Designing Technology for a Symbiosis Between Natural Systems and Information Infrastructure

Matthew Halpenny
Computational Arts, Concordia University
Montreal, Canada
matthew.halpenny@gmail.com

Abstract

This paper is an intermediary between the bio-art sculpture *Mycocene* (2018) created by the collective somme, and the theory that led us towards creating it. *Mycocene* is a hybrid work that blends bio-art, sculpture and media art through the methodology of bricolage. It critiques the current human-technological relationship and its subsequent effects on the environment. Humans have created a symbolic bubble around themselves that attempts to separate them from the natural world. *Mycocene* acts as a conceptual bridge between this anthropocentric bubble and the natural, aiming to exist as the opalescent residue between them and a discussion point around dissolving their membranes.

Keywords

Technosphere, Physarum polycephalum, mycology, systems theory, sentience, autopoiesis, complexity, biosphere, homeotechnology.

Introduction

In this essay I try to grapple with large-scale questions around the human-technological-biological relationship, informed by theories that were influential in the creation of my collective's work *Mycocene. Mycocene* is a bio-art sculpture that occupies a small isolated room. The sculpture explores the relationship between biological systems and information communication technologies (ICTs) through its use of six sculptural segments. In the center of the room a colony of slime mold is housed in an isolated container. Its container is connected to the five other sculptural segments positioned around the space. Each of these segments is composed of discarded electronic waste (e-waste) fashioned into automated, kinetic forms. The automation within the "obsolete" e-waste sculptures is activated by the bioelectrical rhythms of the slime mold, monitored throughout the duration of the exhibition. *Mycocene* is largely informed by three main theories: Peter Sloterdijks's concepts of spheres (and subsequently Peter Haff's concept of the technosphere); systems theory, autopoiesis, and boundary formation; and Sloterdijks' concept of homeotechnologies using the fungal "ecological internet" as a model.

Spheres & Bubbles

The Earth is divided into four spheres, the atmosphere, hydrosphere, geosphere, and biosphere. We exist in the biosphere—a term coined by geologist Eduard Suess in 1875—that constitutes an interconnected web of plant, animal, fungal, and microbial life. [1] The word sphere denotes a surrounding, a space that encapsulates yet separates. The biosphere is omnipresent, it is a vast ecological system containing smaller ecosystems, all of which are constantly keeping themselves in balance through processes such as growth, decomposition, and energy exchange. Though omnipresent, any *sphere*, such as the biosphere implies a separation. It's important to note separation does not necessarily equate to isolation but a constant state of boundary formation and reformation. These boundaries are still permeable to certain processes of information and energy exchange. While semi-separate, each sphere delicately affects and balances the others while having their own internal processes. The German philosopher Peter Sloterdijk's theory on spheres helps us look at the immaterial construction of spheres. [2] He claims that humans have gradually constructed a binary between themselves and the natural world by surrounding themselves in the comfort and order of the technological. In his words, humans have been "building artificial 'spheres' in order to immunise – i.e. protect—[themselves] against the threatening outside world." [2] This technological immunization lets us feel in control of our environment, but its order operates entirely outside the sphere of the biological.

We have reached a point of saturation in our technological evolution. Our mass production of electronic technologies has forced a wedge into the biosphere, causing it to pop and foam into two—the biosphere *and* the technosphere. The term technosphere was first used by the geologist Peter Haff, in what he describes as the "physical properties of a human-technological system that takes on a role equivalent to the biosphere." [3] The sheer amount of material produced to create our information-era landscape has become so large it is not only affecting the geological record but the operations of other spheres as well.

Figure 1. The material component of the technosphere is present in the totalities of electronics both produced and discarded. ©The Basel Action Network

On one side, the biosphere is self-sufficient, autonomous, and, in a sense, balanced. Energy is spread among ecosystems; when one organism dies, it is decomposed, reabsorbed and redistributed. The biosphere involves all organisms in a back-and-forth exchange of energy, feedback, and adaptation. The technosphere is completely non self-sufficient, it relies entirely on humans for its maintenance and distribution. When electronic technologies reach the end of their life, they have no means to recycle their minerals and become waste (Figure 1). This problem manifests in the form of "end-of-life" electronics, a product of Capitalism speeding up technological innovation in the name of profits. Electronics are constantly produced and replaced so we can usher in faster and better modes of information transfer (i.e. 4G, LTE, Fiber-optic internet). [4] The process of making these electronics mines and destroys the Earth, and when they expire, they are discarded, leeching toxic chemicals into the Earth's soil or oceans wherever they land. The issue here is that the current paradigm around technological production (and usage) does not reflect the way the biosphere operates.

Autopoietic systems

In opposition to current technological models, the biosphere relies on the concept of self-regulation to maintain itself. The biosphere is not truly balanced but instead relies on the concept of adaptation and evolution, which operate under the principles of complex adaptive systems (CAS). CAS is a theory stemming from general systems theory, first described by the biologist Ludwig von Bertalanffy in the 1940's. "General systems theory implies that a system is a cohesive conglomeration of interrelated and interdependent parts that is either natural or man-made… Changing one part of the system usually affects other parts and the whole system, with predictable patterns of behavior." [5] To understand systems within the biosphere, we need to think in scales. We must consider systems within ecosystems, systems within organisms within ecosystems, systems within cells within organisms, and so forth. All these biological systems have a common thread, feedback. Early ecology perceived biological systems as fixed and predictable, whereas AST views them as adaptive and self-regulatory. From single cells up to complex organisms like humans, regardless of nervous systems, we see self-organization and adaptation through feedback. When confined within boundaries, such as a cell wall, this organization is a self-regulation called autopoiesis. The term was introduced in 1979 by the biologists Humberto Maturana and Francisco Varela to explain the self-maintaining chemistry of living cells, a process which may be paraphrased as:

> "a system organized of self-referential components that consist of a network of processes of production (transformation and destruction). Through their interactions and adaptations, they continuously regenerate using the system's network of relations. They constitute the system as a unified topology within the space they exist, defining boundaries from their environment without closing off information exchange" (Figure 2). [6]

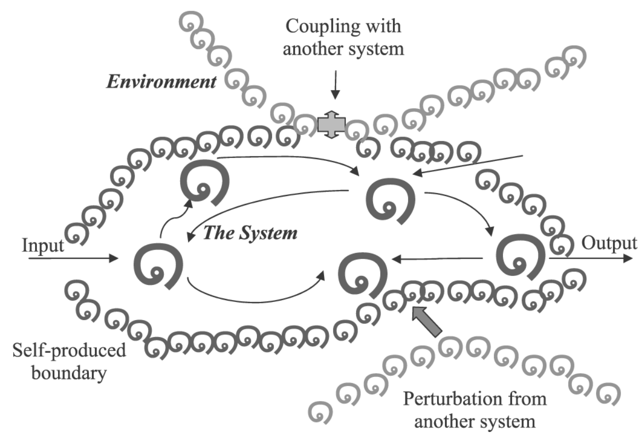

Figure 2. Autopoiesis diagram highlighting internal self-regulation, boundaries, and information exchange.

Feedback can either be control based (negative) or consuming (positive). To self-regulate, a system must go against the second law of thermodynamics - that entropy increases within isolated systems. To do this autopoiesis governs regulation via negative feedback loops. As an example, let us think of a home thermostat. In order to monitor temperature, it will sense actions from its exterior environment (the room) and then respond in order to regulate how much or little it needs to act on the environment to maintain a constant temperature. In simplified terms, one can represent this action in a while loop, a code-based control flow (Figure 3)In our thermostat scenario, TRUE is assumed to be met until it heats the environment to a set temperature, otherwise it is FALSE and discontinues heating. This is a control mechanism due to the fact entropy will always try to destabilize this regulation through the escape of heat. Sensing is

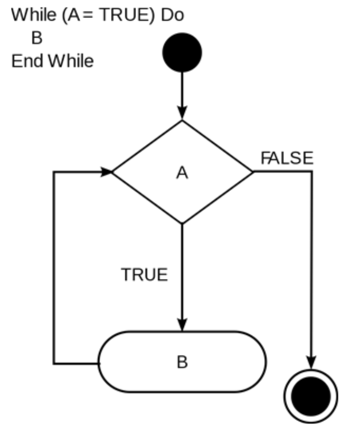

Figure 3. UML diagram of a while loop. ©P. Kemp.

crucial to feedback; it must be acted on and respond to that action. Positive feedback may include sensing but does not require it. Instead of monitoring and responding, it responds with an increase in the initial action. A condition being met executes a chain reaction of energy spending without a termination mechanism. To order a system, positive feedback may be present, but autopoiesis requires predominantly negative feedback to maintain control of internal processes. [7]

The more processes a system contains, the more complex it gets. [7] Complexity is often associated with difficult problems, the reason for this is the exponential difficulty in solving a complex problem as its variables rise, each of which further compounding the amount of possible solutions. In the scope of CAS, "complexity is considered "a group of 'agents' (individual interacting units, like birds in a flock… existing far from equilibrium, interacting through positive and negative feedbacks, forming interdependent, dynamic, evolutionary networks". [8] If cells are self-organized out of molecules, and bodies self-organized out of cells, then colonies and cities are self-organized out of organisms. Figure 4 represents organisms as agents (in this case birds in a flock) interacting as a complex group. As can be seen, a structure is formed by the individual actions of the agents, manifesting on a hierarchical scale. Using feedback (to proximity), the birds avoid colliding with one another, and through this process *emergent* behavior forms. Systems cannot be solely defined by their parts. We need to holistically examine the system to see how these parts interact and what emerges out of them. A common biological example of emergence comes from ant colonies. The colony is ordered in a way that exhibits emergent properties. These emergent properties exist separate from the sum of their parts. [8] An individual ant does not "know" its role in the system, it is acting on a combination of sense, instinct, and adaptation. If it is hungry (and a forager), it knows it must search for food. Each individual action relies on feedback from the whole, and as the number of agents grows new patterns emerge that are not the intention of any individual; emergent behavior is the tipping point where the behavior of the whole does not reflect the behavior of the individual. Complex systems emerge out of smaller self-regulating

Figure 4. Flocking is a form of hierarchical complexity within natural systems. The birds (organisms) use proximity feedback to form an emergent structure during flight. ©Manuel Presti.

clusters. An ant's body is homeostatic, it self-organizes itself in opposition to the external environment. Here the body acts as a boundary to its environment, yet the body still interacts with that environment. When hungry, it searches for food, and eating that food affects the environment. There is feedback between boundaries, if we are to follow a previous train of thought: if ecosystems are self-organized out of colonies, and the biosphere is self-organized out of ecosystems, one might say it is possible the planet is self-organized out of its separate spheres. Since systems interact with other systems through permeable boundaries, information and energy exchange can trickle across spheres. The scope of such a hierarchical system's agency is outside the scope of this essay, the important point to remember is systems are hierarchical and any change at a local level can affect the system on a larger scale.

Homeotechnologies

If entropy is the state of disorder, we can say negative feedback reduces entropy. But could we not say the same thing about information technologies? By creating digital technologies are we not creating order? One of the defining characteristics separating our current ICTs and biological systems is randomness. Biological systems organize and adapt, a process that requires a degree of random action. As we move up system scales randomness leads to increasing potential for adaptation or unpredictability. Even with the vast number of components involved in modern ICT infrastructure, the components are predictable, they do not adapt, a requirement that would assume environmental sensing and acting, or mutation. Instead, when machines such as ICT infrastructure employ feedback strategies the outcomes will always be consistent. [6] If technology is to behave fundamentally analogous to biological systems, we must include random processes and self-regulation. Peter Sloterdijk has built a foundation of theory for designing symbiotic technologies that avoid using nature as a function to be mimicked, instead designing technologies that operate under the same fundamental principles. [2] While studying biomimicry - the methodology of designing technologies based *on* natural principles - he realized that mimicry alone does not bridge the divide between the biosphere and technosphere. Biomimicking is designing based *on* nature rather than *synonymous* to it (i.e. modelling aerodynamics of birds is biomimicry but does not behave systematically similar to a bird's flight). In response to biomimicry, he coined the term homeotechnology to mean designing "alike" to natural processes. [2] Homeotechnologies are unique in the sense that they exist outside the technosphere. They are technologies, but if we return to Haff, they do not have a "role equivalent to the biosphere", for they do not impact the Earth's spheres but are self-regulate with them. Due to their regulation, they could theoretically interact and adapt with the biosphere, rather than leeching from it. As a model for how homeotechnological ICTs may operate, let us look at the example of the "ecological internet".

The Ecological Internet

Within the biosphere lie many gigantic, complex examples of self-regulating, sentient systems –mycelial internets. Mycelium is the most common state of fungal organisms. It is a thread-like web of branching cells chained together with string-like 'hyphal' structures one cell wall thick (allowing nutrient exchange with its environment). [9] These networks exist underground and can cover entire forest ecosystems. Mycelial "internets" consist of a variety of co-existing species such as mycorrhizal fungi (fungi that form symbiotic relationships with plants). Mycorrhizal fungi can break down specific elements in the soil such as nitrogen that plants cannot (Figure 5). These fungi connect to the plant's roots and exchange nutrients in return for food in the form of sugars. Symbiotic exchanges are common in nature, but studies found that the exchanges between mycelium and surrounding plant life, benefit forest health with no immediate benefit to the mycelium. [9] Exchanges between mycelium and the forest ecosystem go against the Darwinian dogma of survival of the fittest. This observation is again examining individual agents within a larger system. I speculate that the larger CAS at play benefits from the symbiotic networks,

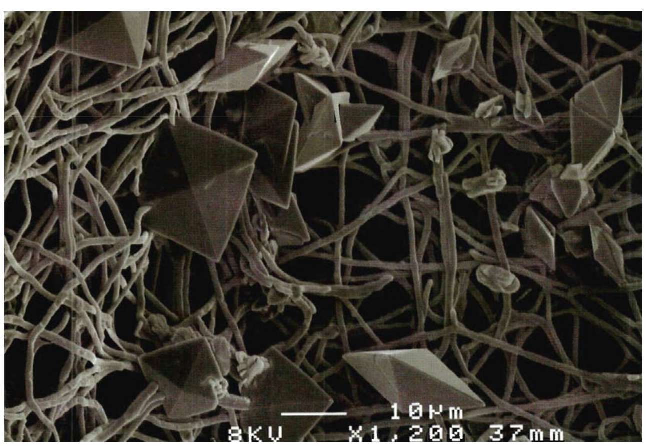

Figure 5. Mycelium creating Oxalic acid by digesting rocks in a dynamic soil sample. ©Bill Cheswick and Hal Burch

which in turn benefit the mycelium as part of the system. Regardless of the cause, these operational processes are fundamentally different from ICT networks we maintain today. While the technological internet sends and receives information on request, the mycelial internet operates with energy through biomolecules. Our technological internet infrastructure sends discrete data "packets" (small units of binary values) along its network, receives a response (sometimes), and responds using a protocol (which will never involve randomness or adaptation). In contrast, the mycelial internet is sending biochemical elements (as information) along their tendrils. Due to their biological nature, randomness causes new processes to arise allowing evolution and adaptation. "[Mycelial] systems are aware, react to change, have the long-term health of their host environment in mind, and devise diverse enzymatic and chemical responses to challenges." [9] ICTs are unable to process change and are therefore disconnected from biological systems. Homeotechnologies would instead reflect the mycelial internet, using sentience to adapt.

Sentience has been previously defined as the ability to sense *and* emotionally process an environment subjectively, but in an autopoietic sense in can be defined as "sensing of the surrounding environment, complex processing of information that has been sensed (i.e. processing mechanisms defined by characteristics of a complex system), and generation of a response." [10] Sentience plays a key part in CAS, without it there could be no adaptation. Within *Mycocene,* somme worked with the organism slime mold, formally known as *Physarum polycephalum.* Slime mold was chosen due to its example of autopoiesis in a colony setting. Slime mold is a single celled organism but operates under a collective "slime". Its sentience comes from its ability to "communicate" with other cells in the colony, which relay information they have sensed in their environment amongst each other. In Figure 6 we can see the slime mold foraging for food in it's environment – it's yellow tendrils can be seen inching towards the detected source while other pathways are abandoned. Because the way they convey information utilizes biological feedback, emergent behaviour forms (i.e. complex problem-solving capabilities). [11] Using the models of the ecological internet and slime mold (which I will expand further on below), we can start to think about how to create homeotechnologies that behave analogously to biological systems.

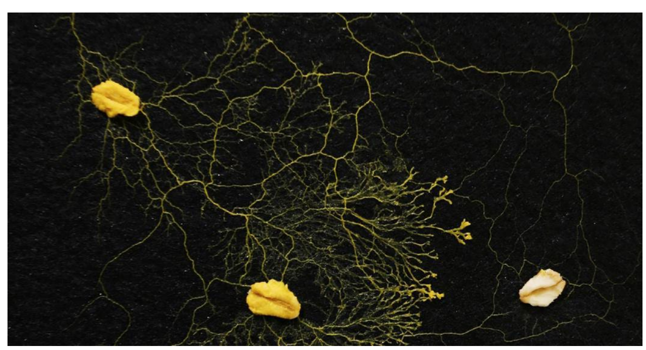

Figure 6. Slime mold sensing its environment for oats. ©TedX.

Artistic Manifestation

Mycocene is a room sized installation occupying a dimly lit space. The viewer's attention is immediately to the center of the room. A bright green light bathes a container of slimy fungal-esque cells. The container is suspended from the ceiling, upon approaching the cells the viewer notices branching electrical cables inside the container. Electrodes are monitoring the cells, the signal flowing outside the box into an oscilloscope mapping their pulse onto a green waveform. Large industrial cables branch outward from the container trailing off to five sculptures, each an organized cluster of various electronic waste components. The sculptures all highlight various stages of decay, remnants of the global technosphere. The e-waste is dimly lit, in one a CD drives sputter, another displays a feed of security cameras autonomously scanning the room, a third suspends hard drives above the others, scanning their drives to the rhythm of an organic pulse. Each sculpture contains e-waste microphones, broadcasting a live disconcerting symphony of their motors, discs, and lens pulsed back from obsolescence. Their chorus of sound and movement is controlled by an organic rhythmic pulse flowing out of the slime mold and through their circuitry.

Figure 7: The suspended container of Physarum polycephalum and their silver electrodes. ©somme.

Mycocene attempts to create symbiotic communication between living materials working in unison with technological bodies. It attempts to create Peter Sloterdijk's concept of a homeotechnology – a technology that works in parallel with natural systems. Here, the central homeotechnology is the custom-built container for the slime mold. The container is embedded with silver needle electrodes that send an electrical current through the cells. The cells take up the current and allow it to flow through their cell membranes. This current encourages growth through a process known as galvanotropism (stimulation of cell growth with electricity). As they grow towards the source of the current, the other electrodes, a circuit is completed, creating a biological circuit. The slime mold allows electricity to flow through its plasmodium. As the plasmodium pulses to transport cells it

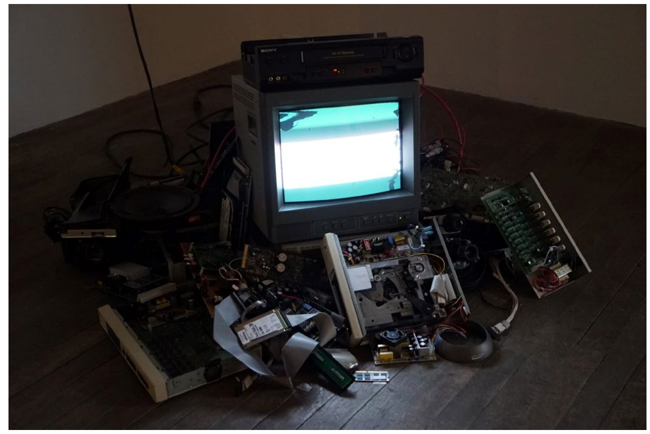

Figure 8: A cluster consisting of a CRT monitor with a surveillance camera embedded in the sculpture, providing live feedback (where the transmission is scattered by aged components) to the viewer. ©somme.

modulates its resistance values. The resistance is the amount of electricity that doesn't make it through the circuit. Using this value, we can calculate changes in growth and convert the digital values recorded into a form readily readable for the electronics. Digital technologies transmit data based on discrete 0s and 1s, while analog technologies require a waveform to read in data. To communicate between devices, we take the digital data and create a series of reference points. We can then map the time and decrease in the resistance values into output voltage. This voltage is called control voltage, or CV, and communicates with the clusters of electronics via ON/OFF voltages at 0v and 5v. This directly ties into the timing of the cluster actuation. By measuring the growth of the slime mold we can detect how much it is sensing, and map it's sentience onto the clusters.

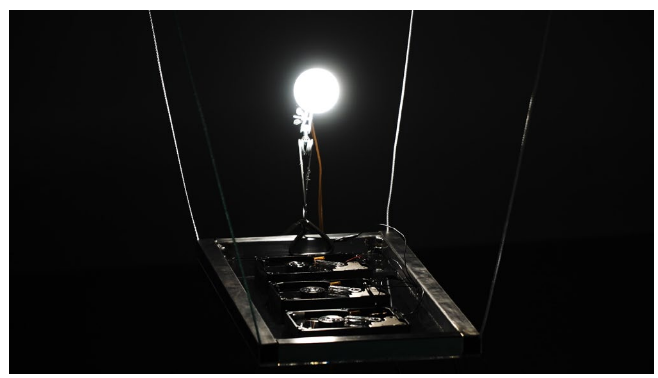

Figure 9: A sculpture consisting of cameras, CD drives, motherboards suspended in the room. ©somme.

Discussion

Mycocene positions itself as the membrane between spheres, coalescing the bubbles of the technosphere and biosphere into a unified whole. One way to collectively start designing for a sustainable future is to consider the three core theories covered by *Mycocene* as stepping stones into a garden of technologies inseparable from the systems surrounding them. The first step in this coalescence is to reconceptualize how we design technology. Homeotechnologies offer us a design methodology that creates symbiosis between the two spheres. Secondly, we must dissolve both the conceptual and material bubble that has become the technosphere. No longer can we isolate and immunize ourselves from the natural world in order to gain a sense of immediate control. The element of control that manifests out of the technosphere is one out of sync with natural systems. The last step is to consider ways of composting the current material traces of technology. We must find a way to utilize or decompose the existing technospheric waste in a beneficial way.

Designing Homeotechnologies

Both our technosphere and biosphere operate as systems, the biosphere being a complex, emergent system, and the technosphere a static one. The line that separates the two is the process of randomness. In complex systems there is always a chance for mutation and emergence, patterns that emerge outside of their regular functioning. Even if the technosphere was complex enough to emulate the biosphere in its current form it would be mechanic. Every outcome would be the same because its programming cannot evolve. [6] To overcome this boundary, we can use Sloterdijk's concept of homeotechnology. Homeotechnologies move beyond the concept of a bio-mimicking technology for a kind of technology that, at its core, functions as a complex system.

Before I propose methods of designing homeotechnologies, it is useful to again look at why we should be designing them. While the biosphere operates on self-regulatory mechanisms and non-discrete processes (not reducible to 0 or 1, as in digital technologies), the technosphere is non regulatory and discrete. As an example, ICTs are the backbone of the modern technosphere. Yet, these ICTs do not regulate with their surroundings. They are unaware of natural processes; they are unaware of their origin or their impact. ICTs connect the entirety of the global technosphere together using large industrial sized server farms, creating a massive network of communication. This element of the technosphere connects most of humanity, but further isolates us from nature by reducing our communications to binary packets to be signalled through isolated channels, never to be acted on by nature.

Mycocene is symbolically shaped to represent server farms that have expansive information cables, spreading like roots across vast oceans and connecting communities by wire and tower. *Mycocene* further mirrors vast ICT networks with its positioning of central processing (the slime mold container) and cables branching towards its clusters. Each of the connected sculpture shadows the impact of the technosphere through their representation as mass piles of electronic debris, yet resurrected by the slime mold, a metaphor for the potential remediation of ICT systems and their redesign to include natural systems.

As aforementioned, the "end-of-life" design that plagues the design of technologies is causing the extraction of minerals, destruction of the environment, and subsequent pollution of the environment through their disposal. Waste products are shipped out of sight from the consumer, but *Mycocene* shifts the observer's lens to make the entire cycle visible. It is clear that information technologies are a beneficial tool to humans, yet the ethos behind their production is not sustainable. Homeotechnologies break this cycle by designing within the systems of the biosphere, allowing them to sense and react with their surroundings.

One homeotechnology that directly involves the biosphere as we know it is biocomputing. Biocomputing constructs computers out of organic materials, whether that be DNA, cells, or even entire organisms. These computers need not follow the digital paradigm and can operate systematically, as they do in nature. *Physarum polycephalum,* the organism used in *Mycocene* was chosen as the representative of homeotechnologies because it happens to be an organismal biocomputer. Slime mold has been proven to have the ability to solve complex computational problems such as the "Travelling Salesman" problem. Researcher's at the University of Tokyo were able to calculate network efficiency of the Tokyo rail lines using slime mold as a biocomputer (below). [12]

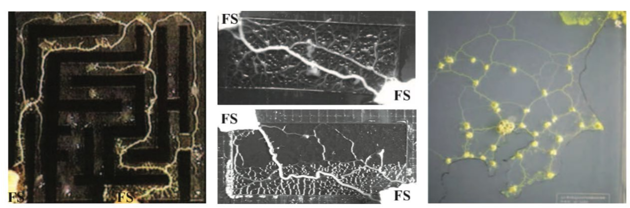

Figure 10: From left to right: a) example of maze-solving by physarum. (b) Examples of connecting path in uniformly/nonuniformly illuminated fields. (c) A tubular network formed by the physarum for multiple food sources, which could be applied to Tokyo rail system design. ©Liang Liu. [12]

This method of computing relies on the communication pathways in the slime molds plasmodium. Instead of approaching the problem discretely, the organism uses sensing and communication to analyze its environment. Any error made initially is corrected by the emergent dynamic of the group, or more interestingly, these errors can lead to solving the problem itself (emergent behaviour). As for its logic capacity, *Physarum polycephalum* has the potential to be used as both an organic logic gate or a memristor. [13][14]

Within *Mycocene*, somme created a rudimentary monitoring system for slime mold using silver needle electrodes. These electrodes monitor resistance values (within the plasmodium) and communicate with the scattered technosphere of the room. This process may be classified as homeotechnological through its integration with complex systems. To

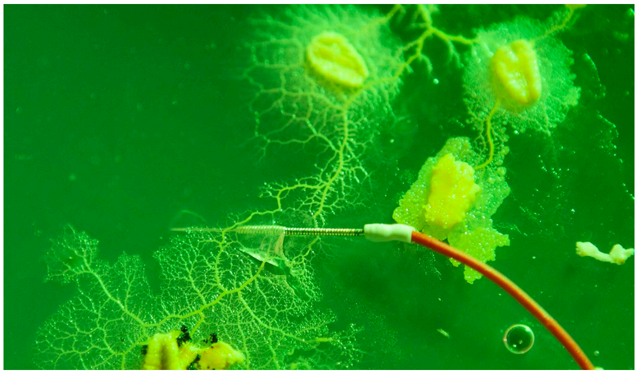

Figure 11: Silver electrode needles used to induce bio-electrical conduction and subsequent resistance measurements. ©somme.

create a truly homeotechnology *Mycocene* would require feedback from other systems within its environment. So *Mycocene* is not designed as a homeotechnology itself, but a hybrid technology hinting at the possibility of bridging the current technosphere with the biosphere. The biosphere itself is manifested in the project as the slime mold container – a biological sensory device – that communicates with the non-systematic technosphere. One potential step forward may be building these semi-homeotechnologies to monitor and relay environmental feedback to ICTs, for example. The ecological internet, mycelium, already function in a similar manner to ICTs, but again, rely on environmental feedback. Because the organisms have basic sentience, they are able to respond to their community and supply beneficial nutrients when needed. Using methods of sensing akin to those in *Mycocene,* a symbiotic communication network might be constructed using mycelium and ICTs to sustainably monitor environmental conditions like forest health.

Popping the Bubble

Designing homeotechnologies offers us a tangible way out of technospheric design, but isolated design products will not "pop the bubble" without a reform; we must think about the creation of technology in a newly paradigmatic way. In essence, we need to work towards a paradigm shift – in which "the dominant paradigm under which normal science operates is rendered incompatible with new phenomena" [15] - in both product design and the sciences. Humans have become part of what Stiegler calls spherical immunization: "the loss of knowledge, both practical and theoretical knowledge, which finally leads to the loss of the knowledge of living [savoir vivre]. This is because once the know-how [savoir faire] is short-circuited by artificial organs… taking over more and more functions and responsibilities of the human subjects and social institutions that together form a global technical milieu". [16] Building off Steigler's definition, the most important step forward is an emphasis towards the deconstruction of "technological innovation" and isolation. We must discuss the relation of our "artificial organs" to living systems.

A more holistic view of systems is appropriate if we are to start discussing the impact of the technosphere. The sciences are built off of the methodology of reductionism. To prove an idea, it must be reduced to a logical binary, either something is or isn't. Of course, this is useful for many sciences, I am not debating that here. What I am debating is that if we are to change ideas at a local level, we must discuss technology as having a macroscopic influence. Systems cannot be reduced, they flow emergently upwards, they are the antithesis of reduction. We must follow and make transparent the impact of all technologies in our creation, usage, and disposal phases if we are to change the paradigm of thought surrounding technological innovation - it can no longer be isolated.

Mycocene stands as a conceptual idea that seeks to make transparent and encourage discussion of issues surrounding this "immunization". The discussion of ideas is the discourse needed to thread the needle of the new paradigm and pop the bubble of the technosphere. *Mycocene* encourages discussion through several methods. One, a natural curiosity arises when one is presented with slime mold as a technology. The idea that the biological can interact with technological systems dissolves the idea of the allotechnology (bio-mimicking, discrete, or not-alike to the natural) as dominant. Furthermore, the actuation of electronic waste within *Mycocene* questions the timed obsolescence of technology. Each sculpture has functioning components, most of them being fully functional before adaptation for the work. Much of the waste was disregarded for the reason that data read and write speeds have improved, or a new data medium was introduced. While rewiring the electronics we found that many chips were specially encoded by the creator to be static. Meaning, they *could* be updated or used elsewhere but the encoding would not allow the device to change, a perfect example of planned "dating". These are the aspects of the technosphere that are often not discussed, *Mycocene* brings them into an artistic discourse.

Compost and Compositing

Both designing homeotechnologies and changing the paradigm around the technosphere are goals we should work towards, but there is a more immediate step. The technosphere has littered the planet with electronic waste which must be composted if we are stop the pollution of our water, soil, and air. One of *Mycocene*'s core inspirations and design principles comes from fungi. Fungi not only represent a way of thinking about biological relations but may also offer us a solution to decomposing waste, mycoremediation. Mycoremediation is a direct, sustainable method for rebalancing the biosphere from the accumulated parasitic damage of the technosphere. Several types of fungi are capable of absorbing toxic metals (within soil) through a process known as hyperaccumulation. Hyperaccumulation is a property that allows fungi to absorb a high concentration of toxins, such as lead, cadmium, mercury, and arsenic (among others) in their fruiting bodies (mushrooms) for later removal. [17] By using mycoremediation we can take an immediate and achievable step towards mitigating damage to the biosphere.

Conclusion

In conclusion, through *Mycocene,* the collective somme is seeking to encourage discussion about potential futures that operate symbiotically between technology and the natural environment. By discussing how the planetary can be affected by the local through spheres, systems theory, autopoiesis, and homeotechnologies, we can begin to encourage visions of a future without a technosphere. In order to start creating technologies within the biosphere, we must look at how future homeotechnologies can communicate between existing ICT infrastructure and natural systems, then work towards developing complete homeotechnologies that replace this infrastructure. To do this, a new paradigm of thought is required - one that centers technology part of the biosphere. Even after this point, the technosphere will remain through its waste. Using myco-remediation we could take the final step towards erasing the technosphere by cleaning up its toxins. I am not arguing we are close to this paradigmatic shift, I am instead encouraging us all to think of ways we may finally pop the bubble.

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Author Biography

Matthew Halpenny is an interdisciplinary artist and research associate at Concordia University in Montreal, QC. His research is conducted through the Speculative Life research cluster under the Milieux Institution for the Arts, Technology, and Culture. Halpenny's artistic work primarily oscillates between bio-art and embodied art, which focuses on the creation of works and dissemination of ideas related to systems theory, autopoiesis, perception, identity, and media ecology. He has lectured at the International Marketplace for Digital Art (MIAN) and is a founding member of the collective somme, whose work has been shown at Elektra XX and Le Centre Pompidou.