagrams and thoughts from the lab notebook of Massachusetts Institute of Technology/WHOI graduate student Sophie Clayton; and a poem written by Halliday.

of hydrated glass/honeycombed with pores, each pore a portal between cell and sea."

Describing the detritus of dead diatom blooms falling through the water column "like snow" Halliday writes of bacteria that, "turn life back into building blocks, the raw riches/that eventually will rise again, conveyed by currents to fuel blooms of future centuries."

Initially, instead of poems, Halliday wrote an essay to accompany Wong's artwork, but the artist found that draft freighted with jargon, Halliday says. "She [Wong] said, 'No one's going to come to a museum and read this essay.' But she highlighted a few things she liked and she said, 'I see a poem in this.'"

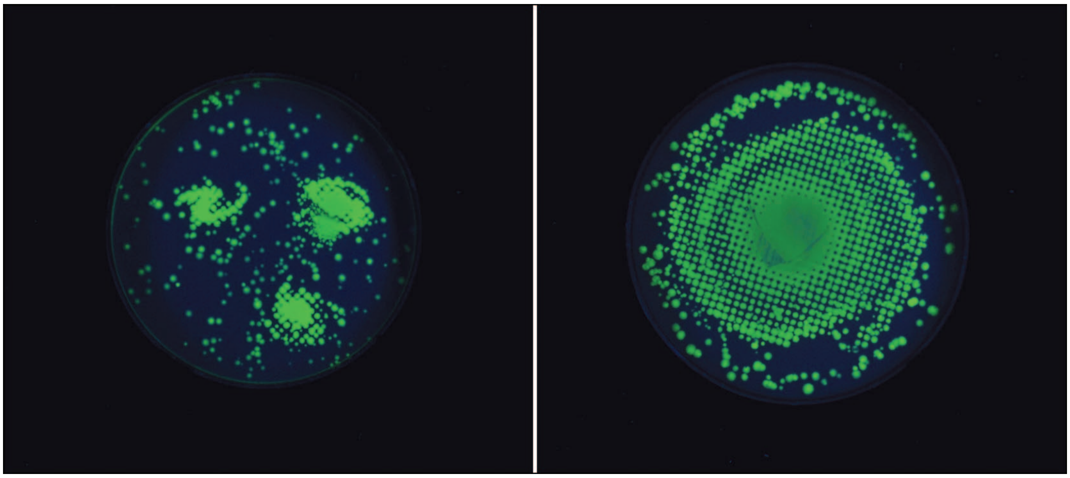
After massaging the most evocative passages and recasting the essay as an ode to the microscopic world, Halliday says she remains nervous seeing her first attempts at poetry on public display, while also being thrilled with the final product. "I love it. I think it showcases plankton in all their glory."

Bacteriographs: Portraits on Petri Plates

For Zachary Copfer, making art led to his leaving the laboratory. After completing his undergraduate degree in biology, he went to work for a pharmaceutical company in a microbiology lab. He found the job rote and uninspiring. "I loved biology classes when I was in the university," he says. "It was fun solving mysteries everyday but then once I got to the commercial lab it was, 'run this sample, run that sample.' I saw the same organisms all the time. It wasn't any fun. Honestly, I forgot what I loved about science."

In the meantime, Copfer nursed a love of photography, quit his job at the commercial lab, and enrolled in a program offering a master's degree in art at the University of Cincinnati. After muddling through his first year in search of an artistic vision, he caught a few reruns of Carl Sagan's *Cosmos*. The earnestness of the classic 1980 television miniseries reawakened his latent

FIGURE 2



Two of Zachary Copfer's bacteriographs of galaxies made with luminescent bacteria.

love of science and, like a bolt from the blue, inspired a heretofore unknown artistic medium.

"I was driving around one day and [suddenly realized] I could grow photographs from bacteria," Copfer says. He also recalled learning about a lab technique in which different materials were tested for UV resistance by placing them over one half of a bacteria-seeded petri dish. If the material effectively blocked the UV radiation, bacteria grew over one-half of the dish grew but failed to grow on the other half, with a neat line of demarcation dividing the two.

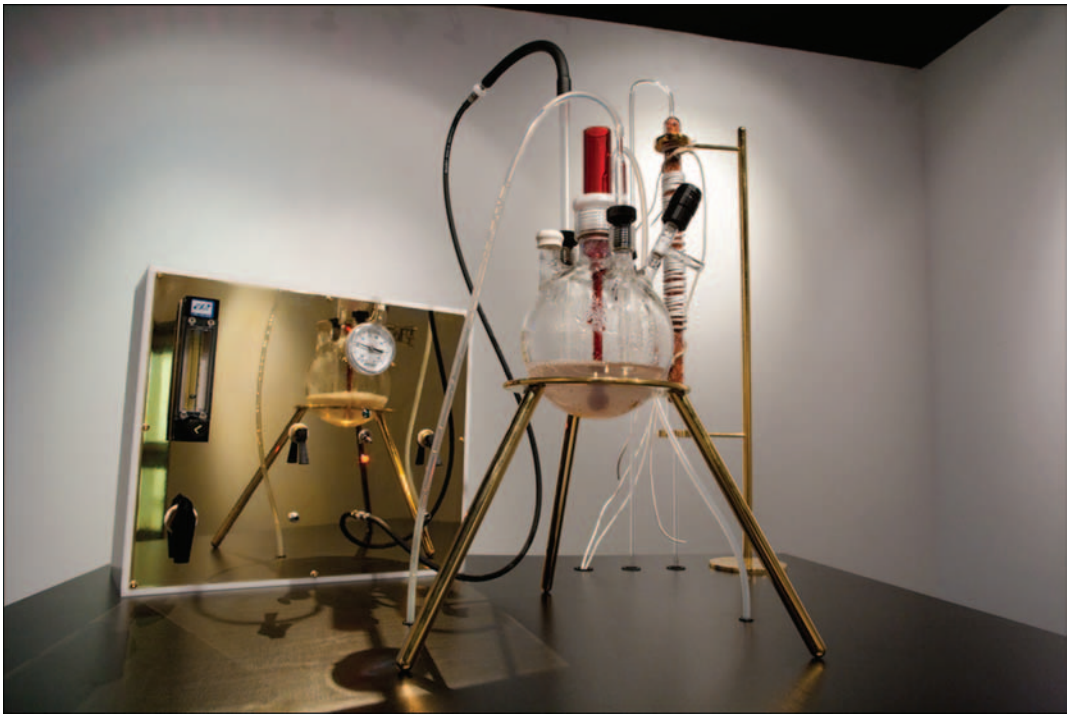
"I thought, 'well I could just make a photographic negative,'" Copfer says. "I could use that same technique and make an actual picture." He set to work with gram-negative *Serratia marcescens* bacteria, which commonly form red or pink streaks along the grout between tiles in damp bathrooms, but which also can cause urinary tract or gastrointestinal infections. The organism boasted weak resistance to UV and an arresting red hue when grown at room temperature. After irradiating a petri dish through a negative, Copfer lets the image develop as the bacteria grow, and then seals the resulting image in acrylic and resin. The portraits have a stippled, newspaper-like quality, a result of the binary nature of bacterial growth, and gradations are achieved by varying sizes of bacterial clusters on the dish.

Copfer's first "bacteriographs," as they came to be known, were portraits of Darwin, Einstein, Leonardo, and Picasso, as a way of exploring the bridge between scientific and artistic thinking. "They're both of the same nature," he says. "They both essentially involve creative problem solving. Einstein and Picasso were exploring the same thing, the idea of three-dimensional space. I got a huge reaction from everybody when I left science and went into art because people thought it was such a strange transition. But I said, 'no, it's really the same thing.'"

More recently, Copfer began using other microorganisms and exposing them to different nutrients and growth conditions as a way of expanding the versatility of his new artistic medium. For instance, Copfer favors *Escherichia coli*, which is not as colorful as *S. marcescens*, because of its ease of manipulation—embracing an appreciation for this species that he now shares with countless microbiologists. In the installation "Star Stuff," Copfer genetically modified *E. coli* to express green fluorescent protein by introducing a segment of DNA isolated from jellyfish. Copfer created bacteriographs of galaxies from the luminescent bacteria colonies, arranged them all over the walls of the Sycamore Gallery in Cincinnati, turned off the overhead lights, and turned on the black (UV) lights. The installation pays homage to Carl Sagan, and the galaxies glow with the warmth of billions and billions of bacteria (Fig. 2).

"When I was bored in the lab and forgot about science, photography kind of served the exact

FIGURE 3



Adam Brown's art installation "The Great Work of the Metal Lover." http://adamwbrown.net/projects-2/the-great-work-of-the-metal-lover/

same purpose for me," Copfer says. "I was using it to investigate everything around me in a physical sense and in a spiritual sense. Now I use the scientific method and scientific thinking in exploring and creating my process. But to me science and art are just methods of inquiry. I'm trying to dissolve the borders between them."

Microbial Alchemy: Gold Salts into Purer Gold for Painting Extremophiles

At Michigan State University (MSU), associate professor of electronic art and media Adam Brown is reframing the age-old dream of alchemists, who toiled vainly to transform base metals into gold. As Brown reveals in his museum installation, "The Great Work of the Metal Lover," the philosopher's stone—that elusive substance capable of catalyzing such a transformation—is an extremophile (Fig. 3).

Brown bathes extremophile bacteria in liquid gold chloride, which can be highly toxic, sealing them within an anaerobic bioreactor and forcing them to metabolize the gold chloride, spinning out usable 24-carat gold in the process. One part of the exhibit is the laboratory experiment itself. The second part is a series of portraits captured by a scanning electron microscope of the newly created gold flecks in their bacterial realm. Brown painstakingly applies the gold produced in the lab equipment to the greatly enlarged pictures.

Following a trip to Yellowstone, Brown's interests in alchemy converged with another passion of his, origins-of-life research. A former biomedical engineer, Brown traveled to the national park to learn more about the extremophile bacteria and archaea that might be examples of early, if not the first, life forms on Earth. Extremophiles thrive in conditions once thought entirely unsuitable for life, whether in boiling waters, extreme salinity, heavy radiation, no oxygen or highly corrosive and toxic conditions—much like that of a bioreactor containing high levels of gold chloride. That last idea was inspired by the work of his MSU colleague and friend Kazem Kashefi, an assistant professor of microbiology and molecular genetics, who helped Brown create the installation using the organism *Cupriavidus metallidurans*.

"I read a paper that he wrote in 2000 that showed that these extremophile bacteria were able to precipitate heavy metals and even gold," Brown says. "When I saw that I was amazed. So it started out as a simple question. Was it possible to create a biological system where you could make enough gold so that you could see it in the palm of your hand with the unaided eye?"

Mastering techniques for working with anaerobic bacteria is almost an alchemical skill itself, Brown says and, like the alchemists of old, he apprenticed with Kashefi to learn the exceedingly difficult trade of the anaerobic microbiologist. "People who work with these organisms jokingly refer to the people who work with aerobic organisms as 'soup doctors' because you don't have to worry about maintaining the strictly anaerobic integrity of the air around the organisms," Brown says.

There are 10 parts per million of dissolved gold in the Earth's oceans, Brown continues, and chemists have searched in vain for reasonable ways to access this diffuse deposit. He remains uncertain whether his process can be scaled to a commercially feasible gold-harvesting operation, but he is not particularly interested in pursuing the answer. "Just because you can doesn't necessarily mean you should," he says. "How do we know that organisms in the ocean ecosystems don't depend on dissolved gold for metabolic processes."

This hubristic human desire to shape the natural world to our own ends is at the heart of his masterpiece, "The Great Work of the Metal Lover." His work, he says, sheds light on the modern quandary of genetic modification (of the same kind evident in Zachary Copfer's glowing bacteria). "What's interesting is that 1,000 years ago or more, we were having the same sort of debate," Brown says. "Now you can get a kit and do a sort of do-it-yourself garage hacking of *E. coli*, but alchemy was also very much about this notion of perfecting nature. There was a big debate even back in the Renaissance between the artists and the alchemists about whether it was alright to bend nature to our will to make it better than nature itself."

Brown's work asks us to grapple with this human propensity. Like the other artists and scientists who have attempted to bridge cultural and epistemological worlds, Brown sees little division between artistic techniques and scientific ones. "I think artists are starting to see there's this huge world science offers that's really unexplored and untapped," he says. "For instance there's a 1,000-year history or more of painting. It's really hard to make new paintings. But let's say I'm going to work with laboratory experiment processes. Almost anything I touch is uncharted territory."