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Understories: A Common Ground For Art And Science

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The most commonly told story of modern art and science in the so-called West is one of increasing divergence. If the Renaissance was defined by Da Vincian polymaths equally engaged across fields of anatomy, art, and engineering, the Enlightenment ushered in the logic of specialization. As the arts, sciences, and humanities became distinctly siloed in their methods, so the story goes, "scientific reasoning" also became a dominant social ideology. No longer one possible framework amongst others – a method of analysis more or less appropriate to a given problem – scientific reasoning, instead, became the unacknowledged assumption structuring modern thinking, living, and even governing. Within such a story, art and science most often struggle as dueling forces. Within such a story, contemporary artistic practice would seem to demand relentless, oppositional critique of the scientific worldview.

There is another story, though, which can be pulled from the threads of each field's internally defining, and occasionally cross-pollinating, struggles. This is not a story about art and science as oppositional practices, but rather of their parallel negotiations and generative resonances. It is a story that unfolds between the autonomy of the work of art and the genetic isolation of discrete organisms. It is also a story that brings into focus overlapping tensions between abstraction and materiality, the universal and the particular, and the all-important question of what spaces remain open to wonder and contingency. Perhaps most vitally, it is a story that aims not to distill some descriptive unifying history between these fields, but rather to speculatively explore what connections these reverberating struggles might open in our present.

Plasticity

In biology, the focus on organs, organisms, and environments, prominent in the 19th century, shifted to a focus on genes, as biology became a science of "information, communication, automation, and systems theory."[1] Evolution went from being the paleontological reconstruction of ancient fossils to becoming the mathematical analysis of gene frequencies. Embryology went from being a science of organisms and tissues to becoming the cellular readout of inherited genes. However, this 20th century view of life, where abstraction provides certainty and the unity beneath appearances, is being replaced. While many programs in biology continue from one century to the next, the biology of the 21st century stands in stark contrast to the biology of the 20th century. The reductionist analytical tools of the late 1990s have, ironically, revealed a world where processes are more critical than entities, and where "competition cannot be separated from numerous flavors of cooperation"[2]. Processes from the periphery of biology have moved toward the center. These processes include plasticity, mutualistic symbiosis, and extinction.

The 20th century has been called "The Century of the Gene," bracketed at one end by the rediscovery of Mendel's mathematical "laws" of inheritance, and at the other end by the sequencing of the human genome[3]. It was an incredibly productive and exciting century, a time when the discovery of the DNA structure explained how biological inheritance could be transmitted through physical molecules, a time when the elucidation of the genetic code enabled us to understand how proteins were made and how metabolism sustained life, and a time when the evolutionary relationships of animals and plants could be elucidated by comparing their DNA sequences.

However, molecular tools revealed that the genome does not encode for a particular outcome, a particular phenotype. Rather, the genome is a repertoire of possible phenotypes. The sex of a turtle, for instance, is not controlled by genes, but by temperature (making it vulnerable to global climate change). Organisms evolved to respond to different environments by activating different genes. Many organisms alter their development when the embryo or larva senses a predator. Such organisms will channel their development to make defensive structures (such as larger muscles, bigger bodies, or lymphocytes), often at the expense of reproductive organs that won't get used until later. In mammals, a pregnant mother's diet can affect the genes active in her offspring's liver. Plasticity is not peripheral to life; it is a characteristic of life[4]. The view that Richard Dawkins proposed, where organisms are just survival machines for the genes that built them, is so twentieth-century. The environment and organisms have agency, as well as the genes.

Some of the most incredibly plastic organisms are the social amoebae, often known as **slime molds**. These are single-celled organisms that eat bacteria they find on the dead leaves of a forest or field. But when the bacteria are no longer plentiful, the single cells undergo a dramatic change. They link together, forming streams, then aggregates, then large masses containing tens of thousands of cells. The cells within these masses organize – some become leaders, some become followers, and the new composite organism starts migrating. When it reaches a sunlit spot, migration ceases and the leading cells form a stalk, hoisting upward the posterior cells. These posterior cells become spores, shutting down their metabolism and acquiring a hard shell. These spores are then dispersed into the wind, possibly to find new logs where bacteria are plentiful. The stalk cells die, having sent the spores on their way[5]. Here, the environment – food availability – has changed many starving single-celled organisms into a single multicellular organism that can create new cell types that promote its survival.

Mutualistic symbiosis

The biology of the 20th century rested on two pillars it acquired from the late 19th-century biology: a competitive model of evolution and the view that bacteria and viruses are predators. Bacteria and viruses were declared to be outlaws, dangers to our pure but susceptible bodies. The past century saw the eradication or taming of some of humanity's most virulent scourges – smallpox, Rubella, polio, diphtheria, and whooping cough, among others. But as microbiology became a medical science, the knowledge and study of most microbes, non-pathogenic microbes, was banished to the periphery. However, in the early years of the 21st century, detailed molecular accounts of animal development and health announced that normal development and normal health depended on having "good" bacteria. Mutualistic symbiosis – the ability of organisms of different species to cooperate for their mutual good – is the signature of life on this planet[6].

Lichens, of course, are exemplary symbioses of algae and fungi. Lichens don't exist without the algae and at least two species of fungi coming together[7]. The fungi give the algae a place to reside; the algae can perform photosynthesis, giving food to the common organism. But lichens are only the most obvious example of plant-fungi symbioses. Most trees have symbioses between their roots and mycorrhizal fungi. Such fungi are like drinking straws for the roots. Extending the roots of the aspen, they bring in nearly 90 % of the tree's phosphorus and 80 % of its nitrogen. The tree provides the fungus with the sugars that its leaves make through photosynthesis[8]. Cooperation must take its place beside competition. Mycorrhizal fungus is essential when replanting pine forests and may be critical in its surviving climate change[9]. Sometimes, reproductive fruiting bodies – Matsutake and chanterelle mushrooms – appear out of these underground fungal mats. Algae are also important symbionts. In animals, algae are critical symbionts in coral. Here, they sustain the coral by providing it with sugars and oxygen. The coral, in turn, forms the basis for the entire reef ecosystem.

However, the most critical symbionts are bacteria, and among them are the organisms responsible for our planet's life – **Cyanobacteria**, the photosynthetic blue-green bacteria. About 3 billion years ago, these organisms caused the Great Oxygenation Event, pouring oxygen into the atmosphere for nearly a billion years. About 25% of the oxygen in our atmosphere today is the product of their continued photosynthesis[10]. One species, *Prochlorococcus marinus*, may be the most abundant organism on the planet – there are around 3 octillion of them (3×10^{27}, about as many as there are atoms in a ton of gold). These bacteria can be a blessing or a curse for the future inhabitant of earth. As symbionts, Cyanobacteria-plant complexes appear responsible for creating much of the biologically usable nitrogen in the northern Atlantic Ocean[11]. Important and unseen, some of the these photosynthetic cyanobacteria once participated in the grandest symbiotic feat of all time, invading cells to become the photosynthesizing chloroplasts that enable the life of plants, and thus of animals and fungi[12]. However, the warming of polluted water can also initiate zones of explosive cyanobacteria growth, which has caused the death of hundreds of thousands of fish. Context determines how we view any organism.

Symbioses also form the basis of animal life. We think of cows and termites as eating grass and wood. However, the genomes of neither of them have any genes that allow them to digest these plant cell walls. Rather, the digestion of cellulose and wood is done by communities of microbes living inside their guts. About 50 % of the cells in the human body are bacterial, and we usually acquire them as we pass through the birth canal or get held. These symbionts don't just travel with us. They help finish building our capillaries, our nervous system, and our immune system. And once we develop, they help keep us going, helping to keep our immune systems and nervous systems functioning[13]. We are never individuals in the old sense. Each of us in not only an organism, we are also a biome, a collection of ecosystems. The name for our bodies, including both the zygote-derived cells and the symbionts, is "**holobiont**", the bodily consortium of several species[14].

We are all lichens, partnerships that are necessary for survival. Twenty-first century biology has become a science emphasizing reciprocal relationships and processes, not entities. The new centers of life are cyanobacteria, lichens, mycorrhizae, and coral.

Extinction and survival

Whereas 19th-century and 20th-century biology had assumed lush and vibrant ecosystems, 21st-century biology is a catalogue of continuing loss. We live in the Age of the Sixth Extinction[15] , the Anthropocene, not in the robust nature of Darwin or von Humboldt. In the past 50 years, more than 97 % of bluefin tuna are gone and probably 80 % of all flying insects. Our narratives of nature went from those of a dramatic novel to those approaching apocalyptic horror. "There are the functional extinctions, the extinction cascades, the extinction vortices... Relationships unravel, mutualities falter, dependence becomes a peril rather than a blessing, and whole worlds of knowledge and practice diminish. We are looking at worlds of loss that are much greater than the species extinction numbers suggest"[16]. Biologists are left studying DNA sequences and the sickened survivors of an ongoing mass extinction. Biologists who have studied a certain species for decades mark the extinction its last member and become "speakers for the dead"[17].

The organisms becoming emblematic of the Anthropocene are **fungi**. Lacking the locomotion of animals and the photosynthesis of plants, fungi are the archetypal detritovores, metabolizing dead animals and plants back into soil. Throughout the West, they have been emblematic of decay and degeneration. Now, they are being revitalized as emblems of obstinance, resourcefulness, and regeneration. For Anna Tsing[18], fungi are the embodiment of sisu: clever, resilient survivors. Fungi are moving from the periphery to the center of biology. They know how to play with others to form holobionts, and they can live at the extremes and in depleted environments. As the extreme becomes the new normal, we behold fungi.

And yet, fungi have not traditionally been given much space in either biological science or the fine arts. Neither political humans, active animals, nor beautiful plants, they defy easy definition and so are found only lurking in the margins. Stroll a few blocks from Kiasma to the Ateneum and view Ferdinand von Wright's 1886 masterpiece, *The Fighting Capercaillies*. It is Darwinian sexual selection at its climax: the contest between two taut cocks, their feathers flying, being observed by us and, more importantly, by the well-camouflaged hen in the background. But look in the foreground, on the fallen birch. There is a third observer, a beautifully rendered polypore fungus, quietly converting the dead tree into soil while the animals perform their frenetic mating ritual. The contest is framed by a perimeter of *Cladonia*, *Hypogymnia*, and *Rhizocarpacae* lichens. Alma Heikkilä brings these same fungi and lichens to the center of her work, not only through descriptive observational rendering, but also through the generative operations of her creative practice. Heikkilä does not shape inert matter into some predetermined abstract form, but rather facilitates a space in which we're able to perceive the inherent liveliness of these materials and the force of their comings-together.

Fungi are marked by ambivalence. While some fungi are necessary symbionts of lichens and pines, other, pathogenic fungi are the agents of putrescence and death. Fungal pathogens are spreading rapidly throughout the warming world, leaving dead forests and dead amphibians in their wake[19]. *Mycosphaerella pini*, which kills Scots pine, had not been seen in Finland before 2009, when it arrived here from central Europe[20].

Nature has changed, and with it, humanity. Says Tanya Steele, chief executive of the World Wildlife Fund[21], "We are the first generation to know we are destroying the planet and the last one that can do anything about it." We have helped make the world safe for fungi; we are causing the Sixth Mass Extinction on this planet; and we bear the anxiety that we may have become our own executioners.

To be sure, responsibility is not shared equally. As Heschel[22] said, "In a free society some are guilty, but all are responsible." Can and how do we redeem ourselves? Can art and science, together, support an ethic of "being in right relationship" and "becoming with the other"?[23] And if it can, will it matter? Is this new relationship we recognize in symbiotic earth, Gaea, mirrored in our holobiont bodies, which are themselves complex ecosystems? Becoming with the other always involves recognition, maturation, and transformation. "Relationship between all things appears to be complex and reciprocal, always at least two-way, back and forth. It seems that nothing is single in this universe, and nothing goes one way."[24] In the hidden parliaments of the earth, in the grand interactions of the understory beneath our feet, in the accumulated wisdom of slime molds, mushrooms, lichens, and cyanobacteria, may reside the stories of reciprocity, cooperation, competition, and integration we need for survival. Can art and science, together, mediate that?

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1 Waddington, C. H. 1970. *Behind Appearance: A Study of the Relations between Painting and the Natural Sciences in this Century*. MIT Press, Cambridge.

2 Powers, Richard 2018. *The Overstory*. W. W. Norton & Company, New York.

3 Keller, E. F. 2002. *The Century of the Gene*. Harvard University Press, Cambridge.

4 These and many examples mentioned here can be found in: Gilbert, S. F. and Epel, D. 2015. *Ecological Developmental Biology*. Sinauer Associates, Sunderland, MA; Sultan, S. 2015. *Organism and Environment*. Oxford University Press, Oxford.

5 Bonner, J. T. 2009. *The Social Amoeba: The Biology of Cellular Slime Molds*. Princeton University Press, Princeton. Also, his video: https://www.youtube.com/watch?v=vjRPla0BONA

6 Margulis, L. 1999. *Symbiotic Planet*. Basic Books, New York. See also (5).

7 Tuovinen, V., Ekman, S., Thor, G., Vanderpool, D., Spribille, T. and Johannesson, H. 2019. Two basidiomycete fungi in the cortex of wolf lichens. *Current Biology* 29: 1-8.

8 Schaechter, M. 2017. Fine Reading: Unearthing the roots of ectomycorrhizal symbioses. https://schaechter.asmblog.org/schaechter/2017/04/fine-reading-unearthing-the-roots-of-ectomycorrhizal-symbioses.html

9 Park, J. L., Linderman, R. G., and Black, C. H. 1983. The role of ectomycorrhizas in drought protection of Douglas fir seedlings. *New Phytologist* 95: 83-95; Smith, J. E. 2016. Multi-host fungi may facilitate migrations of pine species with climate change. https://www.fs.fed.us/research/highlights/highlights_display.php?in_high_id=673; Cripps, C. 2009. Using thread-like fungi to help high elevation pines grow. https://www.sciencedaily.com/releases/2009/07/090717150250.htm

10 Flombaum, P. and several others. 2013. Present and future global distributions of the marine Cyanobacteria *Prochlorococcus* and *Synechococcus*. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3683724/ *Proceedings of the National Academy of Sciences USA* 110: 9824–9829. Chisholm, S. 2008. The tiny creature that secretly powers the planet. https://www.ted.com/talks/penny_chisholm_the_tiny_creature_that_secretly_powers_the_planet?language=en

11 Harding, K., Turk-Kubo, K. A., Sipler, R. E,. Mills, M. M., Bronk, D. A., and Zehr, J. P. 2018. Symbiotic unicellular cyanobacteria fix nitrogen in the Arctic Ocean. https://www.ncbi.nlm.nih.gov/pubmed/30538206 *Proceedings of the National Academy of Sciences USA* 115: 13371-13375.

12 López-García, P., Eme, L., and Moreira, D. 2017. Symbiosis in eukaryotic evolution https://www.ncbi.nlm.nih.gov/pubmed/28254477 *J. Theor. Biol*. 434: 20-33. Doi: 10.1016/j.jtbi.2017.02.031.

13 Lehtimäki, J., Sinkko, H., Hielm-Björkman, A., Salmela, E., Tiira, K., Laatikainen, T., Mäkeläinen, S., Kaukonen, M., Uusitalo, L., Hanski, I., Lohi, H., and Ruokolainen, L. 2018. *Proceedings of the National Academy of Sciences USA* 115: 4897-4902.

14 Gilbert, S. F., Sapp, J., and Tauber, A. I. 2012. A symbiotic view of life: We have never been individuals. *Quarterly Review of Biology* 87: 325–341. See also (5).

15 Kolbert, E. 2014. *The Sixth Extinction*. Henry Holt, New York. The fifth extinction was the demise of the dinosaurs and nearly 75% of the earth's species some 66 million years ago.

16 Rose, D. B. 2017. Shimmer: When all you love is being trashed. In Tsing, A., Swanson, H., Gan, E., and Bubandt, N. (eds) *Arts of Living on a Damaged Planet: Ghosts of the Anthropocene*. University of Minnesota Press, Minneapolis and London. Pp. G51-G63.

17 Haraway, D. J. 2016. *Staying with the Trouble: Making Kin in the Anthropocene*. Duke University Press, Durham and London.

18 Tsing, A. 2017. *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins*. Princeton University Press, Princeton and Oxford.

19 Linnakoski, R., Forbes, K. M., Wingfield, M. J., Pulkkinen, P., and Asiegbu, F. O. 2017. Testing projected climate change conditions on the *Endoconidiophora polonica* / Norway spruce pathosystem shows fungal strain specific effects. *Frontiers in Plant Science* 8 DOI: 10.3389/fpls.2017.00883

20 Müller, M. M., Hantuala, J., and Vuorinen, M. 2009. First observations of *Mycoshaerella pini* on Scots pine in Finland. https://apsjournals.apsnet.org/doi/abs/10.1094/PDIS-93-3-0322B *Plant Disease* 93: 322.

21 Steele, T. 2018. Wildlife population report. World Wildlife Fund. Cited in Pichetta, R., 2018. This is the 'last generation' that can save nature, WWF says. naturehttps://edition.cnn.com/2018/10/29/health/wwf-wildlife-population-report-intl/index.html

22 Heschel, A. J. 1962. *The Prophets*. Harper Collins, New York. P. 19.

23 Haraway, D. J. 2016. *Staying with the Trouble: Making Kin in the Chthulucene*. Duke University Press, Durham and London.

24 Le Guin, U. K. 2017. Deep in Admiration. In Tsing, A., Swanson, H., Gan, E., and Bubandt, N. (eds) *Arts of Living on a Damaged Planet: Monsters*. P. M15. University of Minnesota Press, Minneapolis and London.