A Materiality of Agency//Speculations on the Impact of Biological Computation on Materiality and Space

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Architects have traditionally viewed space as a static entity that is defined, shaped, and enhanced through the use of material objects that give form, structure and order to our daily existence. There have been clear boundaries between inside and outside, delineation between distinct building materials, the program and the project. But looking forward, is it possible that human interactions with objects and environments might be drastically re-envisioned, encompassing a more malleable and adaptive view of space and materiality? In this paper, I will explore how potential human interactions with space, objects and information may be transformed in the future through analyzing recent developments in biological computing, synthetic biology and object-oriented philosophy. To start, I propose an expanded definition of agency with respect to materials and objects. How can we begin to formulate conceptions of agency as they relate to objects or new categories such as *object-beings*[1]? Recent writings from object oriented philosophers may offer a way forward through a novel reframing of the conventional pattern of interactions between humanity, materials and environments. Object oriented ontology allows for a total reconsideration of the relationships between ourselves, object-beings, and object-object associations. Humans are highly complex "machines" operating within a dense network of dynamic experiences, yet currently our spatial organizations are highly static, rigid and inefficient. The capacity of materials, networks and objects to possess emergent capabilities and behaviors requires our acknowledgement of this agency, and new relationships with space will likely be defined not by static physical boundaries, but rather by a series of negotiations, signals and exchanges. Space may well take on a more active role that transcends utility, function and normative or fashion-driven aesthetics in favor of a shifting, responsive condition rich with varying emotions, perceptions, temporalities and interactions.

In complex systems, extremely sophisticated forms of higher-level order at the global scale can emerge from relatively simple, local interactions among individual agents. This ordering is a phenomenon seen across many systems and scales in biology, from the macroscopic to the cellular level. Engaging in the practice of design at these newly accessible scales might allow for a variety of information and intelligence to be configured into the materials and objects that we interact with. Towards these ends, biologically-inspired mechanisms of scaling, information reception and signaling can help us understand what makes a system resilient, complex and able to evolve. Such a shift towards a non-human centered understanding of systems and their interrelationships will become increasingly important as our environments and materiality expand their agency.

ON SIGNALING

Signaling is a fundamental mechanism in biology that operates at many different scales, typically at some cost to the individual. Put simply, signaling is any method of actively transmitting information from one entity to another. Signaling occurs in individual molecules and cells, among individual species and between species at the level of an ecosystem. These interactions may be fairly simple but can become highly complex depending on the density of the network and the specifics of the signaling pathways. The signals we may exchange and our relationship with other entities, objects and systems has not been adequately addressed in architectural design, and the signaling potential of new categories of objects including synthetic biological hybrids deserves further analysis.

A series of signals, exchanges and feedbacks operating at multiple scales presents a useful model for how we might re-imagine the ordering and adaptability of space. The emerging discipline of biological computing relies on various pre-existing biological mechanisms to process information, make connections and "learn." While much of this research is still in early phases, it seems imperative to begin speculating about its potential implications for design and architecture. Signaling in biology takes many beautiful and provocative forms, such as the synchronized bioluminescent flashing of fireflies, wherein the aesthetically impressive visual effect is merely a byproduct of an evolutionary-driven informational agenda to find a mate. Similarly, various camouflage strategies, such as that of the cuttlefish or certain species of octopus, demonstrate a variable and highly localized strategy of adaptation that is fluid and situational. These examples suggest novel ways in which we might begin to mediate our interactions with our external environment as well as with each other in a more adaptive and intuitive manner.

One intriguing development from the United Kingdom involves a series of slime mold robots. Scientists have used the slime mold *Physarum polycephalum* to create the first fully biological robot, a substance with an embedded intelligence. Professor Andy Adamatzky explains that, "the robots will have parallel inputs and outputs, a network of sensors and the number crunching power of super computers. The plasmobot will be controlled by spatial gradients of light, electro-magnetic fields and the characteristic of the substrate on which it is placed."[2] These biological robots are capable of processing and transmitting information, and therefore this biological substance can be manipulated to perform computational tasks depending on varying gradients of light and substrate. It can be difficult to assess the processes by which biological entities perform computation as they are somewhat different than digital computing. While in digital computers information is of a single bit, unchanged unless programmed and centralized, in biological computing the information is "often analog in nature and of different types (e.g., reflected in real-valued rates of interaction or concentrations of different substances), continually changing, decentralized (distributed over large areas and over large numbers of system components)…"[3]

The flexibility and built-in redundancy of distributed information processing systems breeds resilience. With a wide variety of connections and paths of information transfer, these systems are able to handle disruptions and anomalous occurrences. "In biology, information processing is massively parallel, stochastic, inexact, and on-going, with no clean notion of a mapping between "inputs" and "outputs."[4] The notion of a biological system with embedded intelligence is quite appealing, and it is easy to imagine systems functioning with similar principles embedded seamlessly into our materials, objects and environments. The ability of such systems and entities to adapt to shifting terrains, conditions and information in an evolutionary way would radically alter the way we conceive of materiality and the static nature of spatial definition.

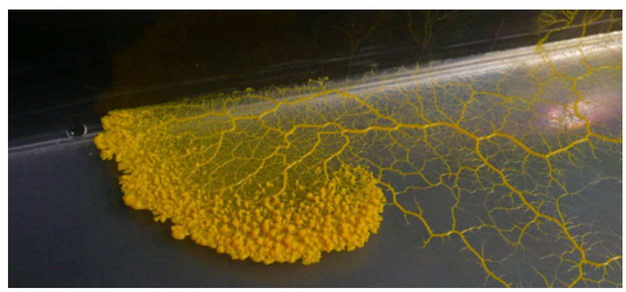

Figure 1. Slime Mold

THE BIOLOGICAL HYBRID

Future synthetic biological hybrids will operate at a very fine resolution, and our ability (or lack thereof) to control the composition, growth and evolution of material formations will necessitate a reorganization of the relationships between these material entities, information and ourselves. In reassessing our relationship with space, nature, objects, and our "dominance" over them, we can open up a more symbiotic relationship with space that envelops us. The artistic and ethical dimensions of these new relationships are explored in the *Tissue Culture and Art Project*, led by Oron Catts and Ionat Zurr. "The project focuses mostly on investigating human relationships with the different gradients of life through the construction/growth of a new class of object/being – that of the 'semi-living'… Evocative objects, they are a tangible example that brings into question deep-rooted perceptions of life and identity, the concept of self, and the position of the human in regard to other living beings in the environment."[5] What might this relationship to the "semi-living" entail? As synthetic biologies, biological hybrids and artificial intelligence systems become more prevalent it is more than likely that they will begin to evolve behaviors that we can not entirely imagine or envision. With this near inevitability approaching, it seems useful to contemplate how we might relate to, communicate, interact and exist with these new forms.

Rachel Armstrong examines the impact that these future emergent systems and categories of materials may have. "New emergent relationships and identities will exist at this intimate level that will rival the alleged uniqueness of animate matter and challenge our definitions of life."[6] The definition of life referred to here is one tied to questions of agency, intentionality and imperative. What rights do these new categories of materiality hold? What is able to be controlled in these systems? The architects' role in specifying materials and systems to accommodate human activity is no longer a straightforward task. The nature of self-organization, emergence and agency necessitate a rethinking of traditional ideas on control and "design" processes[7]. This will require a thorough re-examination of our relationship to these unseen objects, systems and desires.

The post-continental philosophy of Object Oriented Ontology and the related speculative realist movement provide an interesting framework to consider some of these new relationships. The speculative realists and Object Oriented Ontologists object to a correlationist view of philosophy that is primarily originating from the interplay between humans and the world. Object oriented ontologists assert that objects are not defined or exhausted by their relationships to other objects or humans. Graham Harman defines his position with two clear principles: "1. Individual entities of various different scales (not just tiny quarks and electrons) are the ultimate stuff of the cosmos. 2. These entities are never exhausted by any of their relations or even by their sum of all possible relations. Objects withdraw from relation".[8] The object oriented classification of events expands traditional classifications of "objects". Systems, stories, particles, animals, inert materials, organizations are all considered objects. This movement away from a human centered world view acknowledges a multitude of realities that exist simultaneously at all scales for all objects. It is important "…to underline the point that humans are beings among the swarm of differences and hold no special or privileged place with respect to these differences."[9] Only by reexamining the status and consideration given to humans as a default can we recalibrate our relationships to systems, materials and environments.

ON PERMEABILITY

When reconsidering our relationships to objects in the broadest sense it is helpful to consider barriers, membranes and connectivity. The interconnectedness of our inhabitations is not always readily apparent. The presence of walls, doors, opacity, transparency, thickness and the presence of visual and physical barriers in architecture help define the various functions of a space and how humans operate within. These distinctions and "zones" create a superficial construction of enclosure and exclusion. The reality is that there are a variety of phenomena, events and activities which permeate these physical constructions. Those living in close proximity to large scale factory farming operations have to contend with an enormous amount of olfactory intrusion and pollution. This is a wafting and seeping entity that windows and doors are unable to stop. The complexity of scent molecules and their subtle diffusion throughout the air is an example of a small scale interaction that permeates. Each specific scent is comprised of distinct molecules that are mixing with other molecules and then interacting with human receptors[10]. The complexity of scent alone is staggering. The way that our brain processes these sensory inputs and the fleeting and ephemeral condition of any one scent at any given time is informative. This flowing and constantly shifting organization of molecules and their interaction with other systems, materials and objects deserves attention.

Radiation and chemical pollutants are other examples of small scale particles that are able to penetrate our physical barriers. These examples are composed of things which cannot be necessarily seen but are felt, sensed or experienced in different ways. The effects on us both psychologically and physiologically are becoming increasingly legible and these effects happen at a very small level of disruption whether it is through cognitive signaling and disruptions or through cellular changes. Timothy Morton, another object oriented philosopher, has defined the term "hyper-objects" to denote these larger or smaller events that are operating on a level that we are unable to directly observe or understand in a typical manner. Examples of hyper-objects include radioactive disasters and global warming. "As well as being about mind-bending timescales and spatial scales, hyper-objects do something still more disturbing to our conceptual frames of reference. Hyper-objects undermine normative ideas of what an "object" is in the first place. Let's consider the fact that hyper-objects disturb our habitual ideas of time and space by stretching them and by distributing effects across them."[11] An awareness of the effects of these microscopic factors on our physical and mental experiences could be mitigated, informed or modified in certain ways through the use of small scale biological interventions both within us and around us. Other toxins in our environment waft through our spaces as well. Pesticides, chemicals and irritants such as mold spores and pollen are continually crossing our domestic and environmental thresholds. We make visible delineations in analog materials yet these constructions are permeable and fallible in a variety of ways. An architecture of permeability that contends with small scale matter and information could be much more robust moving forward as we contend with a volatile climate and a series of rapidly evolving social and cultural interactions.

Figure 2. Various protective gear at Chernobyl: Unknown Fields Division Research Group

Radioactive material is quite unsettling in that you cannot sense the presence of danger but it is nonetheless acting upon you. This summer I travelled to sites in Ukraine including the towns of Chernobyl and Pripyat and I was able to experience firsthand this strange landscape. I ate in the Chernobyl canteen and slept at the Chernobyl guest house. While everything appeared quite lush and verdant, the landscape is quite toxic. Levels of radioactivity ranged from slightly elevated to highly alarming. In discussing radioactivity there are two main categories of particles. The first category includes alpha and beta radiation. These radioactive particles are "sticky". They are large enough to adhere to skin or mucous membranes and may be ingested or inhaled. However, these particles are not small enough to permeate skin or physical objects. The second type of radiation is from Gamma rays. "Gamma rays are high frequency photons. They pass easily through most materials including flesh. Gamma rays strip away electrons from atoms, disrupting cellular chemistry"[12]. Gamma rays can pass through people, buildings and other objects. So while our suits and masks protected us from alpha and beta particles, there is no adequate protection against high levels of gamma radiation. The time scale of these radioactive particles' decay can stretch into tens of thousands of years. On a small scale, at the cellular level, as well as at a much larger scale, both geographically and temporally, the effects of this radiation can be seen. If we were to analyze larger networks and systems of migration and animal populations in the Exclusion Zone, there has been a re-organization ecologically in both flora and fauna. Some species have flourished due to the lack of natural predators. Wild boars are prevalent in the zone. Other species such as birds and insects have decreased in number[13]. Current human attempts to mitigate the damage in Chernobyl seem wholly inadequate. We were permitted to visit the Chernobyl Sarcophagus for only a few minutes, due to extremely high radiation readings. The sarcophagus is a concrete tomb that covers the destroyed nuclear reactor from the accident. This aging structure is rapidly deteriorating and a new enclosure is being built to replace it. After the explosion the first line of defense involved helicopters that dropped sand and then graphite into the exploded and burning area of the reactor. The nuclear fuel along with the graphite and sand formed a molten liquid and hardened into a hauntingly beautiful object called 'The Elephants Foot' inside the reactor. These materials did little to help extinguish the blaze and the concrete covering the reactor only provides minimal protection from the high levels of gamma radiation inside. The inadequacy of these inert materials to contend with something operating with this particular set of behaviors reveals the limits of our efforts to order and control space and experience through materiality. Radioactivity operates on a time scale and a spatial scale that differ by orders of magnitude from those of our sensory experience. Our ability to control, contain or remediate these effects is simply not adequate with existing technologies and protocols. Situations such as this may prove to be the ideal testing grounds for response strategies that incorporate biologically inspired mechanisms to contend with such widely divergent spatiotemporal scales.

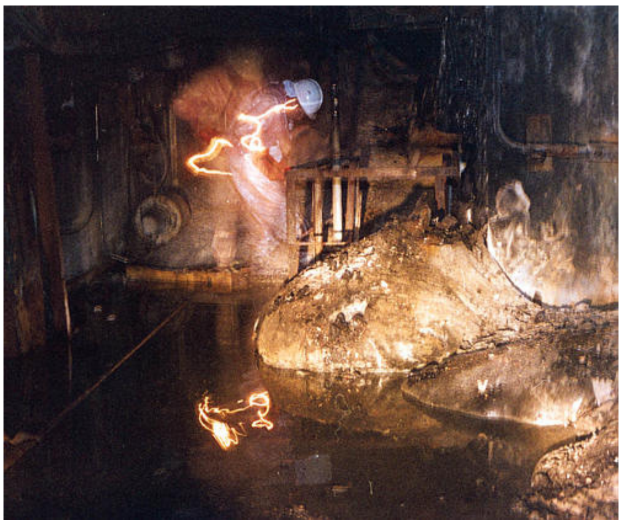

Figure 3. The Elephant's Foot inside the Sarcophagus at Chernobyl Reactor 4

Biological computation and synthetic biological hybrids should incorporate evolutionary mechanisms if they are to be robust and adaptable. A truly "intelligent" permeable membrane operating with biological principles would require a material or biological agency on the part of the filtering system. As designers we have to consider how we may tweak or nudge some of these biological mechanisms. The potential for objects, networks and systems to digitally evolve will be possible through advances in our ability to model increasingly complex systems and interactions. In this way we could "speed" up the process of evolution and utilize optimal solutions that are determined digitally in a much shorter time span than biological evolution operates. Such a process would require the ability to hypothesize approximate parameters while preserving the agency of the materials and hybrids. Levi Bryant references Daniel Dennett's concept of 'design-spaces' in relation to Darwin's evolutionary theory:

> A design space can thus be thought as a sort of topological space of relations among objects that play a role in qualities an object comes to actualize. I speak of a topological space as opposed to a geometric space, for topology allows us to think relations as undergoing continuous variations, whereas geometric relations are fixed. Thus, as a topological space, a design space admits of many variable solutions to the problem posed by the design space, while nonetheless possessing constraints. A point of crucial importance, in this connection, is that design spaces change with changes in relations among objects and in objects. In short, design spaces are not fixed and immutable.[14]

Developing a set of parameters that loosely defines a possible range could offer a useful framework for how we might re-envision our role in organizing these new types of materials, systems and networks. Designers could begin to assemble conceptual topological 'design-spaces'. Such spaces would not have a fixed form but would instead allow for continuous variation and evolution rather than a predetermined outcome.

ON FILTERING

An increasing awareness of the permeability of our relationships to spaces, environments, data and objects calls for a focus on filtering strategies. As humans navigating a hostile environment we are highly vulnerable to a wide variety of assaults. The concept of shelter as delineation between us and them, or us and "the outside," is a fragile and precarious one. Our current method of building is predicated on a static condition, one that gets periodic but very infrequent upgrades. Yet in a more volatile and complex society of both organic and inorganic entities in possession of varying degrees of agency, this idea of shelter will need to be radically reconfigured. In visualizing how we might begin to order these relationships and networks of interacting components the use of Venn diagrams could be quite operational. By grouping all sorts of objects into sets, this permeable condition would accommodate varying states of inclusion and exclusion. Objects can be categorized into (of), (and), (or) and (not). Reframing our interactions with other objects as a series of negotiations which are mediated through a distributed system of decision making, we might then be able to operate on a much smaller and finer-grained scale. I am using the term objects here in the broadest sense to include humans, information, spatial constructs, sets of objects, narratives, data, emotional states and other phenomena. Such a system would serve to redefine the boundaries between human activities as a more nuanced set of gates, membranes which can be made physical, visible as well as virtual or ineffable. These varying filters could operate as gatekeepers for both physical intrusions (pollutants, weather, etc.) and more intangible entrants including communications and information. In this way space, as we define it, becomes highly personal yet able to be highly communal, highly malleable and able to adapt to a variety of situations, socially, environmentally and spatially.

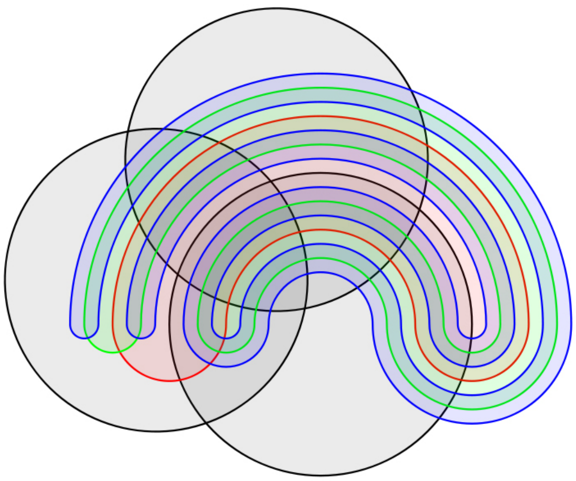

Figure 4. Venn Diagram with 6 Sets

To realize these sorts of organizations, biological and material computation will be necessary. The ability to control to a fine level of detail material formations and data transmission could radically transform how we inhabit the environment and how we interact within it. Massive sets of information and/or objects and materials may combine their efforts to coordinate larger scale endeavors. Just as at present we can lend our computers to large scale distributed computing efforts when we are not using them, a similar idea for our "space" can be imagined, one in which space and material is lent, reconfigured with others' spaces and objects to achieve larger tasks. Biological computing implies a scalability of systems operating within systems. The nature of these systems could comprise: natural/ cultural/ political/ geological/ astronomical. This would require a radical re-conceptualization of our place within these systems and our ability to interact through and within this arena. This is a conception of space that operates as a mediator between you and others, which embodies and regulates small scale, highly nuanced interactions. In this new, more permeable and malleable definition and construction of space one would be able to modulate connectivity and relationships in a much more nuanced way.

ON RE-MATERIALITY

What does re-materialization mean? What does it mean to our field? Materiality needs to be radically re-conceptualized if we are to fully optimize the potential of biological computing into the fabric of our everyday lives. Currently there is a clear distinction between us, our environments and our technology. The idea of a rapidly dematerializing society could be seen as a threat to destabilize that which architecture has traditionally been author over. But just as a reactionary aversion to such developments would be futile, the malleability of material and space should not be seen merely as a pleasure machine or a device to delight. The idea to make legible additional layers of our experience in a tactile and experiential way is one possible benefit. The ability to understand more readily multiple time and material scales, and the interactions between us and our environment is another. It is possible to imagine new materials, new interactions between humans and objects and humans and data. Data could be made spatial and space could be made ephemeral.

With the ability to transform biological materials, it is possible to speculate on the types of experiences we may have with biological and non-biological computational materials. A recent development by Japan's RIKEN, involves the use of a new aqueous reagent that turns tissue transparent. This reagent has been used in mice embryos and it offers a provocative and aesthetically compelling vision of one way in which our understanding of materials and their inherent qualities and effects could be radically altered. The transparent mouse tissue still functions in a biologically similar way and the cellular signaling and performance is not affected[15].

Another intriguing development concerning materiality involves the creation of an inorganic cell. Professor Leroy Cronin has been working on developing a cell from non-organic materials. "This research is part of Cronin's larger project to show that inorganic

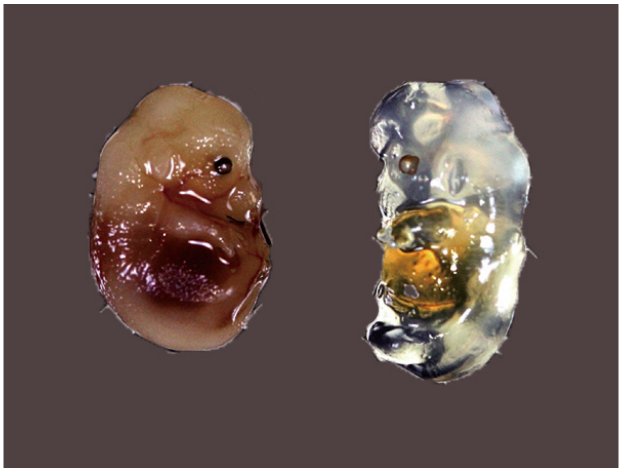

Figure 5. Two mouse embryos, one (right) incubated in Sca*l*eA2 solution.

compounds are able to self-replicate and evolve like biological cells do. The ultimate goal is to give these inorganic cells life-like properties so they can evolve and eventually be used in materials science."[16]. The inorganic cell has the ability of selective permeability in a limited capacity[17]. The implications of the effect this discovery may have on our future ability to specify, manipulate and control materials is quite intriguing. It is conceivable that in the near future we will have much greater control over both the particular makeup and inherent properties of a material as well as its embedded intelligence. We will have the ability to modify existing biological systems as well as program and create matter from inert material. Of course, the promise of programmable matter opens up many questions in regard to who is programming this matter and to what ends.

This paper has speculated on utilizing new insights into computation occurring in natural organisms in order to project how these might inform the ways we consider our relationship to materials, objects and environments. The next decade promises to provide an ever expanding list of new developments in science, technology and specifically biological computation. These developments have the potential to influence and dramatically redefine the very nature of our profession. The most promising developments in material and biological computation involve the ability for these systems to learn and evolve. However, if we are to utilize biological strategies of adaptation and evolution it will be necessary to accept entities and systems that are loosely controlled and more entropic. Our management and oversight of these systems will be far less prescriptive. Through enacting a series of ecologies, systems and networks that produce their own order and anomalies we may, however, begin to uncover crucial new insights into the nature of material agency. These developments in science and technology offer provocative new means to experience and mediate materials and objects while also raising serious philosophical questions in terms of sentience, agency and control. With these developments, our future holds a radically redefined relationship with material, space and intelligence systems.

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FIGURES

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