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Conversational ecologies

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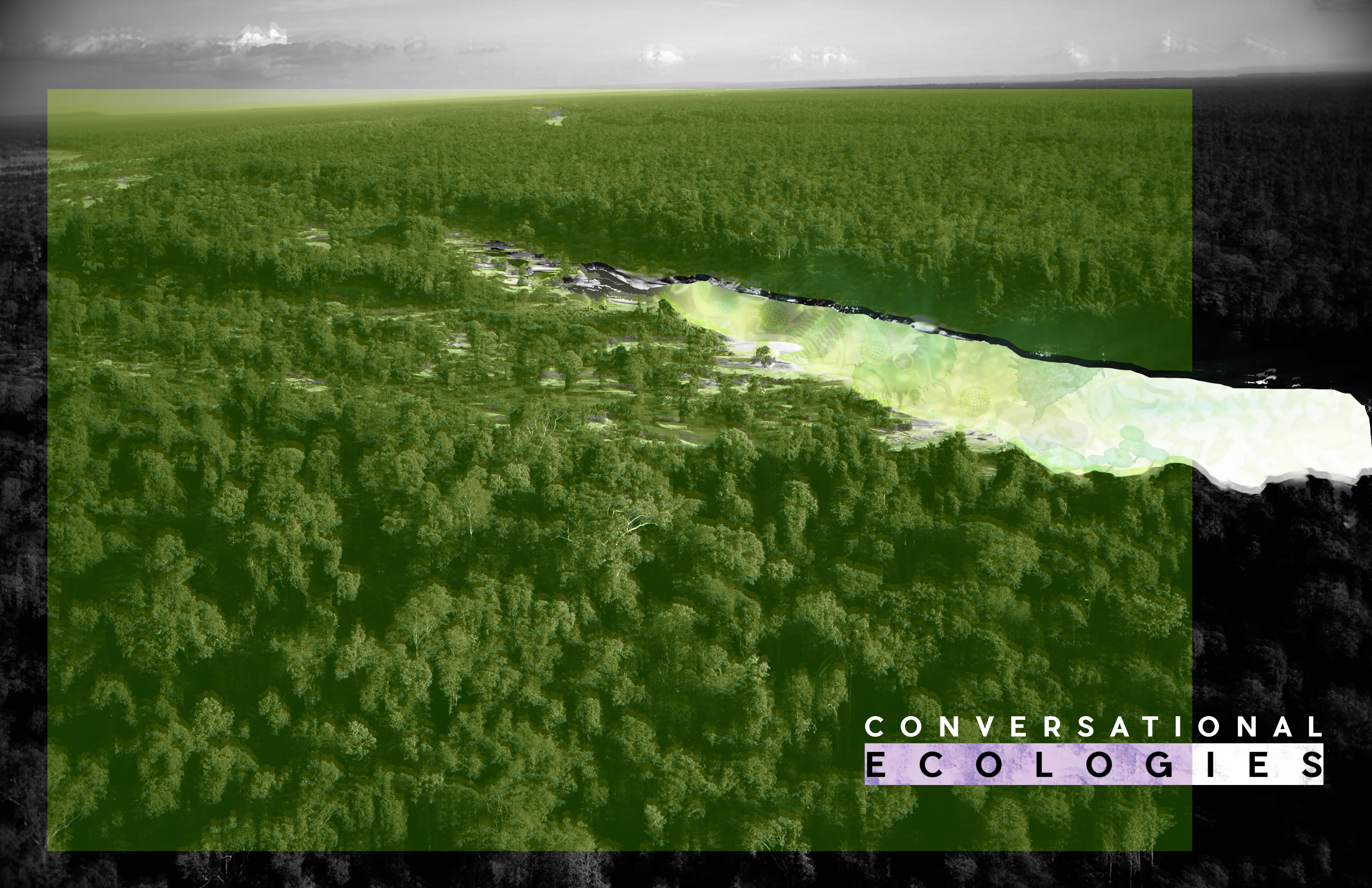
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HARRISON PICKERING

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B.A. MEDIA STUDIES THESIS PROJECT,
VASSAR COLLEGE, 06/2015 – 05/2016

I would first like to thank my advisors Lisa Brawley and Tobias Armborst, as well as Darcy Gordineer, William Hoynes, Meg Ronsheim, John Long, Stuart Belli, Nick Livingston and the Internet for their generous support and faith in me.

This project takes a transdisciplinary approach to spatial interactivity, incorporating elements of theoretical discourse, speculative design, narrative worldbuilding, making, scientific experimentation and video. To me it is destructive to segregate bodies of knowledge, or any bodies for that matter, and it denies the synergism that is possible with transdisciplinary work. I combine scientific materiality with imagined alchemies and interweave these throughout the text with borrowed and original philosophical contemplations to more fully grapple with the shifting complexities of *Conversational Ecologies*. I firmly believe that due to the complex, multisensorial nature of interactivity, the discourse must exist outside of just the written. This discourse can exist simultaneously as fantasy and reality – as long as it engages the senses and encourages people to reconsider their ecological positionalities. This theoretical, textual body acts as both a beginning for these experiments, and as a site to re-incorporate what I learn 'in the field'.

This is an abstracted map of my immersion into the field of interactive ecological design, leaning heavily on my resources here at Vassar College – namely the textual research materials and educators I have access to here, but also the science facilities, project grants, sculptural materials and digital interfaces that are available. This is not to invest the institution with any intrinsic vitality to this project, but rather to leverage the available resources that I, as a current student of Vassar College in 2016, am able to access. I imagine that other students in similar multidisciplinary learning environments, or even independent makers and thinkers unattached to any institutional body, would be able to extrapolate from my map their own tactics of availabilism.

This text is meant as a transparent map, a narrative, a deep immersion into postmodern philosophies of the body and space, a DIY makers guide and, in the end, a genealogy of thought. I encourage all people – regardless of affiliation to an identity politics or institution, but with a shared enthusiasm for interactivity and *life* – to explore this text. Read and Explore, then Appropriate, Experiment, Prototype, Grow, Remix and, throughout these processes, Gift this knowledge and praxis to others.

PREFACE

ABOVE *Haw Par Villa* a surreal theme park depicting scenes from Chinese mythology and folklore, as well as Confucian virtues

...a childhood site of condensed ecology, both mythical and biological

LEFT *Stories From My Childhood* (2016), a process collage I made as exploratory method for tracing this lineage of thought

It was only 8 months into this research that I began to question my locus. 'How did I come to find myself researching biotechnology and interactive architecture?' Propelled by the speed of thought, the hyperreality of our time, I have had little chance to question why and how I chose this. But in this small window of reflection, I allow myself to look back. To ponder, to be nostalgic. To mythologize.

Besides the obvious requirements of my degree, and the intersection of courses in architecture and the environment, there was and is, something that draws me to this topic. A sort of vitality that is being given the chance to emerge. After all of this thinking and honing, the skills that are needed to nurture this seed are beginning to materialize a praxis that I will most likely carry with me throughout life. Although the project exists largely in an academic framework, the impetus is from elsewhere, from a past. This is at once a mythology and reality. Real in that it was lived, rocks of happening in a shifting stream. Mythological in that it has become lore to me. I house it in my body but it grows distant. It needs to be re-membered and nurtured, just as its societal analog must too.

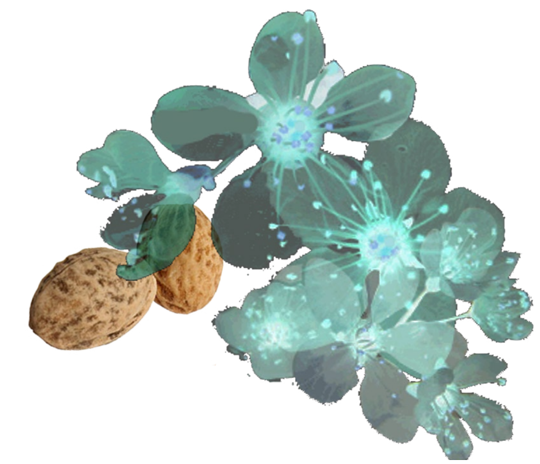
I grew up in a pocket of jungle in Singapore for many years of my childhood, and this time still imprints my being. My first impression of this house in the jungle was before it was renovated. Crumbling into the jungle rot there was mold on every surface, frogs in the toilets, trees growing up through tiled floors. A patch of land claimed by humans, then reclaimed by these jungle creatures. And soon to be re-inhabited by us. The mold was cleaned, and the house was reinstated to its former livability. 200 meters to the east of me there was a subterranean high-security prison beneath the dense jungle. To the north, the Masjid Omar Salmah Mosque, alongside several plant nurseries. Close by was Bukit Brown, one of the largest Chinese graveyards outside of China and the home to thousands of diverse species. A place to contemplate the thick clusters of bamboo, the towering saga trees (*Adenanthera pavonina*) with their epiphytic guests and the constant hum of insect life. And all around were odd patches of jungle and old houses, still retaining some of the Singapore that has not been washed over by capitalist development. This place was so full of life. I would compete with frogs, snakes and geckos for inhabitancy of what I thought of as 'my' room. A troupe of 30 or so long-tailed macaques (*Macaca fascicularis*) would frequently rob us of fruit, and hornbills would show up for breakfast. There was green everywhere, always.

This time imbued my spirit with magic. There were layers to be explored, beneath the soil and through the foliage. There was always something just out of sight. Out of site. Obscured by the thickness of life, the palpable buzzing of metabolic activity, this alchemical space was infinitely ripe for exploration and metamorphosis. I began to coevolve alongside these creatures, adapting their morphologies for my own imagined projects. I wove nests in clusters of ferns and created my own architectures amongst the living. The structures were more often than not imagined, or projected upon the existing flora, but they always shifted with their own growth or mine. I lived within these conversational ecologies, even without the language to interpret them.

And now I sit here, anticipating the next big change in my life, another uprooting to carry me elsewhere in the world. I am able to reflect on the energy of my past and its catalytic nature, with a new critical-constructive lens gifted to me from so many wise people. I am humbled to be a part of the larger Terran ecology, and call this planet home. I have nothing but hope for the future in which we heal the scars of toxic extraction, and encourage new relationships to take precedence over corporate greed.

ABSTRACT

Let's start with a seed, say, that of a *Prunus serrulata*, the Japanese Cherry tree. Embedded in this seed is the architecture of its budding youth, its flowering and fruiting frenzy, its slow growth and maturation, and its eventual death. It is able to adapt to its environmental conditions, exhibit properties of photo- and geo-tropism, navigate the world with its twenty or so documented senses[1], reach sexual maturity, and entice supposedly more intelligent creatures to spread its seeds. Even before it sprouts, the seed contains the architecture for its complex existence based on a relatively simple set of genes, encoded in its DNA matrices. Shifting environmental conditions will produce variations in the morphology of each *Prunus serrulata*, but its initial code will endow the tree with the adaptability and emergence necessary to survive such unpredicted variables. Perhaps some will mutate, or die, or grow sideways, or not at all. But for the most part, the vast complexity that has been embedded into this simple code, of which most seeds share more than 99% of their DNA sequence, will result in unique growth, inevitably followed by entropy. This "unity [in seed DNA] is not uniformity, but is coherence and diversity admixed in collusion."[2] **It is an ecology, embedded within a code, that produces variable architectures.** In this analogy we speak of the 'architecture' of a seed[3]. We could with a similar fluency describe the 'growth' of a building, or the 'evolution' of a city. We can already see a linguistic crossover in the analogies that allude to the converging disciplines of biology and architecture. Now we are beginning to have the technological means to actualize this process that our language has come to accommodate. Just as the seed contains innumerable, virtual iterations of the tree it will become, emergent architectural practice can similarly embrace the ripeness of its virtual[4] programming to generate ecological actualities.



[1] Mancuso, Stefano, and Alessandra Viola. *Brilliant Green: The Surprising History and Science of Plant Intelligence.* Island Press, 2015. Print. – These twenty plant senses roughly correspond to the main five that we humans possess, but have additional senses to measure gravity, humidity and electromagnetic fields.

[2] Pask, Gordon. Foreword. *An Evolutionary Architecture.* By John Frazer. London: Architectural Association, 1995. 7. Print.

[3] "The architectural model is an inherent growth strategy which defines both the manner in which the plant elaborates its form and the resulting architecture" – Frazer, John. *An Evolutionary Architecture*. London: Architectural Association, 1995. 11. Print.

[4] The material properties of an object or organism, i.e. their physical forms, are an actualized reality, where as their capacities, i.e. their potential functions, exist as virtual realities. "The state in which an organism happens to be at any moment is actual, while all the other available states are virtual, waiting to be triggered into actuality by a catalyst" De Landa, Manuel and Achim Menges. *Material Synthesis: Fusing the Physical and the Computational.* Vol. 85. Pg 20. John Wiley & Sons, 2015. Print. Architectural Design.

photo: https://www.flickr.com/photos/dknuth/12795493195

//ARCHITECTURAL BEGINNINGS

This chapter acts as the architectural context from which this project began. In it, I discuss the historical foundation of interactive architecture, beginning in 10,000 BCE with the invention of 'permanent' settlement configurations, travelling through various key movements such as the development of Cybernetic Theory and Metabolism, to reach a temporal contextualization of what is now being done with spatial interactivity. In my view, the moments I have chosen to discuss have radically changed the built environment in terms of the interactant, and are useful to keep in mind when navigating throughout the rest of the text.

It is at once a personal history of sources that have influenced my conceptions of interactive architecture, as well as a societal history of widespread architectural changes that inform our built environment today. From this contextualization, I conclude with a definition of the philosophy and architecture of *conversational ecologies*, as well as the questions and intentions of this study.

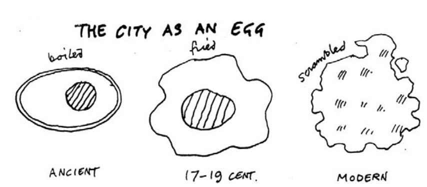
Monumental Stagnancy — Spatial Activation

Imprinted beneath the soil of society are the manifold genealogies of what now exists, like rhizomes in various stages of life and decay. And so, to engage in a conversation of interactive architecture, and subsequently *conversational ecologies*, it is important to delicately excavate and examine these ruins, for we would not be here without them. Early architectural history as we know it begins sometime after 10,000 BCE in the Levant. During this time, human-constructed environments became normalized as sites to live and exchange within, forming loose societal structures based on architecture and geography. What distinguished these settlers from their nomadic, Paleolithic, hunter-gatherer ancestors was the building of "architecturally modified environments,"[5] or 'permanent' settlements. Although built structures were by no means invented exclusively in this space-time bubble, there were several systems introduced which transformed life for these Neolithic people. One material hallmark of this time was the use of pre-fabricated building materials, specifically the mud-brick. This allowed a serial production of uniform components, in which additive structures could be generated. Importantly, "the domestication of plants and animals is a fundamental characteristic of the Neolithic but also paramount to this period is the domestication of humans through architecture."[6] In the millennia following this, many early human communities adopted sedentism and agrarianism, directly resulting in a snowball expansion of culture and technology. We became domesticated by our own invention, but this allowed us to access an entirely new virtuality of architectural technology.

Several thousand years later, the instrumentalization of building materials had reached new horizons. In Malta, beginning around 3600 BCE, Neolithic cultures constructed megalithic temples, and today their ruins are some of the oldest free-standing structures in the world. In Ancient Mesopotamia, ziggurats were built as temples of religious worship: mountains that would connected Earth and Heaven. In 2650BCE in Ancient Egypt, the Third Dynasty Pharaohs and their subjects initiated construction of several architectural monuments to glorify the Gods and inter their own holiness within the Great Pyramids. Later, in the New Kingdom of 1550 BCE, during the pinnacle of Ancient Egyptian power, prosperous pharaohs continued this megalithic tradition. The *Temple of Karnak*, part of the monumental city of Thebes, is one of the most diverse temple complexes of this history, with approximately thirty pharaohs contributing to the site over two thousand years. It is dedicated to the Theban triad of Amun, Mut and Khonsu, a family of gods worshipped in this time. In Mesoamerica, similar trends in pyramidal monumental architecture began in the Mayan Civilization around 500 BC, with the construction of limestone temples in the cities of Tikal and Uxmal among others. Throughout this large time period and all over the planet, human civilizations were utilizing their burgeoning architectural mastery to divide space. More often than not, this meant separating the enclosed spaces of divinity from the wilderness of the natural land outside. This created an osmotic gradient of space, where the humans of these cities wanted to be closer to the divine and therefore enshrined themselves in these large, intentionally permanent structures. In a sense, although microenvironments were always in flux and new buildings would appear, those that already existed as sites of worship were rendered as monolithic structures both physically and culturally, that solidified the presence of a certain God, King or behavior as part of the cultural landscape. The more divine these spaces became, the more people wanted to wrap themselves in their embrace, and so space dichotomized into the increasingly proliferating 'indoor', and the not-too-distant historical space of the outside.

[5] Love, Serena. "Architecture as Material Culture: Building Form and Materiality in the Pre-Pottery Neolithic of Anatolia and Levant." *Journal of Anthropological Archaeology* 32.4 (2013): 747. Web.

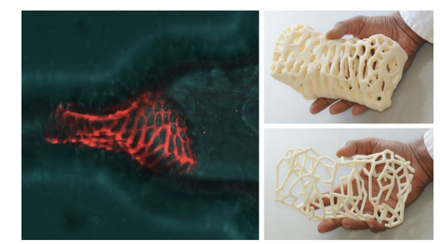
[6] Ibid, 747



The City As An Egg (An Ovo-Urban Analogy), Cedric Price

The postmodern egg is uncooked and floating as droplets in zero-gravity.

[7] Beesley, Philip, and Christine Macy. "Disintegrating Matter, Animating Fields." *Hylozoic Soil: Geotextile Installations: 1995/2007*. Cambridge, Ont., Canada: Riverside Architectural, 2007. Pg 29. Print.



BioProcessing (2015), The Living NYC (David Benjamin et al.)

Together with plant biologist Fernan Federici, The Living utilized plant cells as living computers to generate complex 3D structural geometry based on xylem vessels. With natural evolutionary efficiency coupled with computational generation, the designers were able to maximize structural integrity in this pioneering biomimetic material.

[8] Janine Benyus published her seminal text *Biomimicry: Innovation Inspired by Nature* in 1997

[9] Benyus, Janine. "What Is Biomimicry? – Biomimicry Institute." *Biomimicry Institute*. N.p., 2015. Web.

[10] Fox, Michael, and Miles Kemp. *Interactive Architecture*. New York: Princeton Architectural, 2009. Pg 27. Print.

[11] Ibid, 115

This artificial rift that was created by separating the activities of humans from the powerful flows of natural forces further solidified the concept, held by many civilizations including ours, that Human was separate and therefore better than Nature. A collective ego crisis in which our infancy as forest-dwellers and river-bathers was shameful, a history to be silenced and cast away. Once alienated from the intimacy of knowing ones environment and place in the cycles of life, the destructive process of extracting resources to further adorn these temples to the Divine Human God (cast in our own image) could magnify without the impediment of facing the shadows it casts upon other living beings. In the Greek and Roman civilizations, permanent monumental structures became synonymous with architecture, increasingly being incorporated into civic life. Arising around 150BCE, the Roman Empire took this practice of spatial-construction and domination over the landscape to new extremes, attempting to build a totalizing force of order throughout what is now Europe, North Africa and the Middle East. Their cultural imperialism was bolstered by their effective engineering: resilient roads, bridges and aquaducts facilitated the physical expansion of their borders across new lands, becoming a rigid web of predetermined space – spatial paralysis. Architecture was for the most part a means of concretizing Empire, through the rigid structures (both physical and mental) that were imposed upon the land and people. Unfortunately, this tradition did not fall like so many of these ancient empires, but rather spread across the Earth as a "Platonic, homogenizing, world-enclosing, totalizing grid,"[7] compounded and complexified by the industrial revolutions and the rise of Capitalism.

Although this form of sessile architecture still exists in abundance today, there is a swelling that has begun to disrupt the order, in favor of a more permeable, less prescriptive approach. This exists in many phases and lacks a historically-specific inauguration. Biomimetic architecture for example, has been employed for thousands of years in almost all civilizations. In ancient artifacts we see biological motifs that adorn buildings, pottery, jewelry and texts. However, this form of biomimesis existed mostly as an aesthetic facsimile or reproduction taken from the design templates of the 'outdoor'. Now with the knowledge and technology to understand biological processes and larger ecological systems, design-scientists have been able to apply these same strategies in more complex ways than visually quoting their morphologies. In its current form Biomimicry embraces the already researched and developed architectural systems of the biological environment, a period that spans 3.8 billion years of evolutionary testing, and employs them as technological solutions for human challenges[8]. At the core of this theory is the idea that "a sustainable world already exists."[9] This design approach then, is a way of accessing Earth's ancient encyclopedic knowledge.

In post-war Japan, Metabolism (新陳代謝 *shinchintaisha*) grew as an architectural movement that worked to incorporate megastructures with biological processes, as well as Marxist, ecological theories. Their designs included vast nation-less cities that would float on the ocean and harness natural forces, as well as high-rise housing developments with prefabricated plug-in capsules that would 'grow' organically through an additive process. Although this work was exhibited at many international conferences, it remained largely theoretical and lost momentum towards the end of the 1970's. Around this time, kinetic architecture began to take off as a consolidated design approach, most notably with William Zuk's text *Kinetic Architecture* and his tangible contributions to the field. Drawing from various historical precedents such as the drawbridge, and Buckminster Fuller's work on Dymaxion and tensegrity structures, the kinetic architects intended their practice to meet any functional demand through adaptability. They utilized an approach rooted in pragmatic morphability, building use and material efficiencies, drawing from the physics notion that "kinetics implies relationships of cause and effect."[10] They also embraced Fuller's theory of Ephemeralization, biomimetically modeled on natural resource efficiency, to continuously do more with less in terms of technological advancement.[11] These various global movements suggest that architecture, in its *unity not uniformity*, was beginning to embrace strategies that focus on systems more than just form or monumentalism. These practices began to *activate* built structures and our interactions with them, disrupting the rigidity of our millennia-old constructive heritage.

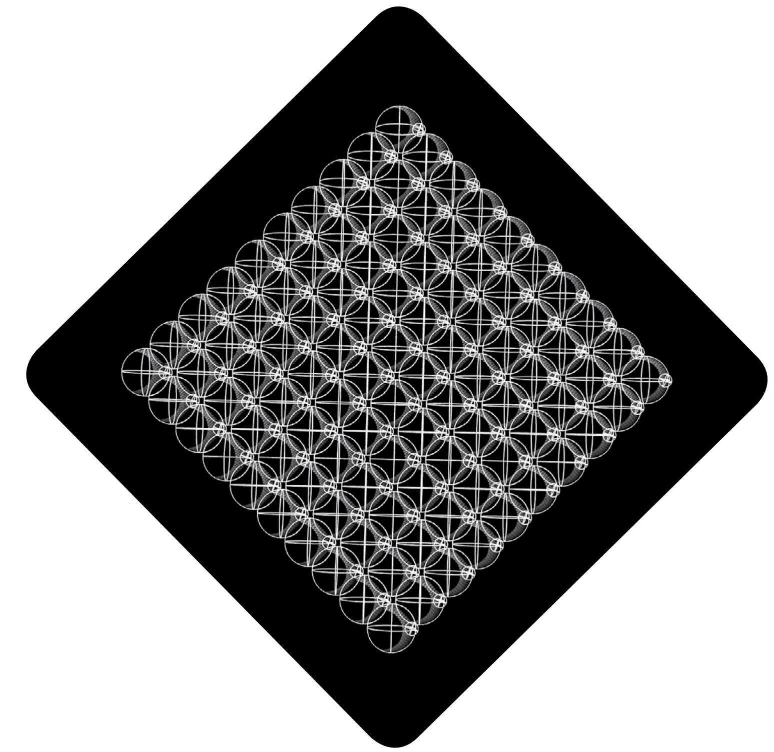
The Computational

Based on cognitive architectural research[12], evidence for the ways the built environment influences our mental patterns and behaviors is gaining traction. Following from this logical connection, we can interpret the increase in experimentation with organic, activated architecture in Biomimetic, Metabolist and Kinetic approaches as a conscious reaction to the rigidity of thought imposed by unmovable structures. With each successive generation this loose collective has grown in scale and diversity, spreading to other practices and parts of the world, shifting in its appearance and taking on entirely new meanings based on the geocultural specificities of various communities. Regardless of the chicken or the egg, these approaches were both informed by available technologies, and led to the invention of new technologies that embodied their principles. In the early 1960's, computational technologies began to catalyze the seed of activated architecture that had been seeking the appropriate methods of dispersal for decades. The *Macy Conferences* between 1946 and 1953 brought together a host of interdisciplinary programmers, engineers, scientists and thinkers, resulting in many shifts in consciousness propelled by this collectivization, most notably generating Cybernetic Theories. Cybernetics began as a dynamic theory of "control and communication in the animal and the machine"[13] that emphasized multiplicity, differences and networks rather than singularity and linearity. It also embraced communication as a key element, incorporating feedback loops of information as a reflexive, generative tool. Building upon this foundation, Gordon Pask established his *Conversation Theory* which leapt from the machinic systems of cybernetic control to the rich, organic beginnings of symbiotic information exchange. "Rather than an environment that strictly interprets our desires," he says, "an environment should allow users to take a bottom-up role in configuring their surroundings in a malleable way without specific goals."[14] Embedded within this statement is a complete undermining of the totalizing systems of Architecture previously engaged with on a large scale in society. It asks the architect to put aside their ego and desire for control, to participate in a conversation where the system, whether that be mechanical, computational or biological, is given a voice in shaping itself and the human user. It also contradicts the notion that a space must be programmed for a specific desire, engendering a flexibility that inevitably leads to the emergence of previously inaccessible virtualities.

Cybernetics and Conversation Theory materialized the systematic approach and computational prowess needed to catalyze the work of architects and designers involved in the interactive realm. By the 1990's, interactive architecture had gained momentum as a legitimate practice due to the development of economically-accessible material technologies and the web-based sharing of relevant knowledge. With the increased interdisciplinary nature of architecture stimulated as praxis by the cyberneticians, advances in diverse fields filtered into the construction of environments and vice versa. In 1990 Michael Mozer, a professor of Cognitive and Computer Sciences, converted a 90-year old school building into *Adaptive House*, a home that incorporates a 'neural network' of sensors and actuators that learn, and then adapt to, the habits of the inhabitants. The intention is to intelligently manage energy consumption in a home to minimize wastage and maximize satisfaction.[15] In 2002, studio NOX installed *Son-O-House* in a large industrial park in the Netherlands. Constructed from steel and robotic components that form "a fabric of larger scale bodily movements,"[16] visitors' movements activate sensors within the structure that feed into a soundwork by Edwin van der Heide in a live feedback loop. The structure and the visitor symbiotically act as an instrument, generating sound based on real-time movement. Various other intelligent environments (IE) have co-evolved alongside embedded computing as it becomes more ubiquitous .

[12] In *Cognitive Architecture*, Ann Sussman and Justin Hollander detail various influences from the built-environment on our cognition, and vice versa. For example, when considering geometry and symmetry, architectural "curves elicit feelings of happiness and elation, while jagged and sharp forms, tend to connect to feelings of pain and sadness." Unfortunately, most of our modern geometries are harsh and rectolinear, which support the rigidity of thought as reflected in the built environment. There is however a shift towards more organic and arabesque forms in architecture by embracing biomimetic, biomorphic and computationally-generated soft geometries.

[13] Wiener, Norbert. *Cybernetics; Or, Control and Communication in the Animal and the Machine.* New York: M.I.T., 1961. Print.



RIGHT computationally generated geometry that I created using Rhino to reflect the principle of 'unity without uniformity'

[14] Fox, Michael, and Miles Kemp. *Interactive Architecture*. New York: Princeton Architectural, 2009. Pg 15. Print.

[15] Mozer, Michael. "Michael C. Mozer." *Research Overview*. UC Boulder, n.d. Web.

[16] Arcspace. "Son-O-House - NOX." *NOX*. N.p., 06 July 2002. Web.

BELOW Son-O-House, NOX

As environments and digital technology begin to interface *into* one another, rather than just layered on top of one another, the physicality of these digital materials becomes backgrounded or completely hidden from view. The window that appears transparent, trying hard not to be acknowledged as there, can easily be revealed as a mediating lens simply by moving one's head. But how transparent can the virtual window become? This attempt to create transparent technologies is not new, but the process of invisiblization is becoming more actual with the proliferation of embedded computation – through the development of bioprosthetics, wireless connectivity, software intensification and the minimization of computational components. It is important however to acknowledge the potential ramifications that this desire for an unmediated experience can have on architectural space, resulting in a loss of critical cognitive appraisal of how these spaces are influencing our participation. It also classifies the information technology, preventing the average user from engaging with the internal functioning of the system and imagining their own potential nuances that could be manipulated in the space.

Political Choreography

Accessibility to these technologies, both by the user and architect, is an important consideration in the creation of interactive spaces. What senses are being activated in these spaces? Are all visitors able to interact with them or not? If you were a designer or architect, you would include a wheelchair ramp for physical access to a building in the design. Would you then embrace an accessible multisensorial design that goes beyond just movement? This can be most effectively employed by not privileging one form or interaction, such as language, and instead opting for a multisensorial spatial experience. The high-tech requirements of this approach act as another barrier, as computation and interactivity have traditionally required resource- and skill-intensive input, available only to a select class of the educated and institutionally-funded. A vital component of this study is to engage with the accessibility discourse of this architectural praxis, exploring means of enacting interactivity without a degree in Computer Science or a large working budget.

Fortunately, within the last five or so years Maker movements have led to burgeoning online and IRL communities of DIY artists, engineers and architects utilizing the latest open-source commercial technologies to develop their independent projects. Physical computing systems like Arduino and Raspberry Pi, as well as design software such as Processing and Rhino, facilitate the individual and collaborative alike. 'Hacking', 'tinkering' and 'programming' have entered the amateur's lexicon of behaviors at an unprecedented rate, allowing makers to mobilize on a clustered, localized scale of invention. It harnesses "self reliance and combine[s] that with open-source learning, contemporary design and powerful personal technology"[17] to render previously inaccessible, institutional design-science approaches a reality for many more people. It is no wonder then, that a society saturated with generic, mass-produced goods and services has reacted with a self-driven, customizable material experience. Studies in *Self Determination Theory* find that "one is likely to feel most secure and satisfied in interdependent relationships when one feels autonomously involved and similarly experiences the other as being involved by choice."[18] This can be applied both to the producer-consumer relationship, where parties are most likely alienated from one another by geopolitical systems, as well as the culture of use and interaction with these objects. With more agency over one's own cultural production and consumption, as well as the choice to engage in certain relationships, comes an increased sense of well-being. This growing movement, alongside studies in self determination and autonomy, imply the activation of the 'every-person' as designer, maker, and producer of their own realities.

On a large scale, we see this Maker movement as one factor in the emergence of Industry 4.0, the supposed fourth industrial revolution. It describes the proliferation of intelligent cyber-physical systems: 3D printing, automated transportation, smart robotics, AI, bioengineering and ubiquitous computing. The first wave brought steampower, the second electricity and internal combustion, and the third digital technology and the Internet. All of these revolutions radically altered the possibility to manipulate our relationships to space and each other. In *Material Synthesis*, Achim Menges postulates that Industry 4.0 differs from the previous three because its primary objective is not increased productivity but rather "higher levels of flexibility, adaptability and integration."[19] The world is already saturated with iterative dumb-goods; the potential in production now is to create products and systems that can last, and even evolve, due to their programmed intelligence and adaptability. Menges continues: "Gone is the Aristotelian view that matter is an inert receptacle for forms that come from the outside (transcendent essences), as well as the Newtonian view in which an obedient materiality simply follows general laws. We can now conceptualize an active matter endowed with its own tendencies and capacities."[20] This intelligence in programming is engendering a move away from material authority and towards material agency, in which the design does not always perform as expected but rather reinvents itself and evolves based on the material's own proclivities and nuances. Programmable materials, alongside computational design[21], decentralized and modular systems of production and formsearching[22] from the vast library of Internet resources, broaches a profound revolution in how we can design interactive spaces.

However, for these design technologies to be utilized to their fullest capacities, we must also, and **vitally**, consider a concurrent (or entangled?) revolution in socio-economical and environmental conceptions. By fullest capacity, I mean that it would have the power not just expedite product circulation or generate novel forms, but rather actualize enhanced human communication, empathy, well-being and collective social empowerment. Notions of accessibility, decentralization, intersubjectivity and ecological design should be nurtured and turned to practice. Technology, fueled by a Malthusian mentality of greed and competition, will always result in exploitation, instrumentalization, slavery and inequality. Technology, employed for Capitalist purposes will never privilege the rights or experiences of the every-person. Technological solutions will not remedy capitalism or environmental destruction: it requires a complete overhaul to this system of extraction, exploitation and unsustainable, unrelenting growth. It is time to critically activate and engage with non-capitalist design approaches for many reasons.

As Fred Magdoff states "Capitalism, in its very essence, is anti-sustainability, anti-harmony, and anti-ecology."[23] This has caused rifts in the homeostasis of all the organs of global society. On a planetary level, we are experiencing sustained environmental devastation and impending ecological catastrophe as global climates change rapidly. "Earth's 2015 surface temperatures were the warmest since modern record keeping began in 1880,"[24] rising an average of 1.0°C (1.8°F) since the late 19th century. If this trend continues uninterrupted we will experience "up to 4.2 feet of sea level rise by 2100"[25] and a wake of submerged island nations, millions (perhaps billions) of climate refugees, food shortages, escalated internal conflicts over resources especially in arid regions, as well as extreme weather systems causing yet more destruction. Scientists posit that we have already entered a sixth mass extinction on Earth: one fueled by anthropocentric greed for material extraction, exacerbated exponentially by global capitalism. Habitat loss, global climate change, pollution, overharvesting, poaching and ocean acidification have resulted in an extinction rate of "1,000 to 10,000 times the background rate,"[26] with "16,928 species worldwide... threatened with extinction, or roughly 38 percent of those assessed,"[27] and many more that have not been identified and perhaps never will be.

Tragic in its own right, and for the dwindling members of their families destined for extinction, this extinction also amplifies a positive feedback loop of loss.

[RHIZOME] **Accessibility**
This study will be working under Sara Hendren's assumption that all technology is assistive. A wheelchair allows a person lacking the functionality of their legs to move. A smart phone allows a person to communicate over long distances when their voice will not carry that far. Without each device, the user is less able to perform. This design theory queers the normalcy of the body, reconceptualizing what it means to be disabled in an age when we are so intrinsically dependent on our prosthetics. All bodies are different, in their form and function, so to proclaim one body-wholeness as 'normal' and others as fundamentally disabled, denies the multiplicity of silhouettes, and negates our quotidian dependence on technologies in all arenas of life.

[17] Bajarin, Tim. "Why the Maker Movement Is Important to America's Future." *Time*. Time Inc., 19 May 2014. Web.

[18] Miller, Joan G., and Rekha Das. "Culture and the Role of Choice in Agency." *Journal of Personality and Social Psychology* 101.1 (2011): 46-61. Web.

[19] Menges, Achim. *Material Synthesis: Fusing the Physical and the Computational*. Vol. 85. N.p.: John Wiley & Sons, 2015. 31. Print. Architectural Design.

[20] Ibid, 16

[21] Computational design is distinct from computerized design in that it considers the algorithmic exploration of indeterminate processes. It approaches computation as a tool with its own specificity and nuance, to be explored and embraced. Computerized design is simply a digitization of predetermined designs based on automation and mechanization, a remediation of top-down approaches.

[22] Mario Carpo proposes a conceptual design strategy of 'formsearching' based on the enormity of the internet and big data. We are able to search through this vast archive of resources, rather than sort and categorize information to enable recall.

[23] Magdoff, Fred. "Harmony and Ecological Civilization: Beyond the Capitalist Alienation of Nature." *Monthly Review*. Rev. 64.2 (2012): Pg 3. Web

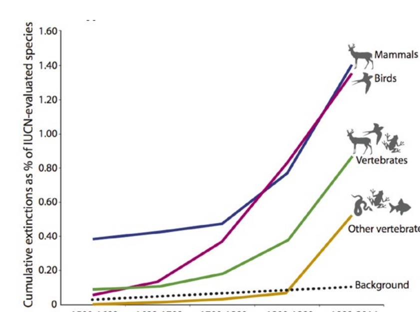
[24] Brown, Dwayne. "Analyses Reveal Record-shattering Global Warm Temperatures in 2015." *Climate Change: Vital Signs of the Planet*. NASA, 20 Jan. 2016. Web.

[25] Lewis, Renee. "Public Action Needed to Slow Rising Seas, Experts Say". *Al Jazeera*, 23 Feb. 2016. Web.

[26] Center for Biological Diversity. "The Extinction Crisis." *The Extinction Crisis*. 2015. Web.

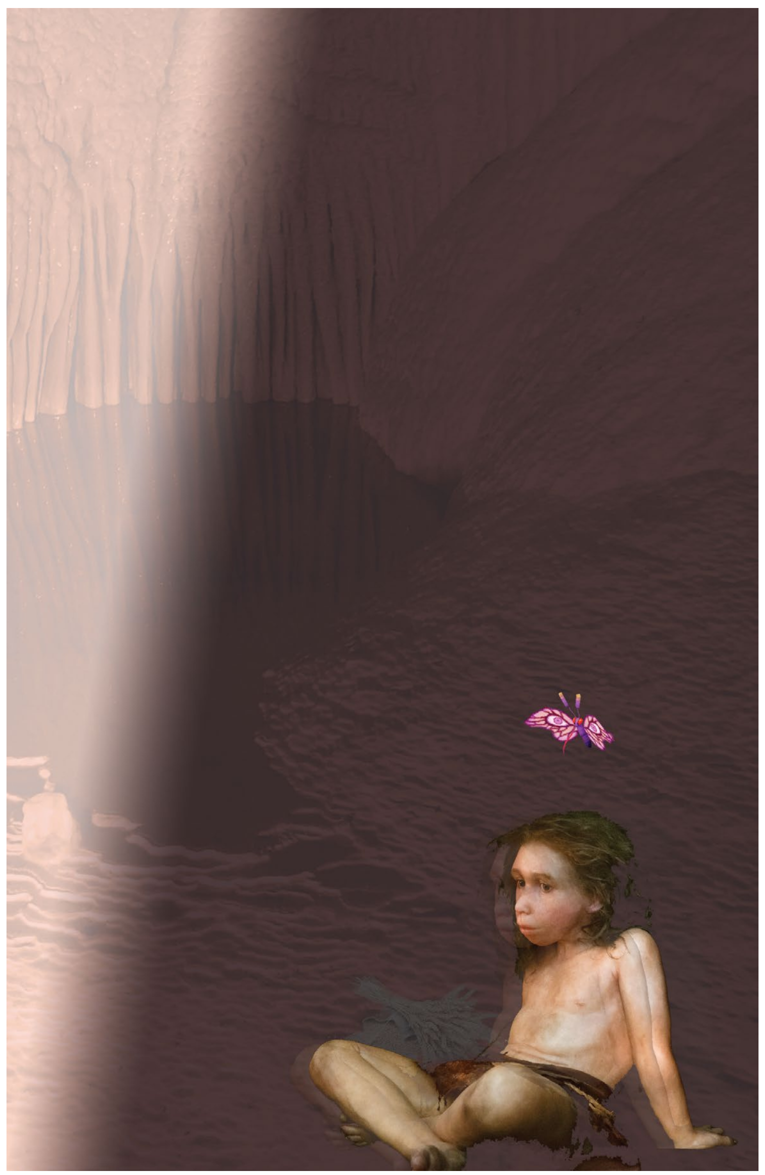
Background rate refers to the natural extinction of species (i.e. non-anthropocentric extinction) at the rate of approximately 1 to 5 species per year.

[27] Ibid



ABOVE Ceballos, Gerardo. "Accelerated Modern Human–induced Species Losses: Entering the Sixth Mass Extinction." Accelerated Modern Human–induced Species Losses: Entering the Sixth Mass Extinction. *Science Advances*, 19 June 2015. Web.

Because every species is connected to others in the web of life, an extinction of one species puts all others that interact with it at high risk. As habitats become smaller and more fragmented, they become exponentially less biodiverse as they cannot support larger apex predators that ensure a balanced system, experience a reduction in genetic pools, and are exposed to further human activity, leading to a massive reduction in ecological resiliency. We are living in the Age of the Anthropocene, in which there is no longer an 'outside' to human influence. With our techno-powers, we as humans, have layed a blanket over the world. This blanket can become comforting and nourishing, or it can continue to suffocate. We are experiencing a catastrophe that threatens the survival of all systems and creatures on Earth, us included. We need to revolutionize our conception of the Earth, becoming critical of our positionality in this complex web of life and taking measures to actualize more constructive and harmonious approaches to ecological interaction.



Project Specificity

These original ecologies have been conversational for billions of years and have developed complex systems of intelligence and interaction within their matrices. It is fairly obvious that other non-human animals exhibit intelligence: in their emotional capacities, tool use, hunting methods, social hierarchies and mating performances. Plants and fungi however, are often thought of as benign, sessile and unintelligent creatures because their movements, communication methods and time scales do not correlate with those of humans.[28] This is a fallacy; and furthermore works to support the reckless overharvesting of their bodies and habitats for capital gain. Let us not forget that hierarchies of intelligence, based on quack science, were used to justify slavery and colonialism within the human species. Recent research in plant neurobiology has revealed hundreds of examples of plants and fungi exhibiting intelligent behavior. We can now hear it because we are listening to the right frequency. Plants can sense an obstruction in the path of its root growth, before the root has even reached it. They are able to locate food stores, to chemically defend themselves from predators and have even developed systems of memory and learning.[29] "Researchers have played a recording of a caterpillar munching on a leaf to plants — and the plants react. They begin to secrete defensive chemicals — even though the plant isn't really threatened."[30] This has also been exhibited with *Acacia erubescens* trees in the savannahs of South Africa. They began to react to an overgrazing by kudu (a species of antelope), producing tannins in their leaves that began to poison the kudu and prevent them from stripping the acacias' branches. Furthermore, they released chemical signals into the air as ethylene gas, that activated this same mechanism in other acacias in the area – even if those individuals had not yet experienced the overgrazing.[31] The more we come to realize that plants are intelligent creatures, the more respect we develop for them and their nuanced behavior.

With this in mind, we can begin to see how plants and fungi could be incorporated into interactive environments as agents of responsive and adaptive communication. This knowledge of the 'natural' or ancient form of ecologies, coupled with our burgeoning vocabulary of techno-interactive tools enables use to fuse these two powerful forces into an adaptive, responsive approach to world-building. Conversational ecologies attempt to form new relationships and processes that emerge from a symbiotic fusion of biology + architectonics, rather than just a remediation from biology to architectonics, as is seen in Biomimeticism. How then do conversational ecologies differ from interactive architecture? Whilst interactive architecture is a specific approach to the construction of the built environment, conversational ecologies exists more as a paradigm of ecological interaction and generation. This theory can be scaled up or down to include the smallest interactions or entire societal systems, where as interactive architecture is more project-oriented. In its most condensed description, conversational ecologies are...

[28] They also do not have a centralized processing core (i.e. a brain) like humans and other animals so it is easy to dismiss them as unintelligent because they seemingly don't possess the apparatus that we conventionally conceive of as housing 'intelligence'.

[29] Monica Gagliano has studied the *Mimosa pudica* plant, commonly known as the sensitive plant or shy plant, which closes its leaves when touched. Without hurting the plant, she dropped it every five to six seconds. After a while it stopped closing its leaves, learning to ignore the harmless environmental stimulus. After this dropping, she then did the same experiment with shaking. Although it did not react to further drops, it reacted to this new stimulus of shaking, showing that it understood a differentiation in stimuli. They were retested every week for 4 weeks, and they continued to remember their lesson, evidence of their stored learning, i.e. memory.

[30] Public Radio International. "New Research on Plant Intelligence May Forever Change How You Think about Plants." *PRI Science, Tech & Environment.* PRI, 10 Jan. 2014. Web.

[31] Hughes, S. Antelope activate the acacia's alarm system. *New Scientist.* 1736: 19.

AskNature. "Leaves Signal Presence of Predators: Acacia." *AskNature*. Strategy, n.d. Web.

(philosophy) *A non-capitalist approach to harmonious world-building that emphasizes intersubjectivity and communication between all organisms, not just humans. It embraces the hybrid, cyborgian and biotechnological possibilities of ecological creation, as*

(architecture) *open interactive environments that incorporate interactant-input and biofeedback into a symbiotic exchange of information. This generates structural evolutions that adapt to changing environmental stimuli in an emergent manner*

This proposes a postmodern way of interacting with ecologies, but it comes with many questions and uncertainties. For example, how is this architecture evolutionary without being prescriptive or top-down? The architect involved is always going to have some sort of design intention and input, but how can mutation and deviation be embraces as fundamental, emergent aspects of the system? Can this be encoded into the DNA of these structures or approaches, and build based on genetic architectural codes that lead to entirely unpredicted interactions? How are these hybridized ecologies going to interface with natural-ancient ecologies? Are they going to outcompete or disrupt native communities? What does this mean for our conceptions of what is natural, biological or environmental?

And, what elements of this study speak to the already described ecological and architectural issues at hand? Agency and *Self Determination Theory* were mentioned earlier, as tools of empowerment for both plants and humans to effect the architectures that they grow within. With current governments still largely existing as top-down, authoritative superstructures that leave little room for determining ones own space on the planet, I find it vital to encourage an alternative means of distributed, decentralized, bottom-up approaches to spatial design. These power structures also prescribe an anthropocentric, capitalist, and often toxic, treatment of our environment. "For Marx, capitalism's robbing of nature could be seen concretely in its creation of a rift in the human-earth metabolism, whereby the reproduction of natural conditions was undermined."[32] This behavior is crucial to disrupt as we are undoubtedly engaged in planetary emergency and will face severe environmental backlash for our (mainly Western, Colonial, Industrial) treatment of the planet as a disposable womb. The Earth is already speaking to us. It is our chance to heal this metabolic rift by involving ourselves intimately in the process of ecological creation, and to gain new insight into hypercomplex webs of exchange that are in constant flux.

How can our spaces respond to this endless flux if they are temporally frozen in just one set of environmental conditions? Adaptability and activation then, are an antidote to this stagnancy. As William Zuk brilliantly encapsulated this call to action, "our present task is to unfreeze architecture, to make it a fluid, vibrating, changeable backdrop for the varied and constantly changing modes of life. An expanding, contracting, pulsating, changing architecture would reflect life as it is today and therefore be a part of it."[33] The 'built-environment' and 'nature' do not have to conceptualized as distinct and separate. They can be intimately interfaced to generate new responses to the conditions of Earth, and to the cultural conditions that we have invented in our short history. Our life-giving ecologies have been steadily shrinking as prescribed systems of order have consumed them. We need to expand ecological possibility as an antidote to this extinction, but also for its own ontological reasons. This approach is not a means of *replacing* biological rhythms already present, but a means of *expanding* ecological possibility. It is about materializing the potential that is currently locked in virtuality. Ecological creation is fully accessible when we develop the social capacities to respect its power and implement it for a constructive future. This is also an expansion of language and understanding, not a substitute for social change. It is not a technological *solution* to environmental catastrophe, but rather a *sociotechnological means of understanding* our relationships to and with the Earth, so that we may change our destructive ways.

[32] Foster, John Bellamy. "Why Ecological Revolution?" *Monthly Review.* Monthly Review Foundation, 01 Jan. 2010. Web.

[33] Zuk, William, and Roger H. Clark. *Kinetic Architecture*. New York: Van Nostrand Reinhold, 1970. 27. Print.

At the core of this study is the desire to interact with our environments and each other in more mindful, meaningful ways. The technological implementation and theoretical analysis are my postmodern methods of supporting that inclination. In this vein, I have formulated these three central questions to guide my material experiments and design methodology:

SELF DETERMINATION _ ADAPTABILITY _ RESPECT _ HYBRIDITY _ ECOLOGICAL EXPANSION

1 Can an individual with no formal background in biotechnology (myself for example) design a conversational ecology without heavy institutional backing or high-tech resources? What does this mean for the accessibility politics of spatial design in 2016?

2 How can we decenter anthropocentric interests and support symbiosis through biotechnologies?

3 Is a conversational ecology, a shifting architecture driven by user-input, able to develop complex interactions that emerge from a relatively simple design?

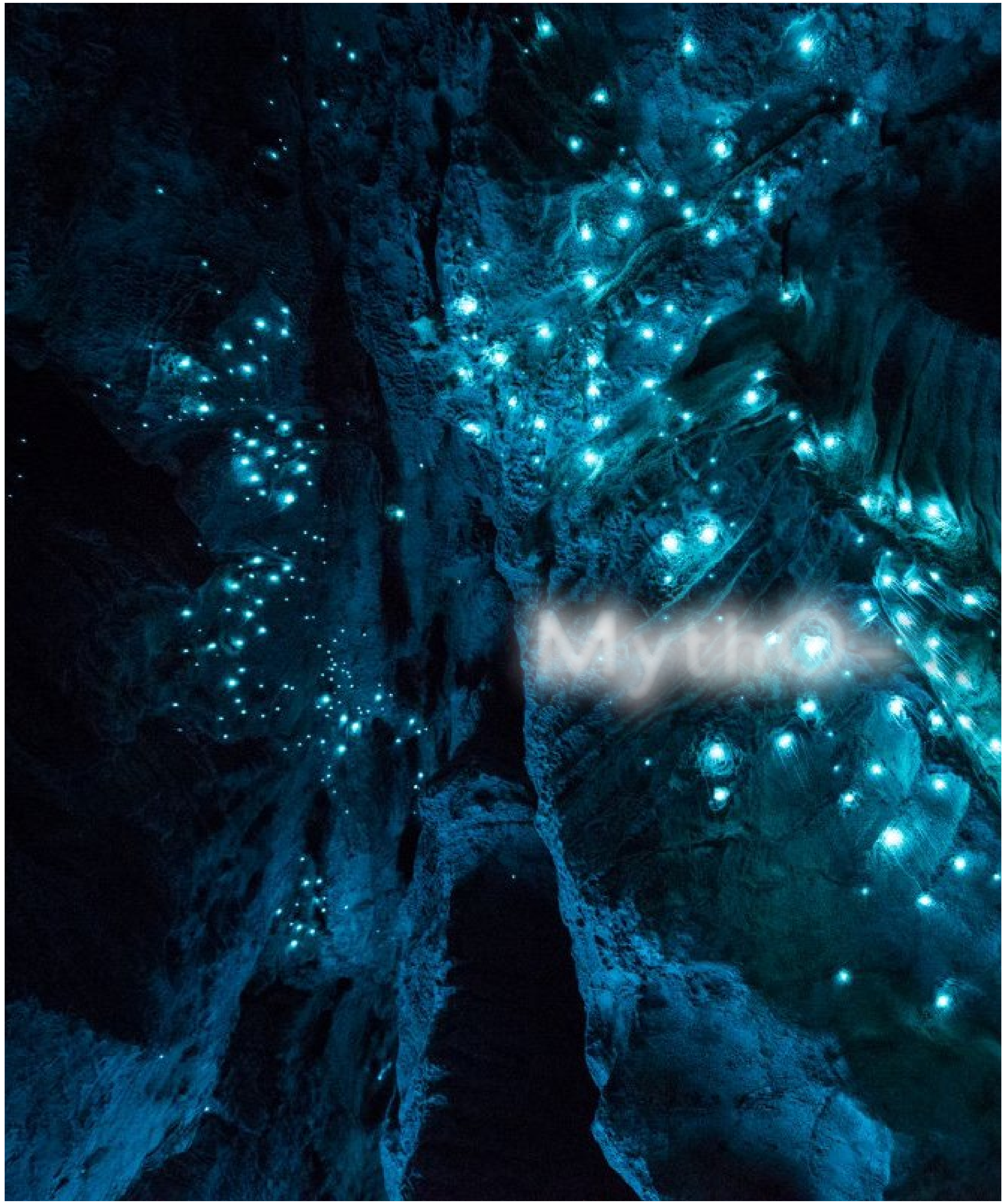


photo: http://www.picrail.com/l/3bkie2/longexposure-photograph-of-illuminated-glowing

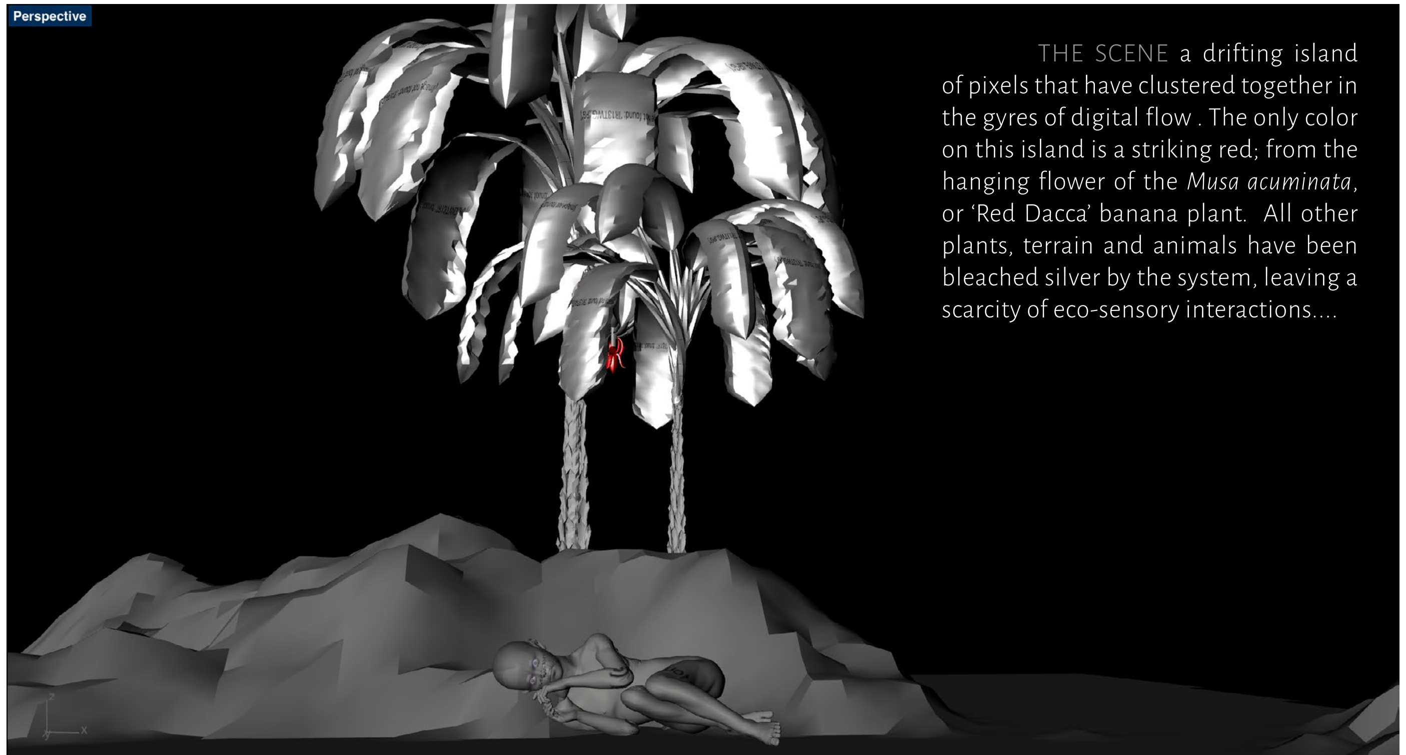
//WORLD_BUILDING

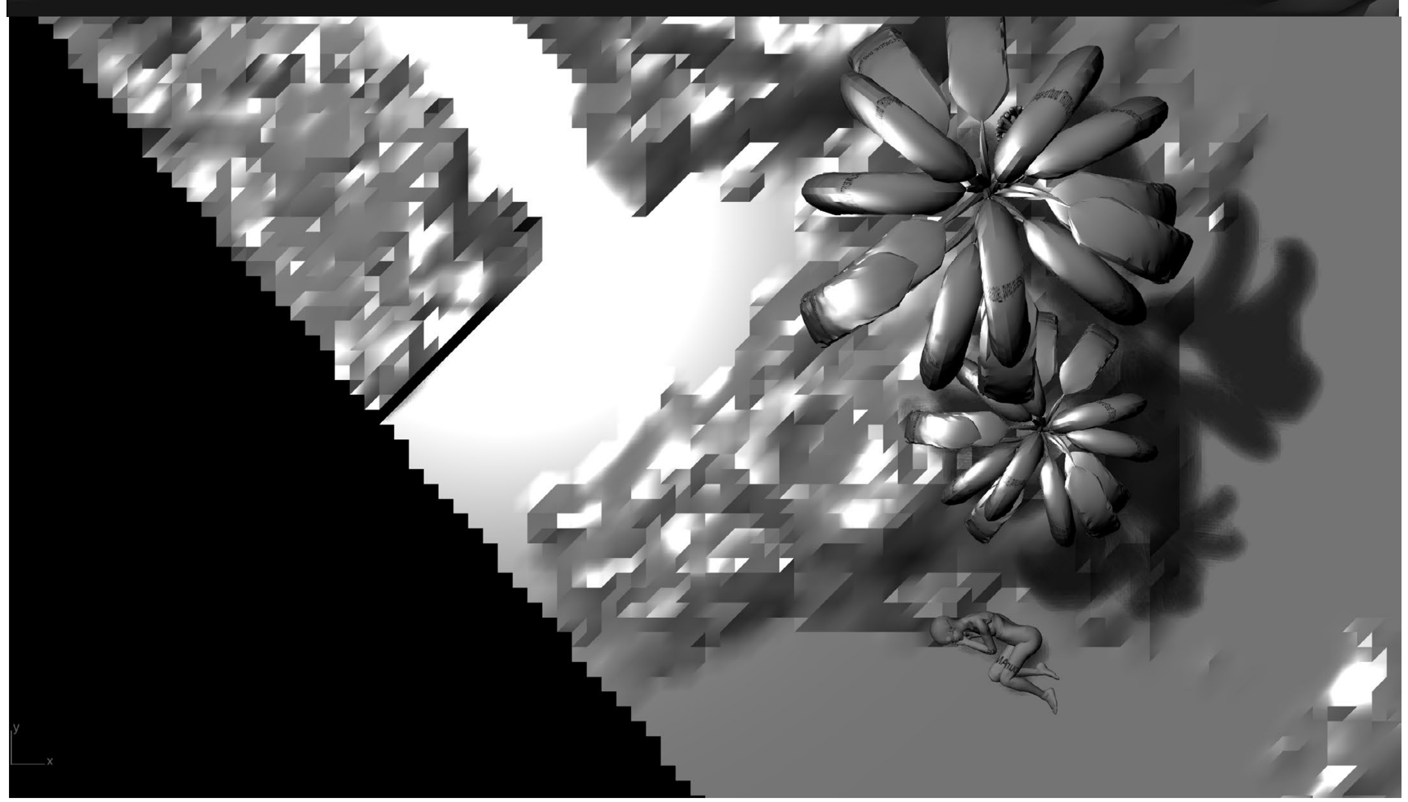
This chapter contains 'alchemical' research that takes the form of various world-building exercises – using video, collage, 3D modeling, 3D printing and narrative. Constructing speculative digital environments allows us, as purveyors of these realities, to implicate our own subjectivities in this world. What are its material qualities? How do these objects react to 'sunlight'? What flora is native to this area? What are the alchemistries of this space? How does an imagined territory interact with your imaginative wanderings?

It proposes a future – or a reality that is temporally-dislocated from ours – that does not yet exist but could one day. At the same time that it enables an imaginative approach to design and 'critical play,' it can simultaneously shift perceptions of what is possible in material reality. A successful vision for a future or technology through narrative and immersion opens up a discourse that, if convincing enough, will be able to shape industrial and societal flows to the point that the object or process becomes materialized. The speculative device then becomes a real device, excavated from the future in a neo-archaeological fashion.

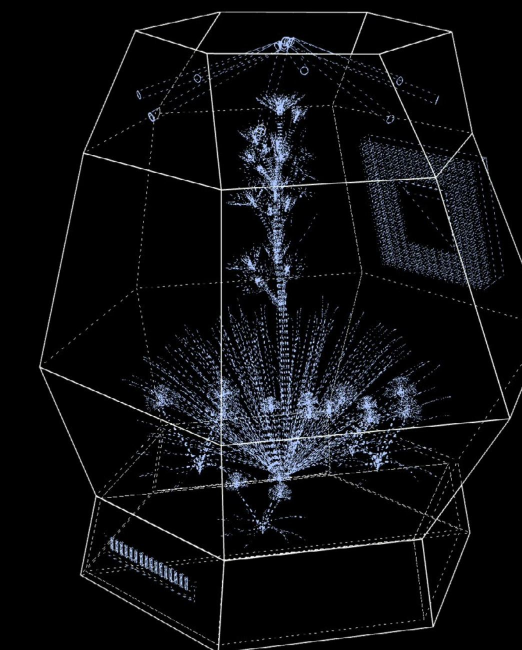
This world incorporates found objects from web archives of free 3D models, as well as original designs (specifically the e-terraria), that have been manipulated, layered and collaged on top of one another to create an environmental scenario in *Rhino*. The altered physics of the digital space allow space for

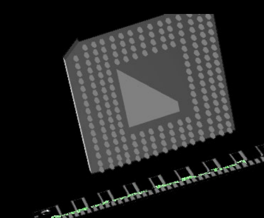
THE SCENE a drifting island of pixels that have clustered together in the gyres of digital flow . The only color on this island is a striking red; from the hanging flower of the *Musa acuminata*, or 'Red Dacca' banana plant. All other plants, terrain and animals have been bleached silver by the system, leaving a scarcity of eco-sensory interactions....

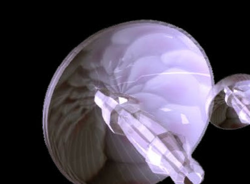


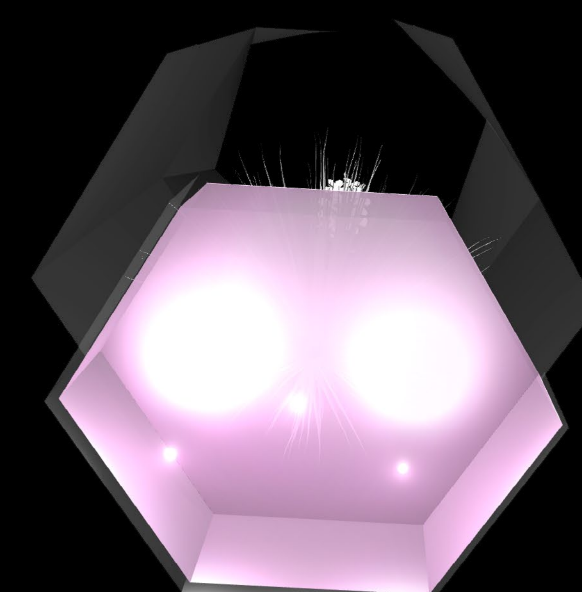


THE ALCHEMISTRY a crystalline e-terrarium that houses multiple species, namely: *Brassica rapa*, Kyoto moss, *Taraxacum erythrospermum* and dwarf hairgrass. The embedded computation system enables an interactive environment in which users affect change in the system, which become visible and tangible over time. This materialization of human effects on plant ecologies signals a larger call for mindfulness with our approach to ecosystems on the global, down to the local and molecular scale.



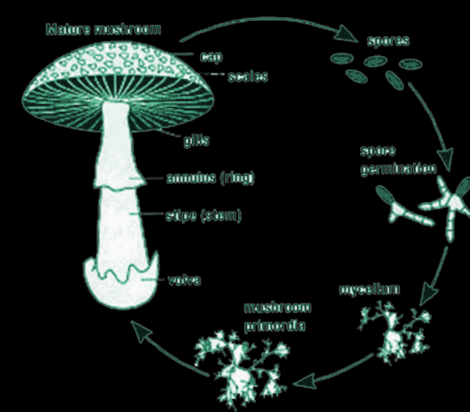


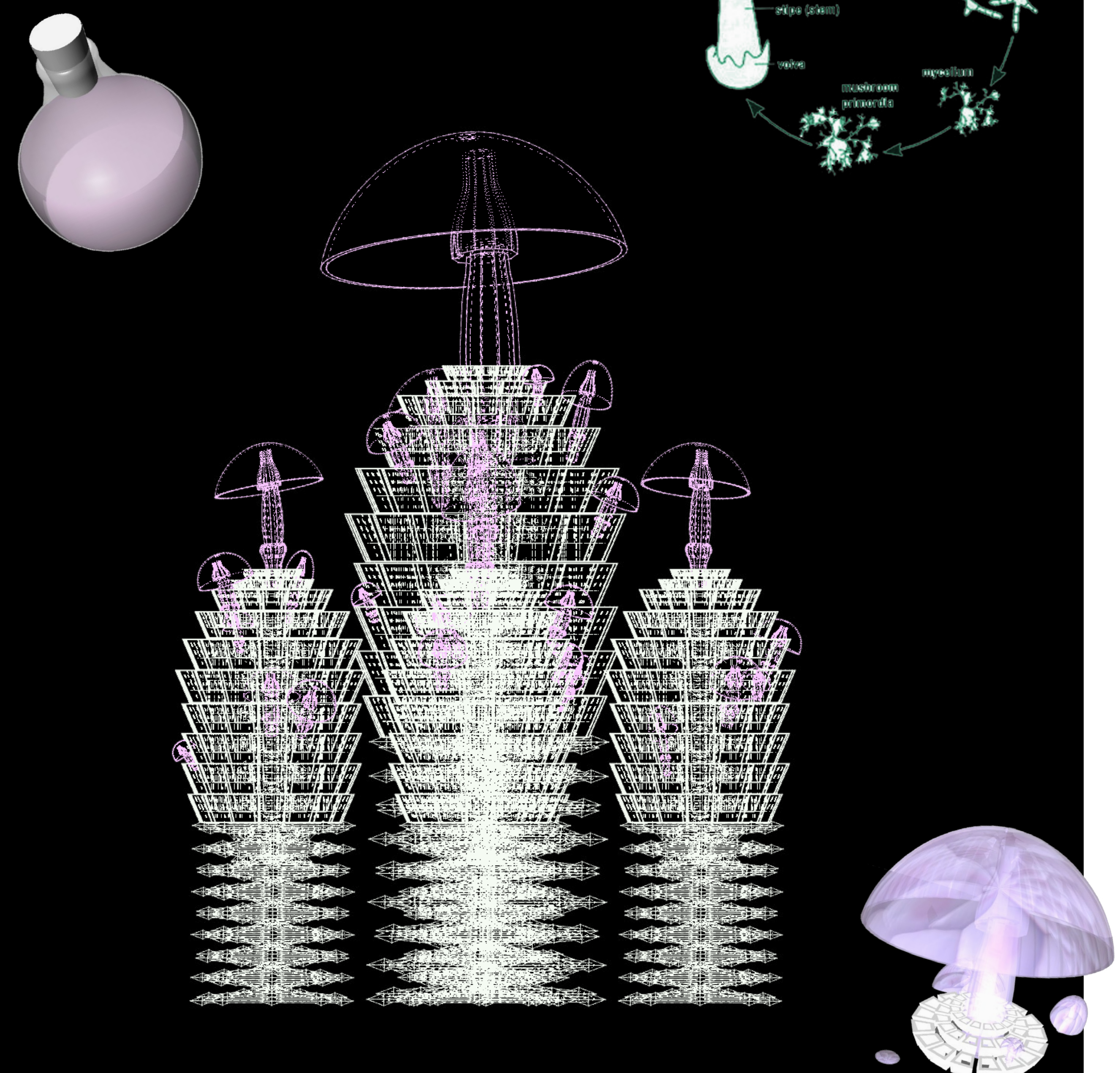




Not only does this e-terrarium register and materialize human input, but it also allows the plants to communicate their needs, as well as a song-voice of electromagnetic activity, through computational translation. The plants sing – perhaps initiating more interactivity with their human co-interactor. The human reacts – perhaps changing their input with each new melody. They enter a sustained dialogue of interactions.

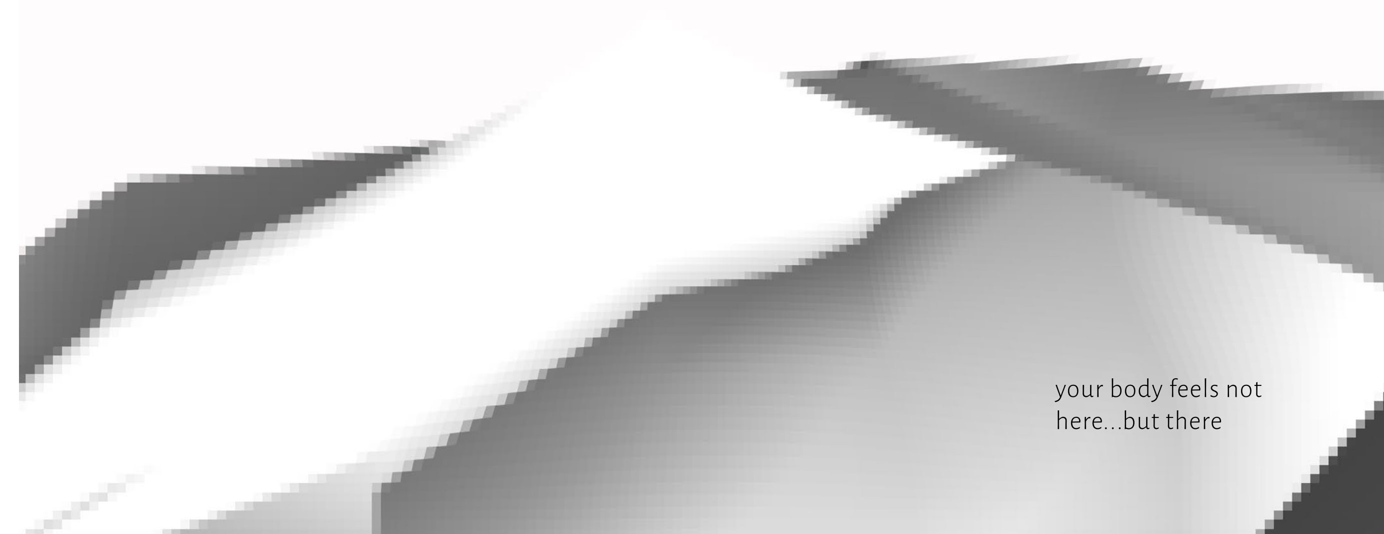
a carefully curated nutrigenomic solution is infused into each cone, optimizing nutrition based on the species' needs. It draws from a biodigester in the core of the contraption, with material composted from waste matter in the home...





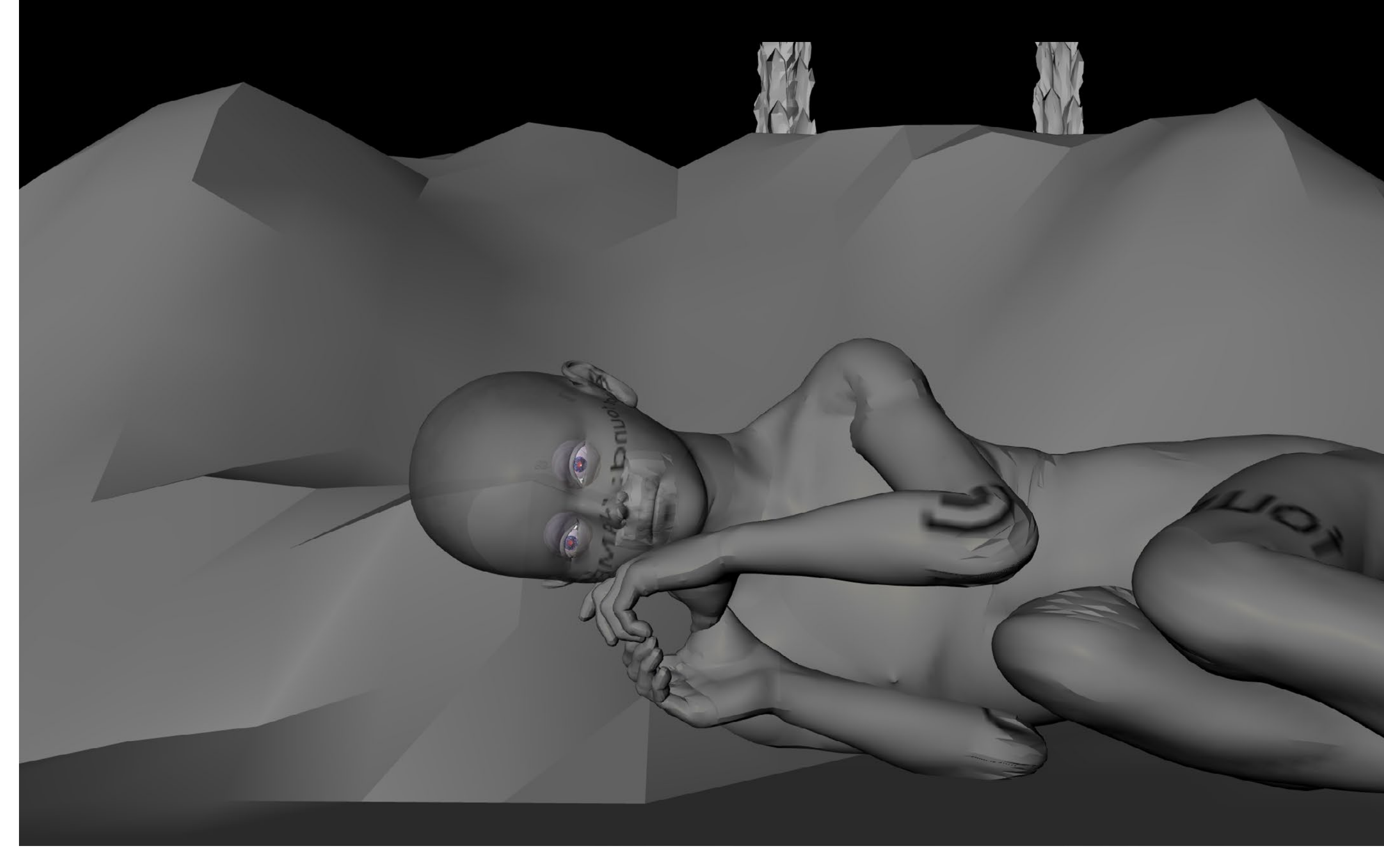
This mycological iteration, infused with the spores of *Mycena chlorophos*, interacts with light based on its grow cycle. Initially buried beneath the floor, the contraption, biomimetically modeled on a young fruitbody, begins to rise after the mushroom mycelia have colonized the substrate in the cones. A flap opens, allowing the springs to gently lift the contraption up through the floor, emerging into light and triggering the fruiting bodies to emerge. At night the *Mycena* emit a soft green bioluminescence, attracting nearby observant, soft humans to watch them glow. Sensitive to humidity and light, the mushroom-apparutus will retract into its cave when conditions become too warm, too dry or too hostile. ...

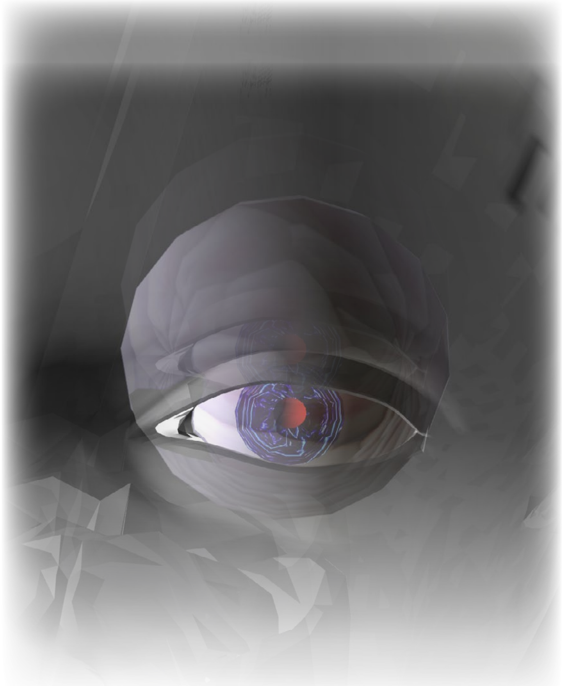
...a blur of pixels too bright to see flashes before your eyes...



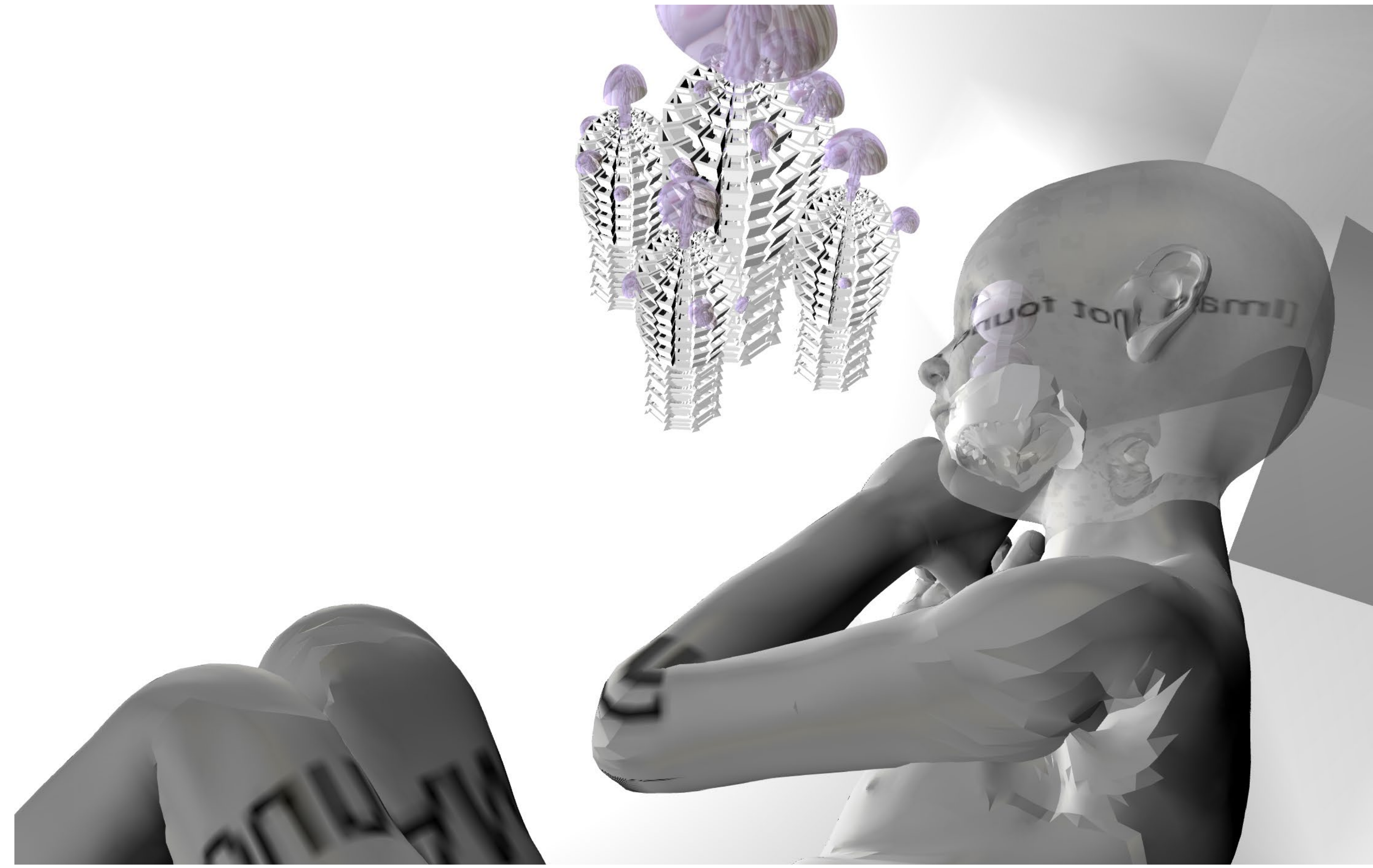
your body feels not here...but there

You lay your head down on a cold geometric facet, unable to remember how you came to be on this island. The dark cavernous interior of the system contains no stars, no points of reference as to the space beyond this small patch of pixels. Haunting, yes. But in a way, it allows you to imagine anything to exist in that blackness, a ripeness of virtuality... you begin to drift into sleep, limbs tired from a forgotten journey....





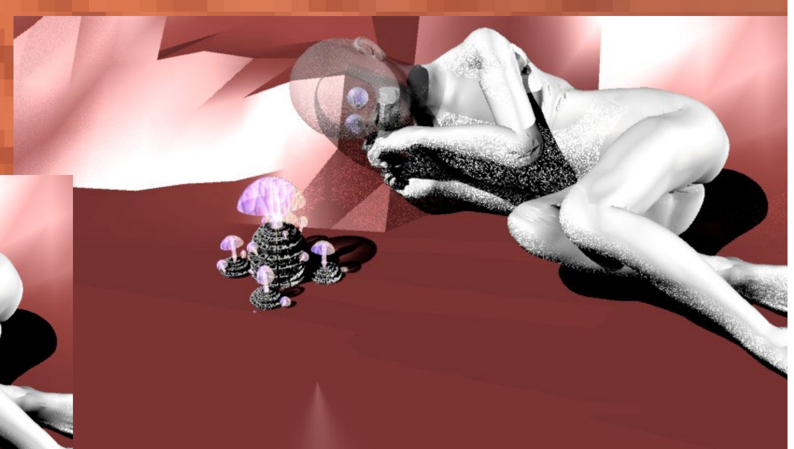
lids heavy with the weight of being stranded... You close them. But nothing disappears into darkness. You see everything around you as before...

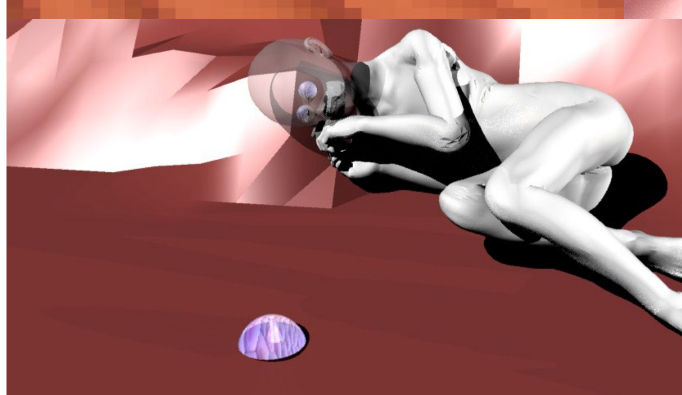


Your mind feels fragmented, overloaded by slices of data that do not fit together. You begin to imagine red sand beneath your body, and glistening ruby rocks where your head used to be. The light has a different quality in this space, softer, more organic. You try to maintain your focus, sure it will slip away into darkness again if you let it. The space feels infinite, but also more filled with something. . . a certain energy

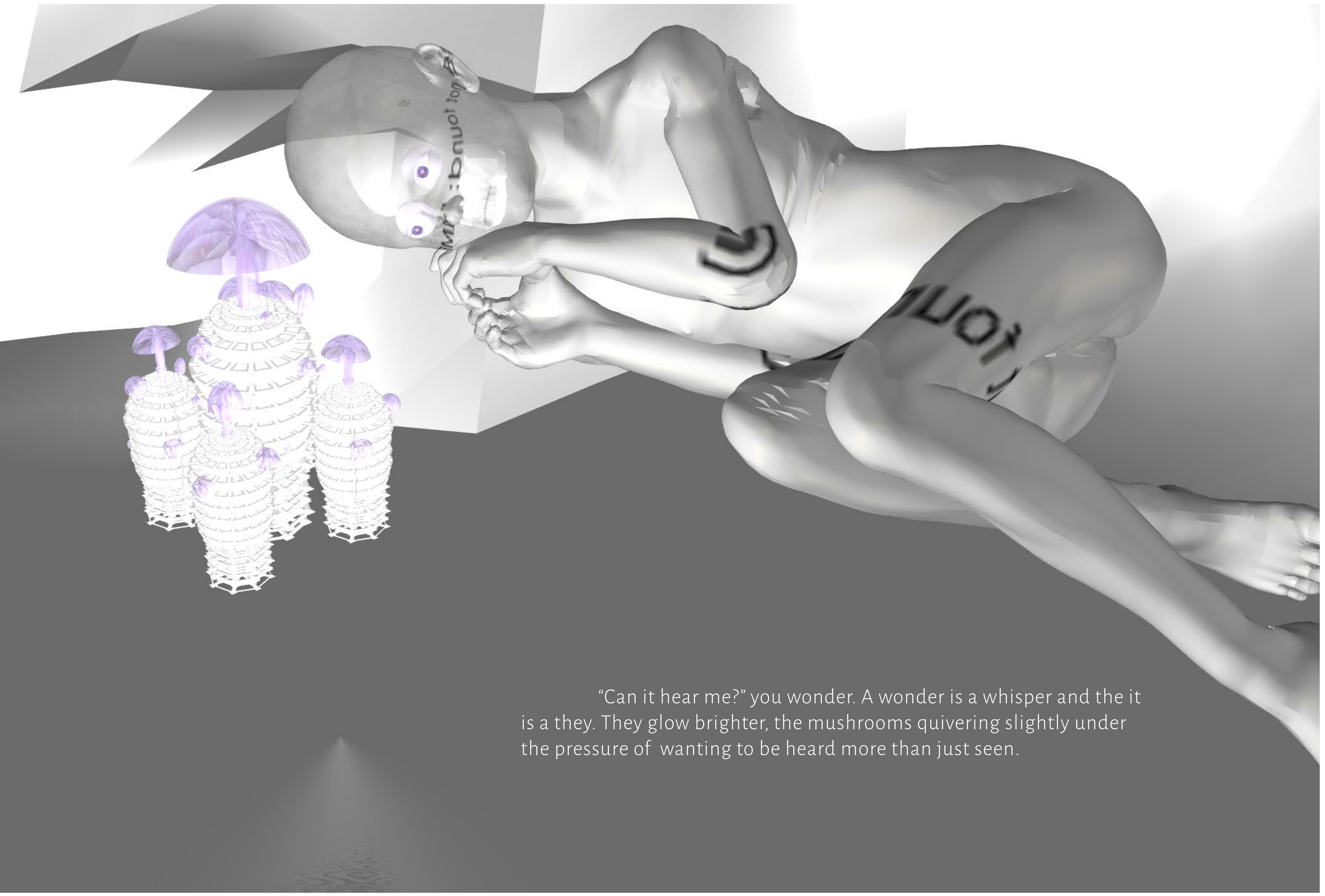
A glowing jelly bubbles up from the sand, purple and speckled with fragments of bioluminescence. The jelly is not a jelly anymore but a mushroom cap. It brings with it a whole family embedded in a conical system, casting pixels of light on to your skin..

Your skin tingles, as if this light is permeating your body, through your pores and into your bloodstream. You feel charged





....the red sand and pink rocks flicker, and disappear. A glitching from the ephemeral red-sand zone to one which is clearer, more perceptible. The mushroom system remains, glowing now with the full force of all of its jelly-cap batteries. You stare into the organo-computational structure, examining the modular husk-like compartments making up the cones. Hexagonal supports stack on top of one another with flexible joint-springs in between. The more you stare, the more it stares back...



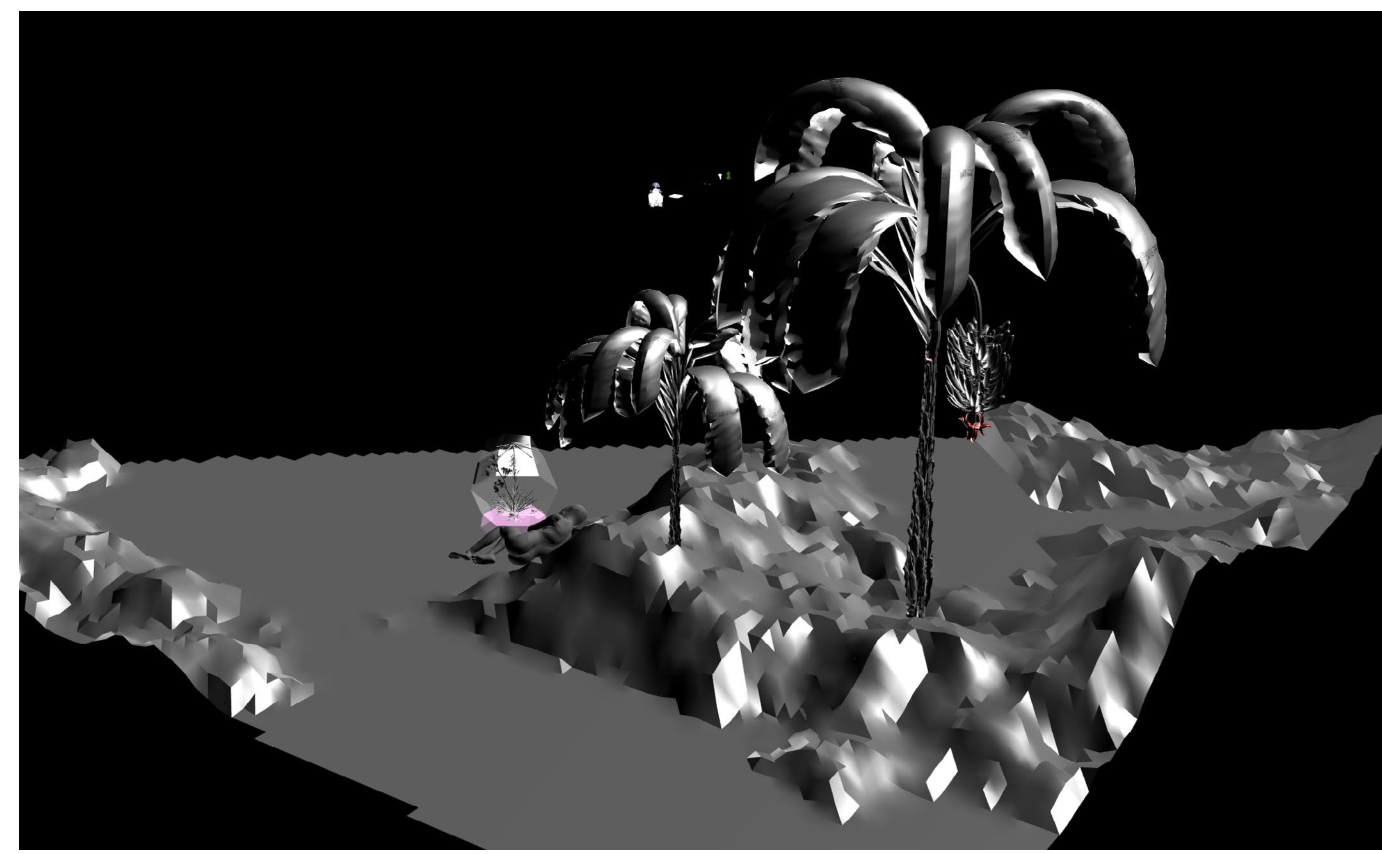
"Can it hear me?" you wonder. A wonder is a whisper and the it is a they. They glow brighter, the mushrooms quivering slightly under the pressure of wanting to be heard more than just seen.

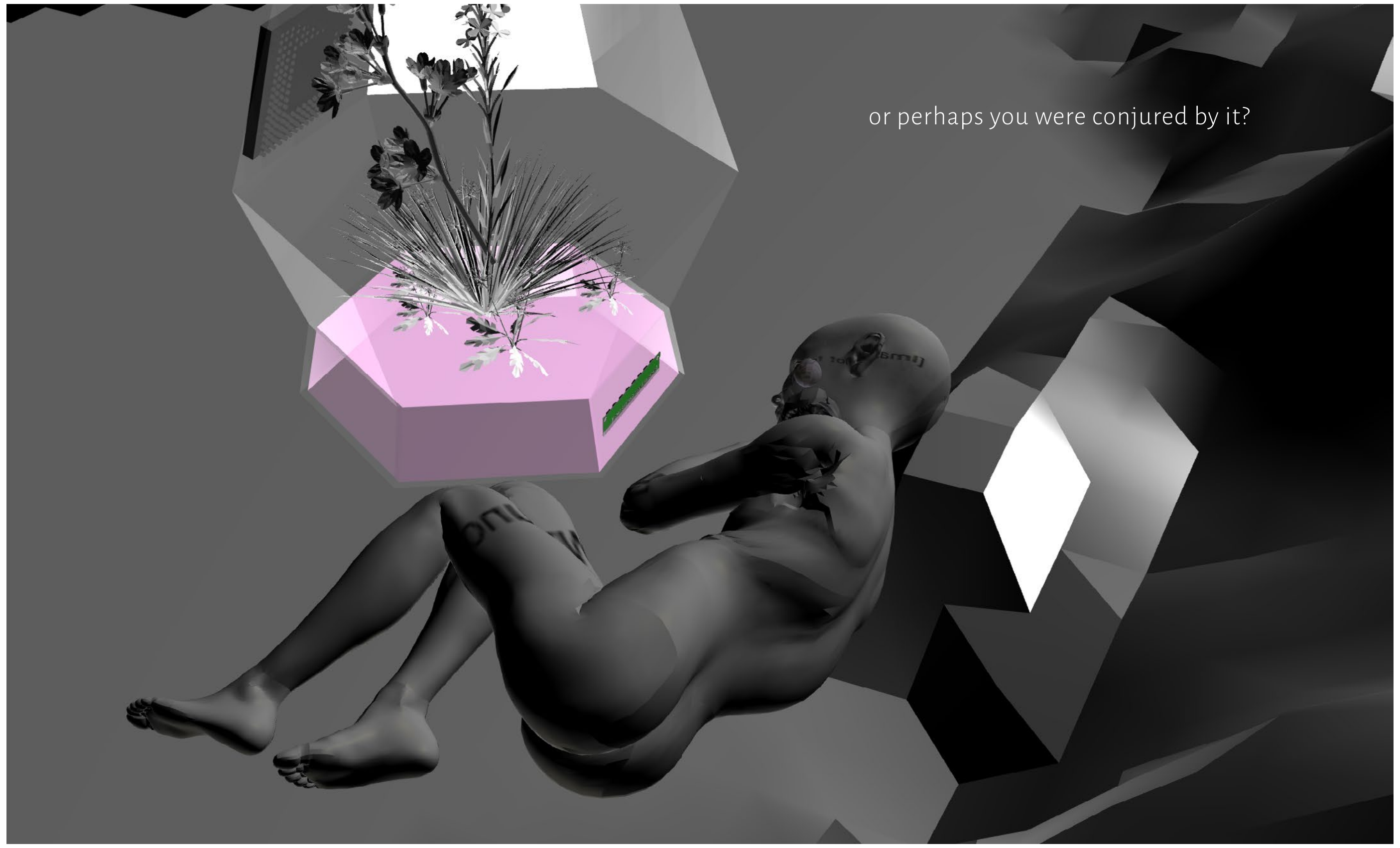
...night falls again on the island and the pixel-sand softens. Light takes on a different rhythm here, as if intention and interaction were influencing the circadian flows more so than the laws of physics. A meditative focus tends to call forth the day in its brilliance, whilst an innocent drowziness can cast the world to sleep if it is let loose. A perpetual flickering of consciousness can lead to a relentless, frenetic light field... A form of stagnancy in which everything is moving so fast that it appears to have stopped...

You continue to explore the mushroom apparatus for the next few days, examining its behaviors and their own emotional entanglements. After what seems like five moon cycles, you loose focus. A blockage has been reached in which each interactant, you and the myco-apparatus, is not willing to let go of an aspect that defines your respective selfhoods. The upper limit of symbiotic information exchange had been reached, and to go further means breaking through the threshold membrane into the path of organismal horizontal data transfer...

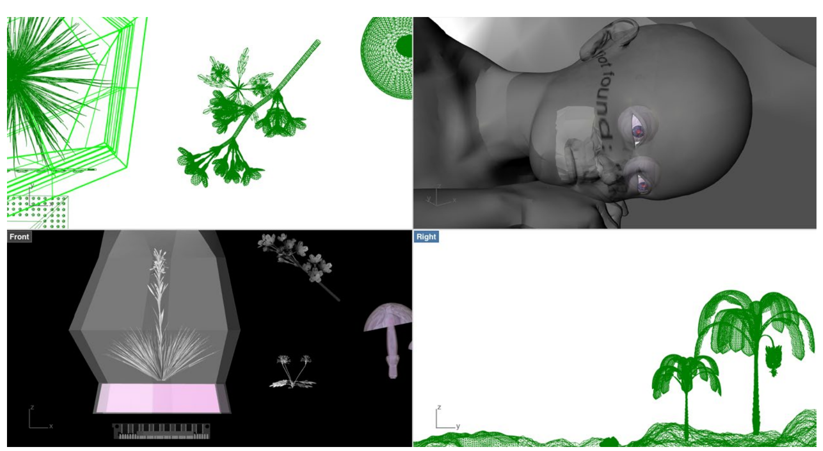
And so the darkness takes over for a while, a necessary respite to remedy the exhaustive learning models of interactivity. You sleep and recover, entering dream-processing states and imagined territories to integrate your understandings. The maternal Red Dacca and her kin watch over – sentient protectors of the lost beings that wash up on this island...

One evening, a new system appears before you...





...this one is prismatic—gem-like and glistening. A soft whistle is being released from somewhere inside, the plants quivering their leaves and fronds. You sing back with their own melody (please sing your melody), and the system responds by harmonizing. The pink fluid pool swirls slightly, unsettling any algae that had been sitting. You and the system enter into a song-voice dialogue, confident now in your ability to pluck virtualities from the manipulable pixel field around you.....



Video Stills

These are stills from a video that I have been working on for the last 2 or so months. I am still in the narrative and cinematic development stages and would like to shoot several more scenes. However, these stills give you a glimpse into the world that I am crafting: one of plant+ technologies, patabotanical examinations, alchemistry, ritual, robots and soil. It will likely develop into a wandering through an imagined plant+ future, with the philosophies and architecture of *Conversational Ecologies* infused within this video medium.

In the first still on the right, you can see the HexA-Morphouse, a pataphysical technology that will be explored further in the following chapters of this text (see pgs 63, 74, 75). To create these scenes, I have utilized green screen and keying, lighting design, costume design and fabrication, 3D printing of props, and of course the camera as mediating manipulable eye.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1400
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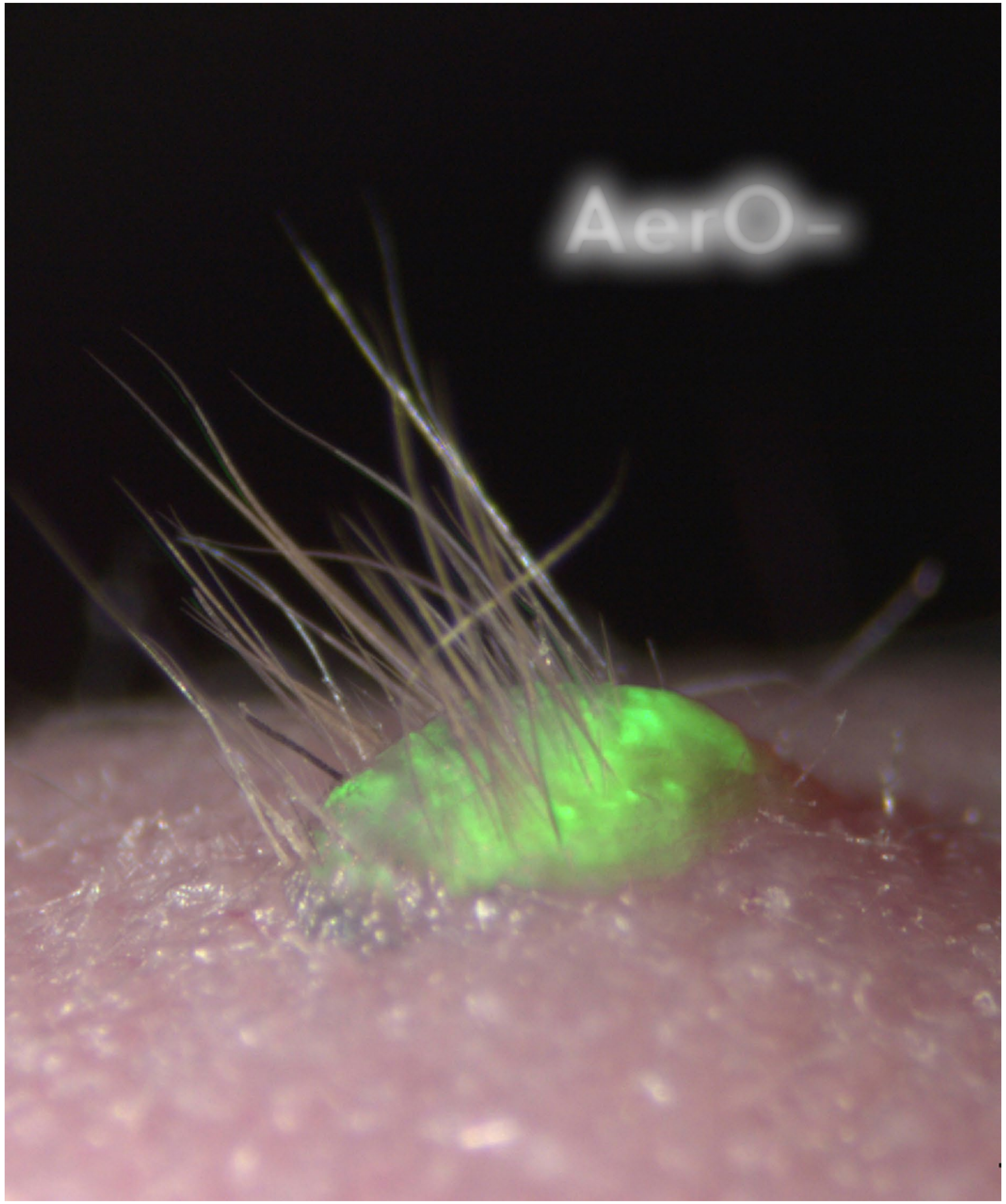


photo: http://www.vocativ.com/304045/lab-grown-skin/

// CRITICAL THEORY

This chapter is an engagement with existing and original concepts relevant to interactive architecture, materiality, the human/nature dichotomy, sensory processing and living technologies. Embedded in this discourse are cyborgian, postmodern and transdisciplinary views of space and subjectivity. The chapter is structured into subsections, dealing with the construction of these conversational ecologies, the immersion of a body into their sensoria, the subsequent processing needed to assimilate this new information and the potential applications of these technologies.

This transdisciplinary approach is often rooted in logic and connectivity – but may also verge on the 'patabotanical' or speculative. It is also, and vitally, a call to examine our own positionality within *all* ecologies, and to consider the Capitalist orderings of spaces and bodies that toxify these webs of life.

Material Intelligence [construction]

And what of the minds of these environments? Logically they must contain intelligence in one form or another to be able to converse with their interactants. If it were a 'dead room', as those described by Caroline Jones in *A Mediated Sensorium*, whose purpose was to not exist, it would not necessitate intelligence and would serve only as a neutralization of the life around it. But the intention of these environments is to activate. It is there to become enmeshed in the fabric of life, to occupy the liminal space between abiotic and biotic. Imagine a rock evolving into a living organism?

We have limited language to describe the ecological niche that these creatures occupy, as they are at once architecture, robot, cyborg, biomorph and extensions of our self. But that should not limit their coming into existence. Flora, fauna... formo? Such categorizations do not even seem relevant anymore. Instead lets look to the intelligences found in their materials, and build from there. The majority of material candidates for interactive environments fall within the world of digital computation, as a cybernetic approach allows for feedback and response to change. Philip Beesley's *Hylozoic Ground* utilizes a distributed intelligence system like those found in coral reefs, rather than a centralized one seen in the human brain and central nervous system. Each limb and tendril has its own sensors, microprocessor and actuator, meaning "this technology results in real-time sensation, the expectation of touch, empathy, eye-tracking."[34] There is no lag time as the information is re-circuited back and forth between a central processor, it is distributed and instant: intimate. In this way, the geotextile[35] can react with a localized response to a singular disturbance, or with a collective one if environmental change becomes widespread. An individual produces an entirely different response in the system than say a herd of creatures. With this distribution of microprocessing, emergence becomes an important factor in the upscaling of intelligence from a single building block to a complex system of synergetic intelligence.

Skylar Tibits at the MIT Self-Assembly Lab is working on a series of responsive building-blocks, using programmable carbon fiber and shape-memory alloys to embed certain behaviors and reactions within the materials. Their goal is to create "robots without robots,"[36] bypassing the bulky and energy-consuming electromechanical devices typically used, to produce more adaptive and dynamic systems. These autogenic materials contain their own intelligence without the need for external processing, meaning, eventually, they will be widely available at low cost and can be inserted into environments without the need for an advanced technastructure. In a similar vein, researchers at the Wyss Institute for Biologically Inspired Engineering at Harvard University have recently 4D printed a hydrogel orchid-shaped structure, that, when immersed in water, undergoes an anisotropic swelling that causes them to fold inwards.[37] This was made possible by mathematical computation of each 'cell', determining the path of movement over time that the aligned cellulose fibrils exhibit when in water, and the subsequent production of this model through precise 4D printing. These materials are being developed to shift over time, and to respond to differing environmental conditions through intelligent programming.

However, this material intelligence is being developed in the ivory-tower echelon of engineering and academia, most likely with a wealth of research that is still inaccessible to the public. This sequestration of a financial and knowledge-based economy creates only the smallest of circulation paths, moving between labs, government offices and private firms. For the most part, these pioneering technologies are being driven by engineers, scientists and designers with access to million-dollar institutional budgets and advanced computational infrastructure. While the work they are doing is radical, there is little room for the rest of us to engage in this dialogue but as passive, mediated consumers. Additionally, a purely mechanical simulation of life does not support life itself. The process and production of this robotic intelligence consumes energy and finite resources, and creates a product that can be more easily owned, participating in a capitalist economy of material goods. To paraphrase Maja Kuzmanovic of FoAM paraphrasing Einstein "we cannot solve a problem using the same kind of thinking that caused it."[38] To institute mechanical measures to subvert the mechanisation of bodies and flows of exchange will not be enough to pull us out of the stream of hypercapitalism that we are swimming in. The further consumption of resources without ecological restoration or sustainable measures will push us further towards environmental collapse, regardless of how 'biologically inspired' these technologies may appear. We will need to lean on many tactics – old, new, and as yet uninvented – to formulate a new set of harmonious, conversational ecologies.

The world contains an infinite number of teachers – they grow all around us. Conversational ecologies have existed for millions of years before human-invented technology was even a glimmer on the horizon. Deep and complex relationships between animals, plants and abiotic variables are the original conversational ecologies. Beavers can engineer a wetland ecosystem through their treefelling, encouraging the growth of new vegetation, water filtration and sediment accumulation. With these actions, a more diverse and healthy ecosystem grows, introducing more nutrition and organisms into the feedback cycle. Hirokazu Toju et al. recently studied the complex interactive newtworks of subterranean plant-fungus symbioses in Japanese temperate forests to determine whether "plant–mutualistic partner networks have nested interaction architecture." They found that "more than 90% of all plant species interact with diverse groups of mycorrhizal fungi (for example, ectomycorrhizal and arbuscular mycorrhizal fungi), which enhance plant survival and growth rate" and that "the diversity of ecological network architecture has been underappreciated"[39] by the scientific community. This reveals the lack of attention that has been paid to an entire strata of ecologies – below the soil – and further articulates the deep and complex interactions that already exist within biological communities. These interactions take place over a larger time-scale and with many more factors than human-designed environments, but they nonetheless indicate a complexity and symbiotic approach that can be learned from and interfaced with. We should not forget the richness of these ecologies in our current technological freneticism.

Combining the natural and technological, we can see transactive intelligence [40] emerging from new biomaterials. These are engineered or intentionally deployed biological building materials that originate from a top-down organizational structure (i.e. via the specific intentions of the design scientist) but function in a ground-up growth pattern based on direct input from environmental stimuli. We see this for example in MTTR MGMT's (Juan Azulay and Benjamin Rice) collaborative project *Vivarium*, for an experimental installation series hosted at SCI-Arc. This habitat acted as a "bridge between biology, cybernetics, media and architecture,"[41] translating temperature, humidity, salinity and movement data of the biological organisms into digital image sequences. Through the digitalization of these living conditions within the vivarium, the computer was then tasked with a judgment call of whether salt or water should be added to the ecosystem, leading either to extinction or overpopulation. The interfacing of biological lifeforms and digital sensing/processing [42] generated entirely new media representations, forms of interaction and synthetic asymmetries within the microecology. The use of such transdisciplinary methods is pertinent to our time – one of fragmentation, combination, complexity and crisis – and contains an underlying imperative to negotiate the increasing tension between naturally-occuring and synthetic ecologies through hybridized praxis.

ABOVE *Pyura chilensis*
photo:https://wikiafacts.wordpress.com/2015/07/03/10-bizarre-natural-phenomenon-that-actually-occur-on-earth/

[34] Schwartzman, Madeline. *See Yourself Sensing: Redefining Human Perception*. London, UK: Black Dog Pub., 2011. Print. Pg 62

[35] large-scale terrain textile; in the Philip Beesley generative approach rather than the Platonic controlling one

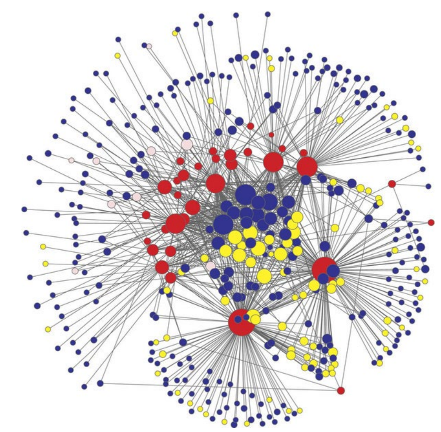
[36] Guberan, Christophe, and Erik Demaine. "Programmable Materials." *Self-Assembly Lab*. MIT, 2014. Web.

ABOVE a series of the hydrogel orchid's movements over time after immersing it in water

[37] Gladman, A. S., E. Matsumoto, L. K. Saunders, and J. A. Lewis. "4D-printed Structure Changes Shape When Placed in Water." *Harvard Gazette*. Wyss Institute for Biologically Inspired Engineering, 25 Jan. 2016. Web.

[38] Kuzmanovic, Maja, and Nik Gaffney. "Luminous Green, Mediated Environments." *The Libarynth*. FoAM, 01 July 2010. Web.

Animal paths shape the Okvango Delta, Botswana
photo:https://www.flickr.com/photos/poliza/176909978



ABOVE architecture of the subterranean plant-fungus interactions studied, in which "plant species (red) interact with ectomycorrhizal (yellow) and arbuscular mycorrhizal (pink) as well as OTUs with unknown ecological functions (blue)"

[39] Toju, Hirokazu, Paulo R. Guimarães, and Jens M. Olesen. "Assembly of Complex Plant–fungus Networks." *Nature Communications* 5 (2014): Web.

[40] architectural intelligence that not only interacts, but that transacts and transforms both the user and itself, Fox, Michael, and Miles Kemp. *Interactive Architecture*. New York: Princeton Architectural, 2009. Print.

[41] Azulay, Juan, and Benjamin Rice. "Vivarium." *Ma77er*. MTTR MGMT, Feb. 2014. Web.

[42] also seen in the The Living's 2014 MoMA PS1 installation *Hy-Fi* and Schwabe & Hulsen's *Xylinum Cones*

There is an increasing arsenal of smart materials to choose from within the rapidly expanding field of interactive architecture. A smart material however does not always translate into an immersive and intelligent environment. A "truly interactive system is a multiple-loop system in which one enters into a conversation: a continual and constructive information exchange." [43] Whether the interaction is taking place between a human interactant and the structure, or the structure and its contextual environment, or more likely a combination of the two, the emphasis is on exchange. A symbiotic learning, between animistic elements of interchangeable value.

Sensorium [immersion]

"Mind, body and tool are on very intimate terms."[44] That is the intention at least, to create a conversation so fluid that one begins to forget that there were boundaries in the first place. A blurring of bodies: so that your *self* does not have to assert it*self*. The aggressive, colonial domination of space and land has for too long required competition, control, enslavement and ownership. Interacting with space in this manner is toxic. It negates the multifold experiential qualities embedded within the fabric of our landscape, hemorrhaging with abstract notions of accumulation and denying many the opportunity to simply *feel*. What we need is less extraction, and more immersion.

"Just as the infant initially experiences the mother as a set of nurturing surfaces continuous with its own body, only later integrating a separate 'self'."[45] we too should approach these spaces with infancy. Embracing the *bwo*[46], immersing our body into this pool of sensational disintegrity we unlearn the contained body and the instrumentalized senses. Everything is in a state of flux, so to deny this reality is inhibitory to our symbiogenesis with spaces, bodies and creatures. When you eat a mushroom, your body digests and assimilates 'its' nutrients, building 'your' cells. What was once considered a separate body, an other, is now fundamentally 'yours'. Later on your egested matter, possibly containing those very cells, may make the perfect growth substrate for a new colony of mushrooms. This environmental exchange happens at every moment, and in infinitely subtle ways. Why not re-member this innate process of immersive learning through spatial play?

You are immersed in this moment, in this encounter, reliving an evolutionarily-ancient experience of discovery in the postmodern. There is something about interacting with an unpredictable phenomenon that produces a presentness in us. It isn't something you can flip back to later, or pause to answer a message on your phone. This media experience is now, so pay attention, it says. If there is a form of interaction we need most right now, it is one that will ground us in a present experience. In this time of postmodern media collision, everything is behaving with a Doppler-like reverberation. The fragmentation and future-shock[47] delivered by the enormity of historical and current mediations renders daily navigation as a technological swamp in which we are barraged with hyperstimulated mediations in almost every sphere of life.

That is, unless we enter an environment that works on intuition, on real-time learning and reaction. On an appeal to meditative flow. At first, "we react with a mixture of suspicion and awe to living forms we don't recognize,"[48] only later coming to understand their behaviors after direct experience. Thanks be to our sensory apparati, conveniently clustered at the surface of our skin membranes for maximal perceptive sensitivity. Very seldom does a 'conversational' ecology rely on verbal linguistics. Instead we must embrace the 'primal' senses in this sensorium of exchange. "Sometimes sensation is generated by the proximal nature of the container and the triggering of neurons via body hair. Other times the senses are stirred by the intermediate air itself," [49] or the olfactory productions of bioresponsive mechanisms. Or, for example with deCOi's Aegis Hyposurface, interaction comes in the form of intimate kinaesthetic imprinting, with a giant screen composed of touch-responsive metal plates that remediate the pixel. Sound and movement generated

[43] Fox, Michael, and Miles Kemp. *Interactive Architecture*. New York: Princeton Architectural Press, 2009. Print. Pg 13.

[44] Haraway, Donna Jeanne. "A Cyborg Manifesto." *Simians, Cyborgs, and Women: The Reinvention of Nature*. New York: Routledge, 1991. 303. Print.

[45] Jones, Caroline A., and Bill Arning. "The Mediated Sensorium." *Sensorium: Embodied Experience, Technology, and Contemporary Art*. Cambridge, MA: MIT, 2006. Pg 31. Print.

[46] Body-without-organs from Deleuze and Guattari, the self freed of automatic habits, "a body actively realizing its potential in experiences with other beings, 'becoming' itself" Beesley, Philip, and Christine Macy. "Disintegrating Matter, Animating Fields." *Hylozoic Soil: Geotextile Installations: 1995/2007*. Cambridge, Ont., Canada: Riverside Architectural, 2007. 29. Print.

neoprimordial sensation in trg, *Transient Reality Generators*, FoAM, 2005

[47] "the shattering stress and disorientation that we induce in individuals by subjecting them to too much change in a short time" - coined by Alfred Toffler in 1965

[48] Schwartzman, Madeline. *See Yourself Sensing: Redefining Human Perception*. London, UK: Black Dog Pub., 2011. Print. Pg 62

[49] Ibid, Pg 58

by interactants activate deformations across the surface as well as changes in light and color. One can wrap their body in a vertical field of moving pixels, dancing in response. Currently, there is no cultural engagement that prepares us for this order of experience. In such an instance, we must rely on our own feedback mechanisms between sensory perception, processing and actuation (muscular response) to affect a language of symbiotic action. We do not communicate directly with the 'mind' of the environment, nor do they with ours. The experience is always mediated by the sensorium of liminal space: the in-between. This in-between is an interface, and interfaces can be manipulated to shift the translation of content from one body to the next.

[RHIZOME] **Scale**

There is almost an implicit assumption in interactive architecture that the scales of interaction are immediate, tangible and user-centric. An artificial muscular system that reacts to the touch, or a sound-looping system that extracts bites from its surroundings, for example. In Simon Heijden's *Phare No.1-9* (LEFT), sensors on the roof of the building translate wind data directly into light data, which induces photochromism in a dye contained by the vessels inside. Light and color dissolve and blend over the walls, constantly changing with the weather conditions outside the building. This system works on a direct feedback loop, where one ecosystem's data manifests in another ecosystems data, for the user's appreciation. Although this immediacy is often the most appropriate for viewership, it should not hold exclusive domain of scalar possibility. There are multiple scales of exchange that we need to consider:

(i) *Time* (is the exchange immediately present or does it take place over a prolonged period of time?)
(ii) *Interactants* (is this exchange between a human interactant and a structural one? Or between the synthetic structure and the existing environment? Or a conversation between all ecological forces?)
(iii) *Materiality* (vs. ephemerality vs. digitality?)

The banyans and temple stone of Ta Prohm at Ankor Wat (RIGHT) have been in conversation for centuries. They are so much a part of each other that neither would exist in the same way independently. The banyans have become as much a temple as the stones have become forest.

photos: http://travelexp.me/angkor-vat.html
www.cfileonline.org/marketplace-miami-design-2013-oasis-oddity/

ABOVE Jesse Kanda's cyborgian creature

[50] Azulay, Juan, and Benjamin Rice. "Architecture Xenoculture." *eVolo 5* (2013): n. pag. Print.

Surrender [processing]

"...apprehensive, desire turns aside; sickened, it rejects... But simultaneously, just the same, that impetus, that spasm, that leap is drawn toward an elsewhere as tempting as it is condemned. Unflaggingly, like an inescapable boomerang, a vortex summons and repulsion places the one haunted by it literally beside himself" [50]

Seeded by a milieu of techno-anxious contemplations on alien invasion, robot armageddon and human subservience (think The Matrix, Ex Machina, La Planet Sauvage, 1984 and on and on), our generation has been primed to be fearful of relinquishing any real power to other life forms, especially those that verge on the uncanny. The equal other, or more frightening; the superior other, poses a threat to human existence and therefore appears more times than not as the villainous projection of our self-doubt and angst.

This is not a new phenomenon, but rather a mental tick that has been translated into each successive medium. As we developed our world-controlling abilities, a sprite of paranoia has co-evolved alongside it. This sprite embodies the fear of returning to a primordial parity: our loss of mastery over the environment and other beings. We will enslave humans and non-human animals as expendable bodies, poison our crops to prevent other creatures from feeding, extract fossils to fuel our movements and suppress any voices that pose a threat to this totalizing blanket of domination.[51] With each gain in mastery, each technological advance that allows us to extract from the Earth and Sun more efficiently, the precipice from which we can fall grows taller. And so the vertigo embeds itself deeper into our minds, into our way of approaching the world.

Carrying with us this fear of the unpredictable other, we approach conversational ecologies with caution. As these environments are responsive and intelligent, they have the power to interact in ways we may not anticipate. Our sprite is triggered: this being that moves and speaks has power. "Does it have power over me?" you wonder. More than just losing control over a set of environmental conditions, we fear losing our contained self, seeding "the intense anxieties that erupt when the perceived boundaries of the body are breached."[52] Our body bleeds into this new environment and we enter identity crisis. Perhaps the interactant will flee, unable to confront their violated conception of subjectivity. Or maybe they will utilize a skeuomorphic tool of reception meant for another medium.

How do we unlearn this engrained fear-complex? To be vulnerable in the presence of an entirely new environment, knowing that we do not have absolute control or knowledge, is a rewriting of behavioral tactics for biological survival. The unknowing seeds paranoia, and will not abate until the system is learned. But can we learn the system without the need to master it? Can we immerse ourselves in a situation with enough humility to forego ego-affect? In being vulnerable and humble to this conversational ecology, we are allowing ourselves as interactants to become permeable, to allow wisdom particles and free intensities to penetrate our subjectivities. To spill forth into the plasma of shared-body.

"A fear of loss, of being overtaken by the system"[53] is then replaced by a symbiotic learning. This exchange of information from interactant to environment to interactant becomes a continuous feedback loop rather than an imposition upon the Earth. The conditions of experiencing this conversational ecology become more equitable. The architects are not imposing an unwavering system upon an environment or people as there is space to grow in new directions - the ecology is alive and transmutable. The plasmic nature of this architecture is similarly reflected in the behavior necessary to fully access its teachings: of de-rooting oneself from the lizard-brain attempts at order. Coupled with this need to surrender, to leave the ego behind, comes a renewed agency in effecting change in the ecology. The master/slave dichotomy dissolves, and is replaced by a non-binary, anti-hierarchical tidal exchange. When a body is shared and fluid, there is no function in owning it.

Transmutation [application]

"Now, after ages of superimposing technological worldviews on living systems, perhaps it is time to evolve technology from life" [54]

Imagine a time when a conversational ecology ceases to be a foreign language, when it bleeds into other arenas of life. What grows out of this spatial approach is not just an experiential exchange or reinvigorated form, but also a shifting philosophy. If we can speak in a fluid tongue within the context of a conversational ecology, it is likely we can transmute beyond the endogenous. What would we carry with us? A renewed sense of agency in light of our current world-hegemony? A greater appreciation of the environments we were birthed from and a reevaluation of our place within them? An expansion of spatial possibility?

[51] The blanket woven mainly by western patriarchal authorities, but exhibited in microcosms throughout human history and all over the world

[52] Hayles, Katherine. *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*. Chicago, IL: U of Chicago, 1999. Print. Pg 23.

ABOVE A visitor interacts with Philip Beesley's *Hylozoic Soil* at the Venice Biennale through the protective mediation of her camera lens

[53] Schwartzman, Madeline. *See Yourself Sensing: Redefining Human Perception*. London, UK: Black Dog Pub., 2011. Print. Pg 62.

[54] Kuzmanovic, Maja, and Nik Gaffney. "GroWorld, Experiments in Vegetal Culture." *The Libarynth*. FoAM, 04 July 2014. Web.

To create spaces that embrace life, that are alive, we need to examine the role that living technologies can inhabit. Defined by Hanczyc and Armstrong in *Bütschli Dynamic Droplet System*, "living technology refers to a broad spectrum of interventions with differing relationships to the phenomenology of life, which include: being integrated as functional components within a living thing that does not possess an innate agency (e.g., hip implants), actively participating within a living system to create designed outputs (e.g., genetic engineering, reproductive technologies, stem cells), and reproducing phenomena that are arguably lifelike, yet do not share the same materiality as biological systems (e.g., the Internet, artificial intelligence, domestic robots, lifelike chemical systems)." [55] Living technologies can morph and adapt, grow, communicate and even perish. They are at once highly sensitive *and* resilient to crises.

The library of living technologies is relatively young, consisting of plant+ technologies, programmable chemistries, bioprosthetics and genetic engineering among several others. With research, and public interest, these living technologies can be evolved and applied to architectures of the everyday. In 1941 "the physicist Erwin Schrödinger (1887-1961) defined living matter as that which actively 'avoids the decay into equilibrium'."[56] If these spaces are alive, then they will attempt to avoid this decay into equilibrium: by shifting to meet the qualities of new interactants, by adapting to rapidly changing environmental conditions and by asserting themselves as beings with a right to space and life. They will deny the stagnancy that eventually comes to dead structures by avoiding the 'equilibrium' of an inactive cultural or functional role. When cultural and environmental tides shift, they will not sink but will bob along with the ebb and flow.

Living technologies alone are not enough to reinvigorate the *viriditas*[57] that has been displaced by "the active aspects of our animal attributes – speed, expansion, predation and consumption"[58] and assuage our socio-environmental crisis. However, by embracing them, we are already casting a vote in favor of life and change, and the subsequent movements to further emphasize the dissemination of this knowledge and praxis may catalyze mass change. These practices have "the potential to become more than 'environmentally friendly' – a benign state of being – but environmentally remedial – active and subversive."[59] To move past the point of sustainability towards positive environmental regeneration, and expanded – not just restored – ecologies. Towards a harmonious convivium that embraces symbiotic potential.

This amplification of living technologies will likely generate friction, as all new technologies do. In this instance however, the techno-angst takes on a new form because it directly confronts the dominant position of humans in world-ordering. It is not just an intrasocietal reordering, but an extrasocietal one as well – suggesting the permeation of other bodies and beings as architects in the construction of our ecologies. As Mark Shepard suggests, "the sentient city thus becomes a contested site: a theoretical construct within which longstanding claims of human qualities, capabilities and characteristics are critically destabilized through their attribution to non-human actors."[60] Through this destabilization, we may evolve beyond our human attributes of speed, expansion, predation and consumption to include softer philosophies of growth suggested by plants and other coinhabitants. Hybridized philosophies that embrace "patience, growth, diffusion, ambient perception, chemical communication, and a continuous quest for light and moisture"[61].... to start with.

...... and the stalk grows flesh...

[55] Spiller, Neil, and Rachel Armstrong. "Protocell Architecture." *Architectural Design* 81.2 (2011): 18. Print.

[56] Armstrong R, Hanczyc M. 2013. Bütschli Dynamic Droplet System. *Artificial Life*, 19(3-4): 331.

[57] viriditas: a vitality of green growth and spirit, credited to Benedictine mystic Hildegard of Bingen

[58] Kuzmanovic, Maja, and Nik Gaffney. "GroWorld, Experiments in Vegetal Culture." *The Libarynth*. FoAM, 04 July 2014. Web.

[59] Spiller, Neil, and Rachel Armstrong. "Protocell Architecture." *Architectural Design* 81.2 (2011): 71. Print.

[60] Shepard, Mark, ed. *Sentient City, Ubiquitous Computing, Architecture, and the Future of Urban Space*. Cambridge, MA: MIT, 2011. 33. Print.

[61] Kuzmanovic, Maja, and Nik Gaffney. "GroWorld, Experiments in Vegetal Culture." *The Libarynth*. FoAM, 04 July 2014. Web.

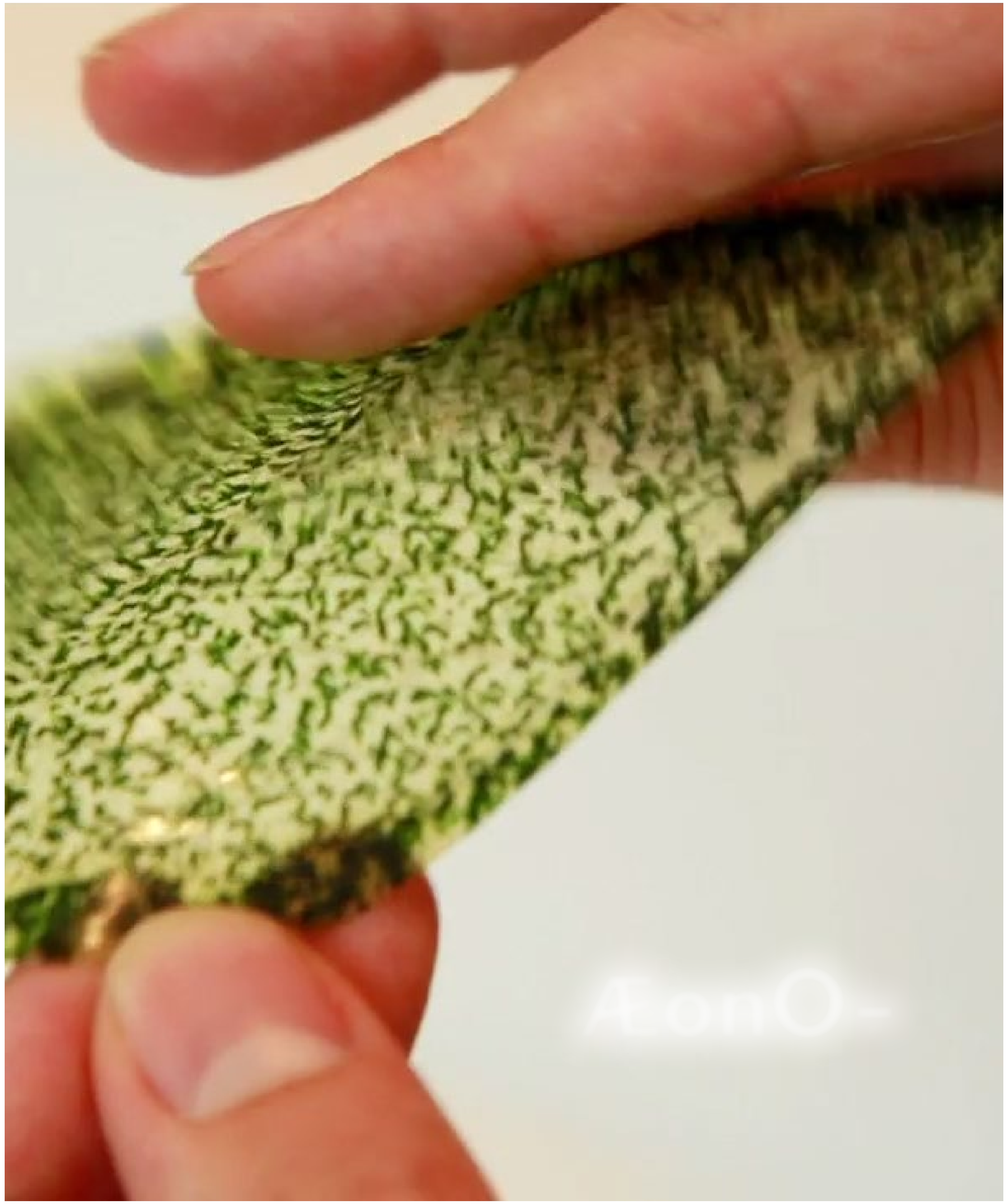
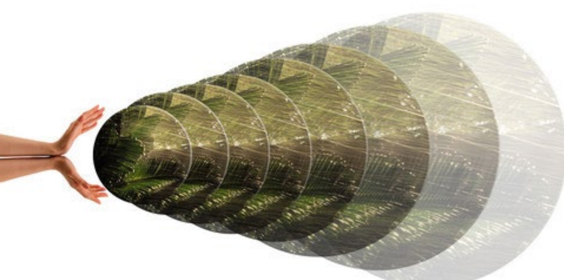


photo: http://www.designcontext.net/living-matters-sintetici-secondo-natura/

//MATERIAL EVOLUTION

This chapter serves as an introduction to viable interactive materials relative to the scope of this project, and my subsequent experimental accounts of these materials, if I was able to situate them in an ecological context. It acts as the physical component that informs and is informed by my theoretical research and worldbuilding exercises. My slim budget of approximately $300 has restricted my material experiments to a 'sample platter', only being able to explore interaction with materials that are relatively inexpensive, free, or obtainable through the institution's existing resources. It is my assumption that a conversational ecology could surely be generated from this budget or less; however, I wish to cast my net wide before I narrow down to a specific set of mechanisms that can be installed. In doing so, these materials become experimental units used to inform other makers, and future ecologies, rather than pieces to fit into a final material product.

From this research, I intend to apply for a grant informed by my material surveys and microexperiments, to situate these technologies into a scaled, hybrid and fluid conversational ecology, that will be installed to reach many senses, and the senses of many.



Flora+ Files

All plants and fungi are part of one or more conversational ecologies. They interact on a daily basis and throughout their lives, always growing, changing and perishing. These interactions may occur on the cellular level, with the uptake of nutrients or the opening/closing of stomata, up to the organismal scale of a full-blody plant reaction. Complex interactions occur between various communities – nitrogen-fixing bacteria symbiotically intertwined into root nodules for example – that are happening quickly but not perceptibly to the human eye. If we assume the analog and visible to be a starting point, both the plant capabilities and the human capabilities need to be surveyed before we begin mediating this interaction. On an organic level, most plants do not react in an immediately perceptible way. To the human scale, most plants are relatively slow, molecular and diffuse, making it difficult for an 'unmediated' interchange to occur in a short time period. Starting from the baseline of creating an organic interactive system that will react in real-time to passing visitors, a cluster of plant+ life is selected that exhibits immediate and perceptible changes. This feedback is typically visual, although other modes of interaction are possible. From this basic understanding we can narrow the choices of plants+ down quite dramatically.

(I use flora+ or plant+ to indicate that I am principally, but not exclusively, speaking of plants. Plant+ may include species of fungi, dinoflagellate and bacteria that, according to systematized scientific classification, appear in other kingdoms. It also suggests an additional layer of complexity, i.e. genetic modification or digital computation, that has been transposed onto these organisms.)

The plants I select are based on this exhibition of interactive properties, through the mechanisms of movement, chromatic abberation, predation, bioluminescence and capacitance viability.[62] These mechanisms can be directly interacted with by humans and other animals without the need for a layer of digital translation. From this starting point, we can understand the analog interactions already available through organic chemical mechanisms that occur on a human scale. It is important to note that plants+ interact with organisms in immediate ways that are not directly perceptible. Janet Braam for example has investigated thale cress (*Arabidopsis thaliana)* finding that the "TCH genes of Arabidopsis are rapidly and strongly upregulated in expression in response to various environmental stimuli, including the seemingly innocuous stimulus of touch."[63] A simple touch of a stem or leaf can alter the epigenetic expression of this plant, and surely others, affecting the production of key proteins that modify cell walls. This lasting effect implicates interactants with these plant+ species as modifiers and suggests a future for making these interactions perceptible. Similar studies have shown that acacia release tannins as well as a biochemical warning (ethylene) to their kin when overgrazed by kudu[64], and certain plant species know when they are being eaten, subsequently releasing mustard oils as a defense mechanism.[65]

These sites of molecular exchange provide an entire microgeography of potential interactions that could be made perceptible with the layering of appropriate technologies and architectures. Not only can we scale our conscious interactions down to the molecular, and therefore share in the *existing* sites of interaction that plants+ initiate, but we can also use this as a research opportunity to understand our position in these ecologies and more mindfully generate *new* sites of interaction based on them. To translate such small, or slow, or even invisible exchanges, microcontrollers and transducers can be interfaced to emphasize and elicit more complex conversations, and go beyond the visible. And perhaps these sites may act as democratizing platforms in which the anthropocentric conceptions of sensory interaction can be destabilized and imbued with new plant+ philosophies.

[62] capacitance is the electrical storage potential of a system, whether mechanical or biological, and can become a biointerface when working with HCPI (read on to find out more!)

[63] Braam, Janet. "Janet Braam : Rice University Department of BioSciences." *Rice University*, 2014. Web.

[64] Hughes, Sylvia. "Antelope Activate the Acacia's Alarm System." *New Scientist*. Relx Group, 29 Sept. 1990. Web.

[65] Appel, H. M., and R. B. Cocroft. "Plants Respond to Leaf Vibrations Caused by Insect Herbivore Chewing." *Oecologia* 175.4 (2014): 1257-266. Springer Link. 02 July 2014. Web.

photo opposite: https://soundcloud.com/michael-beharie/clara

Venus flytrap *(Dionaea muscipula)*

is a carnivorous plant native to the subtropical wetlands along the southeast coast of the United States. Trigger hairs on the inside of the traps are activated by prey, causing the traps to close and the insects to be digested by subsequently-released enzymes. Evolutionary developments have reduced redundancy in the trapping mechanism, wherein two trigger hairs must be touched within a span of approximately 20 seconds for the trap to close. This is one of only a few plants that exhibit direct rapid movements. Because of this, and its wide availability and low maintenance, the venus flytrap is an ideal candidate for developing interactive plant systems.

predation/rapid movement | commercially available | easy to grow | low maintenance

Alice Sundew *(Drosera aliciae)*

is a carnivorous plant native to the cape provinces of South Africa. An ancestral cousin of the *Dionaea* genus, the plant forms small wedge-like leaves in a rosette form. Sundews traps flying insects by secreting a sticky mucilage from tentacles on the leaves. As the plant digests their prey, the tentacles will turn from green to a deep red, through the accumulation of anthocyanin pigments in their cells. This is a viable candidate for its relative ease of growth and commercial availability, as well as its color-changing properties that indicate interaction. However, for the time span of this study it is not possible to germinate the seeds as they may take several weeks, and months for the plants to reach maturity.

predation/chromatic abberation | commercially available | easy to grow | long germination time

Sensitive Plant *(Mimosa pudica)*

is an annual or perennial creeping plant of the legume family *Fabaceae*, and is native to tropical regions of South and Central America. The sensitive plant has captured the minds of naturalists from Robert Hooke to Carl Linnaeus and beyond, for its rapid 'shrinking' of leaves: where in the compound leaves fold or 'collapse' towards the stem center. A stimulus, whether touch, wind or water, triggers a chemical release in the stem, and causes the subsequent evacuation of water from the cell vacuoles. This is a prime candidate for the study due to its immediate reactive nature, its widespread pantropic dispersal, and its ease of growth.

rapid movement | commercially available | easy to grow | low maintenance

Dancing Plant *(Codariocalyx motorius)*

also known as the telgraph or semaphore plant, is a tropical asian shrub and another member of the *Fabaceae* legume family. The plants have paired sets of hinged leaves that move in response to the suns position, or the closest sources of warmth and light. They have been extensively documented as responsive plants since Darwin's time – dancing to touch, high frequency sound waves and jets of warm air. With a similar mechanism to Mimosa pudica, the cell vacuoles evacuate their water with the appropriate stimuli. Their highly responsive rapid dancing, as well as their widespread pantropic dispersal and ease of growth make them appropriate for this study.

rapid movement | commercially available | easy to grow | low maintenance

Wisconsin Fast-Plants® *(Brassica rapa)*

are a rapid-cycling *Brassica* selectively bred by Professor Paul H. Williams at the University of Wisconsin to be used as a research tool for studying plant pathologies and disease resistance in *Cruciferae*. Their wild cousins have a life-cycle of six months, whereas this breed has a rapid life-cycle reduced to five weeks, and is now commonly used in labs and classrooms worldwide. Because it flowers within 14 days and can go to seed within 28 days, the effects of differing environmental conditions can be studied repeatedly, and, along with its hardiness, make this an appropriate plant for interfacing a physical computing programming. It is however a registered 'product', a claim that contradicts my understanding of life.

rapid life-cycle | commercially available | commercial ownership | hardy/low maintenance

Bird's-nest Fern *(Asplenium australasicum)*

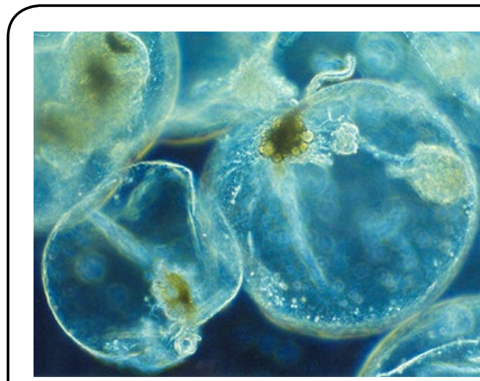
is a tropical fern native to Southeast Asia and the tropics of Australia. It grows as an epiphyte on larger trees or bromeliads, collecting leaf litter and organic material in its rosette 'nest' of green fronds. The sprouts of this plant are eaten in Taiwan and the plant has traditionally been used in folk medicine for asthma, sores and fatigue. Although this plant does not exhibit any immediate responsive mechanisms, it can be incorporated into sonic biofeedback systems using the plants strong fronds and electric capacitance. The plant also holds a mythos to me – as it was an ubiquitous feature of my childhood in Singapore (see Appendix) that now imbues this conversational ecology with a strong connective aura.

strong fronds | commercially available | easy to grow | resilient

Luminous Mushroom *(Mycena chlorophos)*

is a bioluminescent agaric fungus native to subtropical Asia and Australasia. Fruiting bodies have pale, sticky brown caps between 1 - 3 cm diameter, and emit a soft green glow at night. Maximum luminescence occurs at 27°C and may last for 3 days after the cap has expanded. *Mycena*, like most fungi, are sapotrophic and typically grow on decaying wood debris of the florest floor. The evolutionary function of the luminescence is still unknown, but may serve as a warning to nocturnal fungivores. Although spores are now present commercially, it is expensive to culture and difficult to simulate the optimum conditions to encourage glowing, which may take several months of experimentation.

bioluminescent/chromatic abberation | commercially rare | difficult to grow | delicate



Sea Sparkle *(Noctiluca scintillans)*

is a species of marine dinoflagellate found in oceans and bays worldwide, that exhibit bioluminescence when physically disturbed, through a luciferan-luciferase reaction within their scintillons. On a large scale, this produces the 'milky seas effect' or mareel, in which up to 16,000km² of seawater glows brilliantly with bioluminescence and is visible via satellites. Although the sea sparkle has recently appeared on the commercial market as DinoPets and raw mixes, it is still expensive and difficult to install in a synthetic interactive system due to its delicacy and marine ecosystem requirements.

bioluminescent/chromatic abberation | commercially rare | difficult to grow | delicate

Analog Interactive Plant+ System

The structure is made out of plexiglass sheets that have been vacuum-formed with organic clay shapes to form pockets that can act as a planter system. Holes have been inserted into the bottom of each pool, allowing water and run-off nutrients to flow down the system, and if need be, to be collected in the catchment reservoir. This was originally created for a sculpture project about liquid systems, and has been adapted for this project. Threaded rods are inserted through holes in the corners of each shelf allowing the system to be modular and deconstructable.

Planted on the top shelf is *Mimosa pudica*, a tactile field of touch responsive creeping plants. On the middle shelf, embedded in the soil are Kyoto Moss spores, another highly tactile as well as ancient species. Planted on the bottom shelf are *Codariocalyx motorius*, the Dancing Plant. These are currently being tested over their next few weeks of growth with a high-pitched whistle recording to see if they respond to music. Eventually, electronic guitar strings may be woven between the rods of this bottom layer to create a system specific instrument that the dancing plants will recognize and respond to.

Mimosa pudica,
touch zone 1

Kyoto Moss,
touch zone 2

Codariocalyx motorius,
sonic vibrations + plant dance zone

catchment reservoir

Top | **middle** | **bottoM** | **NOTES**

03/04/2016

The mimosa sprouts first with 10-15 seeds germinating within the first 2 weeks of planting. They grow rapidly.

No activity with the moss.

The first leaves of the dancing plant peek up from the soil.

11/04/2016

The dicotyledon leaves gave way to the true, compounded mimosa leaves. They reacted to my touch and it was very exciting! It reminded me of my childhood, playing these sleeping grasses like a dispersed tactile instrument.

No activity with the moss.

The dancing plant has also grown its first set of true leaves. I whistle to it and the plant vibrates.

19/04/2016

The mimosa have developed their second true set of leaves, beginning to creep more and grow sideways.

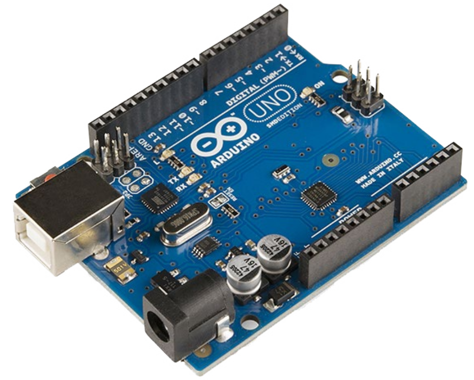
No activity with the moss, but two sprouts have appeared in the middle layer.

The dancing plant now has two sets of leaves, and a two smaller siblings. It is twitching slightly to my whistles.

Although this system has been set up for at least a month (beginning at the end of March), the first sprouts only appeared in the first week of April and are not big enought to be fully interacted with. This project requires more time and also more layering to convert it into the interactive system it could be. Nonetheless, the micromoments of plant responsivity have brought my housemates and I a lot of joy in such little packages.

To extend this analog system and make it more interactive, I plan on interfacing it with a digital computing system. I will program and assemble an arduino device with temperature and humidity sensing capabilities. This could either connect remotely through a wifi connection to Processing and provide a visual feed of the data, or could be directly translated to sonic cues in situ. These sonic cues would be triggered when environmental conditions were unfavorable, producing music that would attract people to the system, potentially finding the plants a solution to their discomfort. Research scientists have documented that trees 'scream' when under severe water stress. However, our naked ears are not sensitive enough to hear them. What else could we be missing in the life of our plant+ friends?

* Popkin, Gabe. "Trees Call for Help - And Now Scientists Can Understand." *National Geographic*. National Geographic Society, 16 Apr. 2013. Web.



Arduino

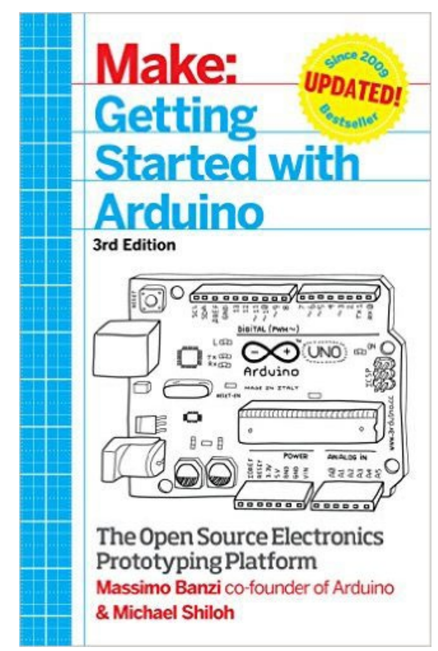
Arduino is a software company and user community that designs open sourced microcontrollers to enable arists, engineers, designers and students to create physical computing systems. The microcontrollers are minicomputers that process information gathered from an array of user-installed sensors and either send this to a computer for data collection, or output it directly into an interactive setup through a variety of connected actuators. Because of its openness and additive nature, arduinos can be embedded within countless systems, allowing users to select the sensors, actuators and programming that will animate almost any project they can envision. In 2009, collaborators Natalie Jeremijenko and David Benjamin installed two floating light displays – one in the Bronx River and one in the East River – that monitored water quality, fish activity and social engagement of this site by using arduino systems, an SMS interface and internal communication system. "An SMS interface allows citizens to text-message the fish, to receive real-time information about the river"[66] and to interact with the rivers that flow through this metropolitan hub, but are rarely interacted with. *Amphibious Architecture* maps an ecology that typically remains invisible, below the murky surface of these waterways, while still limiting the project materials to a relatively accessible level of technology.

That same year, Usman Haque, Nitipak Samsen and Ai Hasegawa situated the technicity of Arduino in their own responsive ecology called *Natural Fuse*. This distributed system is a "microscale carbon dioxide overload protection framework….. harnessing the carbon-sinking capacities of plants"[67] to generate a shared energy economy based on community needs and increasing awareness of energy usage in relation to plant+ life. A plant system is incorporated with an Arduino system to monitor the energy usage of a device, a lamp or toaster for example, and match it to the carbon offsetting potential of that plant. Rather than just individualized, isolated 'on/off' switches, *Natural Fuse* had effectively generated an 'off/selfish/selfless' switch connected to the setups in other peoples homes. Subsequently, your individual energy usage determines and is determined by the group of people with similar systems, asking you to be conscious and generous as it will directly impact energy availability to other users in the network. This system not only created an interactive biotechnological system from simple components, but it also questions our connectedness to others and generates a powerful political and environmental message on how we isolate our consumption into abstract, disconnected actions.

Arduino, along with similar microntroller systems like BeagleBone, Raspberry Pi and LaunchPad, open up the door to a massive reprogramming of analog objects to include digital capabilites, namely: sensing, interaction, remote access and, importantly internet interfacing. This is the beginning of the commercial scale of the Internet of Things (IoT), or ubiquitous computing, allowing the average user to program their objects and homes to become intelligent, interconnected systems of data transfer.

[66] Jeremijenko, Natalie, and David Benjamin. "Amphibious Architecture." *X OOZ*. Environmental Health Clinic, 2009. Web.

[67] Shepard, Mark, ed. *Sentient City, Ubiquitous Computing, Architecture, and the Future of Urban Space*. Cambridge, MA: MIT, 2011. Print.Pg 65



The Arduino Uno is the most popular microcontroller. It costs US$24.95 and includes a USB port, 12 digital input/output pins and 6 analog input pins. You can connect it directly to your computer and download the Arduino software for free from their website. From there, you can experiment with the sketches (programs) included in the software, download user-generated libraries, or code your own. Since I have had no prior experience with Arduino, let alone building electronic circuits, I decided to begin with a starter kit. I bought a kit curated by a third-party company called Vilros, which includes an Arduino Uno, a guide, an LCD screen, several sensors, LEDs, resistors and a breadboard for prototyping for approximately $63. I also bought Massimo Banzi and Michael Shiloh's *Make: Getting Started with Arduino* as it is a recommended resource for complete beginners.

My first sketch was a success: I was able to program an LED to blink at specified intervals (you have to program it to turn on and off with a time delay in between). After writing the sketch from the guide, I experimented with the intervals between on and off, meaning the blink speed of the LED would change.

My second sketch was also a success: I was able to create a theremin, a basic musical instrument that works on proximity, from a photoresistor and a piezo speaker. This is already verging on an interactive piece as the level of light that the photoresistor receives determines the pitch emitted by the speaker. If you block the resistor with your hand, or even shade it slightly, it will change its song.

My third sketch was not so successful. I was trying to program the arduino to work with the LCD screen provided, but it would not connect. It then had issues connecting with my computer. Troubleshooting this based on error messages brought me to various forums, filled with language and jargon I did not understand. I realized that I have to solidify my basic understandings of the components, of soldering, of the coding language, and of the difference between analog vs. digital input before I am able to jump to more complex projects. My ambition to generate an interactive product overtook the pace at which I should have allowed myself to learn. Going forward, I intend to focus more on learning and prototyping than production, which could be a several month long process to reach the desired level before I can begin interfacing the arduino with plants+.

HCPI

HCI or Human-Computer-Interface is a computational design and research lens that analyses how humans interact with computers, and to what extent computers have been designed as medium-specific tools relative to the sensory and cognitive capabilities of its human user. Because both computers and humans are relatively complex and hold an infinite virtuality of actions, the psychological dynamic between the two (i.e. the interfacing of the two 'brains') is constantly shifting, creating an open-ended conversation. HCPI or Human-Computer-Plant-Interface then, is an extension of the HCI with the addition of a biointerface, i.e. a living organism. This further complicates matters as it decenters the human – as both the human user and the human-built computer are infused with anthropocentric tendencies – and includes a living, non-human voice in the computational conversation.

There are many forms that an HCPI can take, as there are infinite ways to interface biological organisms with computers in the context of human learning. With the proliferation of affordable, easily-programmable microcontroller systems like the Arduino, this becomes a reality for many designers and makers to experiment with. Mileece, a sonic artist based in LA, takes the raw electrical signals from plants and convertes them into audible sounds, effectively giving the plant a voice. She creates music from plant bioemission by attaching electrodes to their leaves, amplifying this data into binary code, and then converting that code into sounds through a computer software – all in real time – to create "organic electronic music."[68] *reEarth*, a bioarchitectural project released in early 2016 by Danilo Sampaio and William Victor Camilleri, similarly investigates the agency of plants through the added translational layer of digital computation. The architects created *Hortum machina B*, a geodesic sphere that houses an autonomous bio-robotic ecosystem of native British species. "Electro-physiological sensing of the state of individual plants collectively and democratically controls decision-making of the orientation of the structure and its mobility,"[69] allowing the entire system to migrate if this in the best interest of the ecosystem. Angelo Vermeulen also makes use of the HCPI with his collaborative project *Biomodd*. Biomodd is a "nomadic project" moving between communities and countries to challenge the notion of separation between nature and technology, always reinventing itself with new materials and participants. In 2010, a *Biomodd* iteration was initiated in Slovenia for the Kiblix Computer Art Festival. A team of artists, designers and students approached this from multiple angles, working over the 10 days to create an algae-cooled motherboard, a spiral-stacked re-cycled computer system with 7 working units, an IV drip system for auto-irrigation of the plants, and the production of pedagogical media.

Not only does the HCPI methodology allow for the direct, conceptual reunification of natural technologies, but it also "allows people to perceive the environmental effects of their actions on a human time scale, using their naked senses rather than having to wait years or decades when it may be too late to respond."[70] In this instance, the immediacy of digital technology produces a positive environmental consequence – to translate the micromoments of plant+ responsivity for conscious human appraisal. This capability of HCPIs can make present the effects of pollution in real time, communicate water shortages and epigenetic changes, preempt flowering and dormancy periods, and a host of other plant activities that are not always communicable to the human senses.

[68] Aaronson, Xavier. "The Exquisite Sounds of Plants." *Motherboard*. VICE, 16 Sept. 2014. Web.

ABOVE *Hortum Machinus B* on the street in London, commuting to the next sunny spot

[69] Sampaio, Danilo, and William Victor Camilleri. "ReEarth." *Interactive Architecture Lab*. Bartlett School of Architecture, 29 Feb. 2016.

BELOW detail from *Biomodd* 2010 in Slovenia showing an installation view after the 10-day prototyping workshops

[70] Kuzmanovic, Maja, and Nik Gaffney. "GroWorld, Experiments in Vegetal Culture." *The Libarynth*. FoAM, 04 July 2014. Web.

Plant synth

Botanicus Interacticus is an HCPI developed by Ivan Poupyrev, Philipp Schoessler, Jonas Loh/Studio NAND, and Munehiko Sato in 2012 while at Disney Research Lab.[71] It operates on the *Touché* sensing technology, also another development of Poupyrev's, but is interfaced with a living plant's natural electrical circuit. Sensors are attached to leaves or stems, and any disruptions to the bio-mechanical flow of electricity results in a capacitance difference. A computing system senses these disruptions, and from there can produce music, visuals or other output based on this real-time data change.

This research has led to multiple iterations and recreations by Maker communities, with for example, a DIY guide by Mads Hobye hosted through instructables.[72] This project reveals the inner schematics and components needed to construct an interactive plant+ system that produces music that varies based on interactants touching the plant, similar to Mileece's work. Instructables.com is an incredible resource for makers and tinkerers to access open-source designs and guides, allowing you to build anything from wooden instruments to alternative electronics and beyond.

I have sourced the components and consulted with Professor John Long and Nick Livingston, two roboticists who are familiar with smaller arduino-based projects. I am currently in the process of soldering and constructing the prototype to test this technology and analyze its interactive potential. However, similar to the arduino sketches, this is not as simple as it is made to seem. I have had to start from the beginning by learning electronic schematics, capacitance and transistance.

[71] http://www.ivanpoupyrev.com/projects/botanicus.php

[72] http://www.instructables.com/id/Singing-plant-Make-your-plant-sing-with-Arduino-/

Construction of this site is in progress. It will feature documentation of the materialized plant synth.

Protocells

Unless life was seeded on Earth from extraterrestrial sources, it logically follows that biotic organisms must have developed from abiotic materials – the process of abiogenesis. The protocell is an attempt then to understand the origins of cellular life through these self-organizing, endogenously ordered lipid spheres. Because they are not living, but exhibit certain metabolic properties of living cells, they are the closest version of an early cell that scientists are able to replicate. If the protocell is pushed further towards the behavioural characteristics of life, it may reveal how life on earth developed.

Most protocells can be formed from lipids (fats and oils) water and salt. When placed in water, phospholipids self-assemble into micelles or vesicles due to their hydrophilic heads and hydrophobic tails. "A protocell is the output of research programs aimed at the construction of a chemical life-like ensemble in the form of an artificial cell system that is able to self-maintain, self-reproduce and potentially evolve."[73] The cell membrane is the only structure shared by all cells on Earth – a component that distinguishes the organized "life-like ensemble" from the entropic soup around it. This also endows it with metabolic potential, as a chemotaxic[74] gradient can be produced between the internal compounds of the cells and the external solution, separated by the selectively-permeable cell membrane and using the salt as an energy source. With this chemotaxic gradient, molecules can be transported into and out of the protocell, react to one another, grow, cluster, "transform at tipping points,"[75] communicate and crystallize.

One specific method of protocell formation, currently being investigated by Dr Rachel Armstrong and Martin Hanczyc, is the Bütschli Dynamic Droplet System. First documented by Otto Bütschli in 1898, sodium hydroxide (potash or lye) and oleic acid (olive and canola oils) are combined to produce a saponification reaction in which the lipid is cleaved into fatty acids and glycerol. This initiates a visible set of reactions in which the alkaline droplets become smaller and combine with the fatty acids to form protocells. These protocells then exhibit their metabolic activity, moving throughout the medium and accumulating the crystalline soapy products of their own production. Their 'life-span' is between 30 seconds and 30 minutes. After this, the protocells become imprisoned within their own self-generated crystalline skins and 'die', unable to participate in a chemotaxic gradient any longer. The resulting architectures are dynamic, organic, and at once fluid and crystalline.

"Bütschli droplet lifecycle:
(a) High energy, chaotic [birth] (0–5 min)
(b) Organization, droplets [life] (30 s–30 min)
(c) Quiescent, crystalline osmotic structures [death] (0–30 min)" [76]

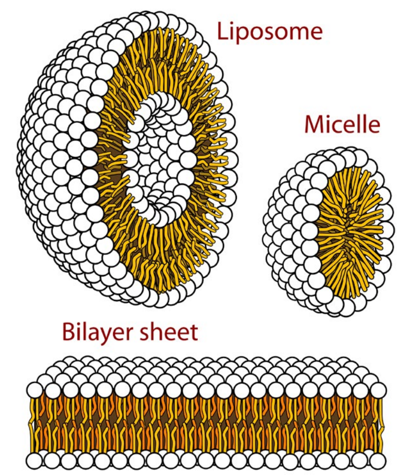
I generated my own protocells in the newly-completed Bridge for Laboratory Sciences building at Vassar College, with the help of Professor Stuart Belli. This is the approximate protocol I followed, based on Armstrong and Hanczyc's paper *Bütschli Dynamic Droplet System* that I obtained from MIT Press Journals via ILLIAD:

11/04/16 Experiment 1
1. Created a 4M sodium hydroxide solution
2. Mixed this into 2 different petri dishes, one with olive oil, one with canola oil
3. Also mixed the sodium hydroxide solution into a cylindrical dropping funnel containing olive oil (and approx 2 inches of water at the bottom) to allow the protocells time to form in suspension before settling
5. documented the protocell formations during and after the 'lifespan'
4. 14/04/16 documented the changes after 3 days of exposure to environmental conditions
5. 18/04/16 documented further changes after 4 more days of exposure

[73] Spiller, Neil, and Rachel Armstrong. "Protocell Architecture." *Architectural Design* 81.2 (2011): 17. Print.

[74] "chemotaxis – directional movement with respect to an external chemical gradient" Ibid, Pg 28

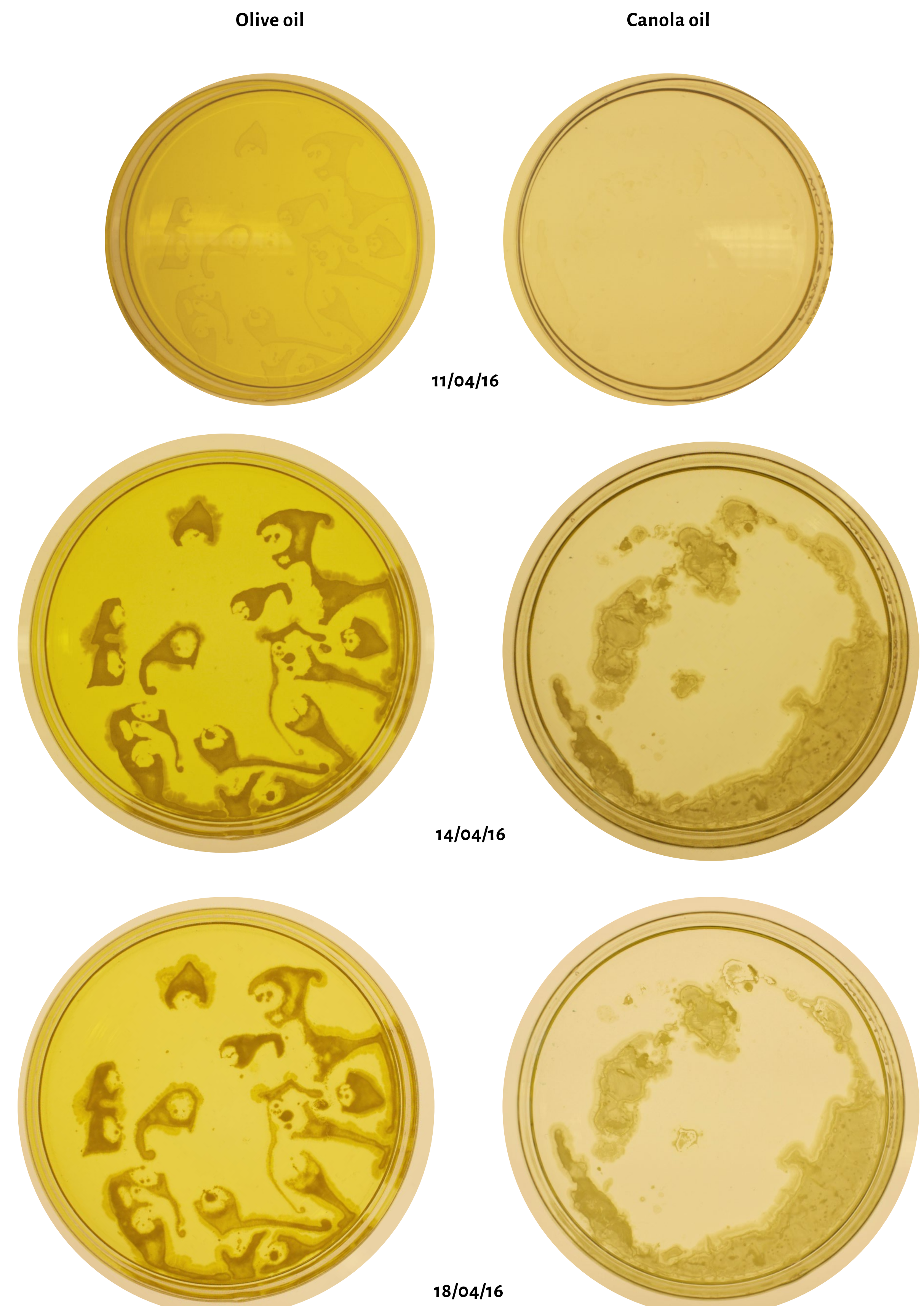
[75] Armstrong, Rachel. "Designing with Protocells: Applications of a Novel Technical Platform." Life 4.3 (2014): 461. Web.



ABOVE Liposomes (with a phospholipid bilayer) and micelles are the basic structures of protocells. photo: Wikipedia

[76] Armstrong R, Hanczyc M. 2013. Bütschli Dynamic Droplet System. *Artificial Life*, 19(3-4): 331-346.

Results (Exp 1 Petri)



Results (Exp 1 Cylinder)

within the first 10 seconds of adding sodium hyrdoxide solution to olive oil; a slight bubbling

the first globules begin to settle on the meniscus separating water from oil

a protocell globule rises through the meniscus into the oil

a protocell cluster falls from the meniscus into the aqueous substrata

flattened protocell globules push each other through the oil medium like lenticular clouds

a swirling strand of semi-formed protocells swim

two globules follow each other down to the meniscus, interfacing and rubbing against one another

protocell globules become smaller, settling at the meniscus

a 4D flower births a 'protopearl'

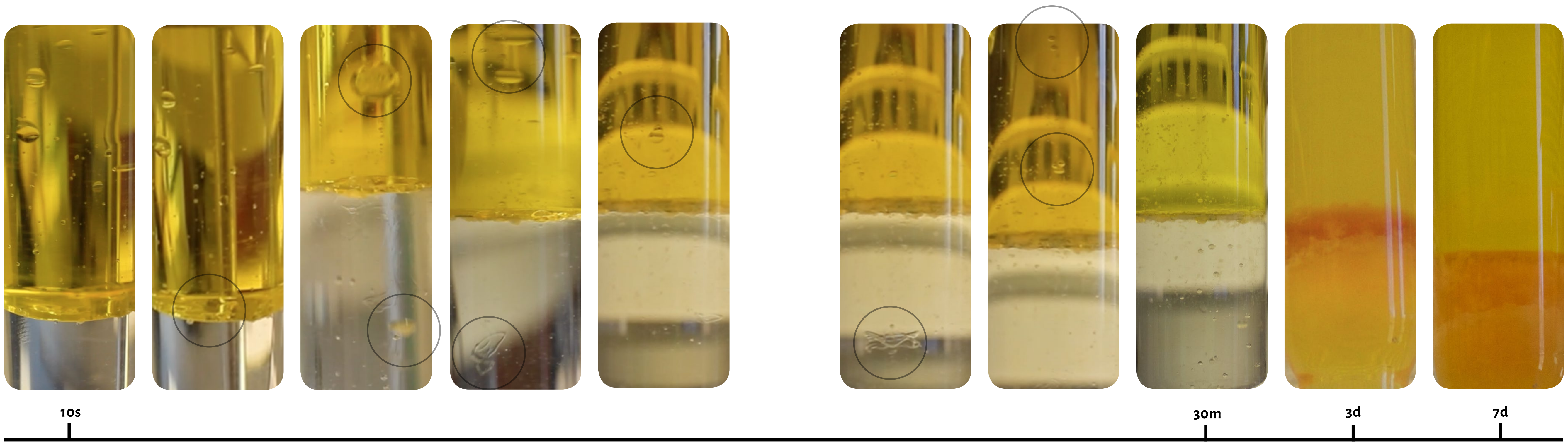
a pair of entangled globules dance

a cluster of 'tadpole swarms' interface

protocell formation slows and eventually stops being visible after ~40 mins. The calcifying protocells mainly settle at the meniscus (the oil-water divide)

3 days in; after exposure to air and light, the oil has become opaque and the site of settlement has transformed into an orange crystalline cloud

7 days in; the orange has become deeper and murkier, but little else has changed. The protocell community has crystallized itself into inactivity



Exp 1 Petri

Because this experiment took place in a petri dish, and one that had not been hydrophobically treated, the protocells instantly became more like pancakes, settling on the petri floor. The depth of the oil in this experiment was only around 1cm, meaning the liquid would have settled before any crystallization would have been possible, also influencing these lower, wide-spread architectures. After several days, they became heavily crystallized, and almost opaque before beginning to disintegrate towards the end of the experiment.

Several key morphological differences can be identified between the olive and canola experiments. The olive protocell architectures are composed of acorn hats, and branching engulfers – some with long whipped tails some without – as well as several spherical globules. The canola protocells clumped together to form large masses in a crescent shape. Overall the olive protocells formed more branching, concave features where as the complexities of the canola protocells were exhibited on the top of its continental masses and spits.

Exp 1 Cylinder

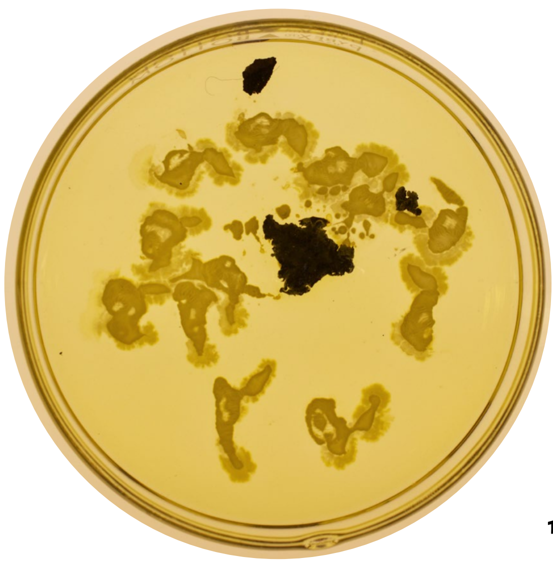
The cylinder experiment shows a strong correlation with the protocell lifecycle suggested in *Bütschli Dynamic Droplet System*. It begins with effervescence and reaction as the sodium hydroxide saponifies the oleic acid into glycerol and fatty acids. Many large and small globules rise and fall through the meniscus separating oil and water. At times they remain suspended in the oil or water, but mostly are very active, recombining and interfacing with one another. This transitions into the 'organization' phase, seen in photos 5-7 in which the effervescence has given way to a more complex dance between pairs and multiples of protocells and globular clusters. This is a more delicate choreography, with more and more coupling and interfacing, all happening near the site of interaction, the meniscus. Photo 8, at a duration of 30-40 minutes shows an almost complete slow down in activity, as most of the protocells settle on the meniscus, with some in the aqueous solution and some suspended in the lipid layer. They have crystallized so much so that the permeable membrane has become impermeable, preventing further microreactions. Photos 9 and 10 show a complete change in color, consistency and opacity. The protocells have become a large tissue mass, blurring the boundary of oil and water and producing a murkiness that is difficult to penetrate with the naked eye.

14/04/16 Experiment 2

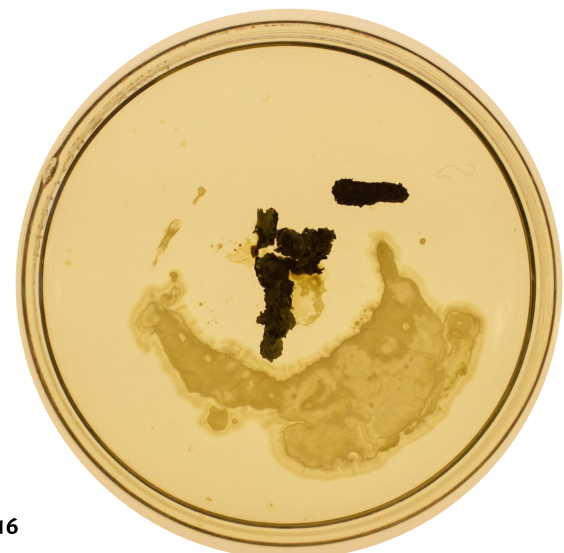
1. Used the same 4M sodium hydroxide solution from Experiment 1
2. Dropped the solution into a tall cylinder filled with olive oil
3. Dropped the solution into a cylindrical dropping funnel containing canola oil
4. Dropped the solution into 2 separate petri dishes (olive and canola) each containing a piece of decaying bark with lichen on it (from the same source)
5. Observed and documented during and after the 'lifespan'
6. 18/04/16 documented the changes after 4 days of exposure to environmental conditions

Results (Exp 2 Petri)

Olive oil with bark + lichen



Canola oil with bark + lichen

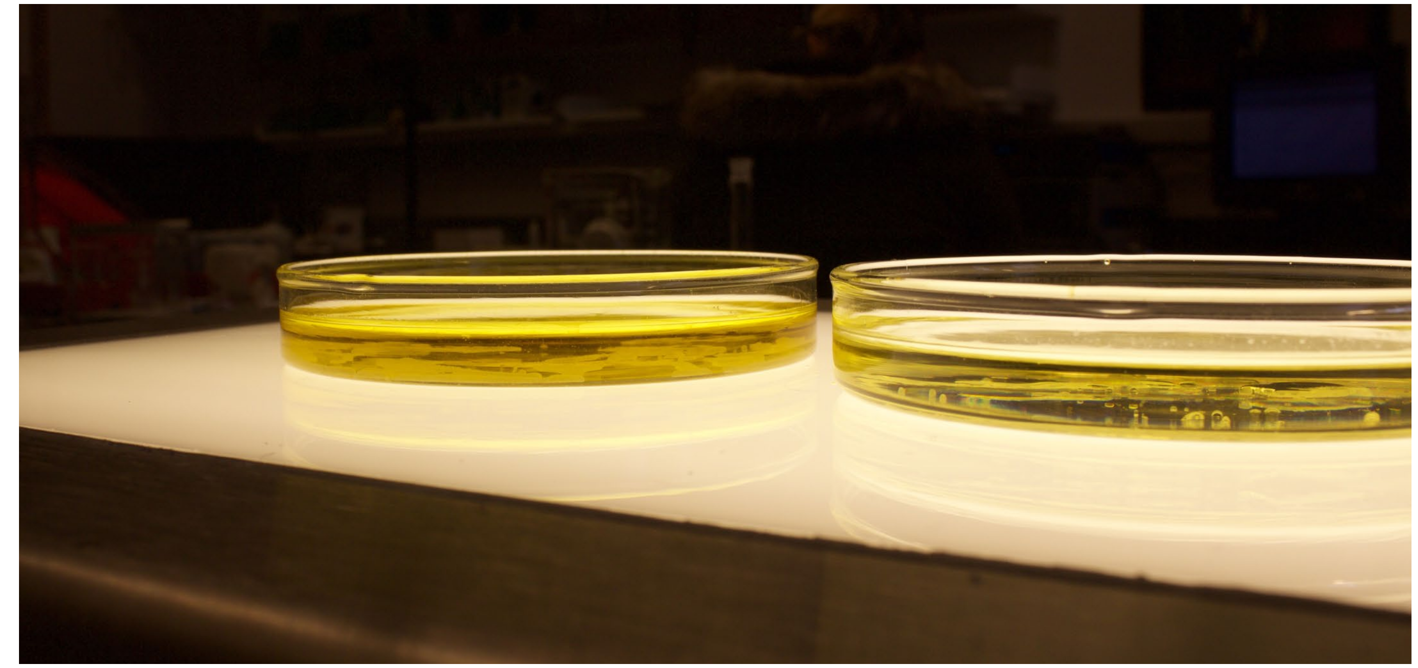


18/04/16

Exp 2 Petri

I included decaying wood with lichen growing on it in this experiment because I was interested to see if the protocells would interact with organic matter, and if they would colonize it or be repelled by it. The morphologies seem consistent with Exp 1 Petri, showing similar acorn/concave shapes in the olive oil and a clustered crescent-shaped mass in the canola oil. The bark seems not to have affected the protocell architectures significantly, but more repeats and possible microscopic examinations would have to be performed to identify correlations. This experiment was also only left for 4 days, where as the others lasted 7 days. Perhaps over a longer time period, the protocells would have shown perceptible interaction with the bark.

One variable that could have influenced the different morphologies between the petri dish and cylinder protocells, besides the obvious structural ones, is heat. During the experiment, the petri dishes rested on a lightbox emitting a perceptible field of warmth, where as the cylinders were attached to stands that hung in the air, with all of their surface exposed to the cool, air-conditioned environment of the lab. This heat may have sped up the reactions and caused a faster crystallization rate in the petri dishes. Also, there was a greater surface area for air exposure in the petri dishes than the cylinders, meaning more compounds could theoretically have dissolved or settled in the petri dishes.



Discussion

This experiment is more a macromolecular examination of protocell communities than it is an analysis of individual proto-*cells*. An extension of this research would incorporate a microscopic view of activity, and not just the larger architectures of crystallization. It could also benefit in the experimental setup from more replicability: for example, by standardizing the amount of oil, the concentrations of oleic acid within those oils, and the amount of sodium hydroxide added to each cylinder or petri dish. The documentation could also be more standardized, with an even lighting and a plain white background instead of the depth and chaos of all the lab instruments that may obscure smaller formations from being visible in the documentation. The protocells exhibited a certain vivacity that was near-life, but it still behaved more like a chemical reaction than a birthing of life. To push this further as living technology, I need to examine interactions on a smaller scale.

The material could also benefit from more programmability, either through additional chemistries or with a data-storage and replication system such as RNA. If I consider myself as not just an observant to this interaction, but as an interactant with these chemistries, it becomes apparent that there is little influence I have once the reaction has begun. To push the interactivity of this material further, variables that disrupt or encourage new formations – such as variable heat, light, UV, sonic vibrations and added chemicals – could be introduced *during* the lifecycle.

Because these chemicals are easily accessible to the independent researcher and can be used on the amateur scale, they make an appropriate starting point for generating protocellular systems that can potentially be programmed as emergent architectural materials with more research. Several projects have already proposed applications of these protocellular agents, one of them being Dr Rachel Armstrong's *Future Venice*, in which protocells grow an architectural limestone reef to buttress the crumbling foundations of the city. Acting as a dynamic photophobic fabric they would grow in areas of low light, i.e. underneath the building structures – calcifying to form an artificial reef system that could generate new ecologies for native organisms, as well as their obvious mitigation of the drowned city. In a similar vein, Magnus Larsson proposes the deployment of *Bacillus pasteurii* – a bacterial agent than can convert sand into sandstone – throughout the Sahara to form an anti-desertification wall. By experimenting with these alchemistries, Armstrong suggests that they may reveal to us "living technology that just might free us from architectural deadlock"[77]

[77] Spiller, Neil, and Rachel Armstrong. "Protocell Architecture." *Architectural Design* 81.2 (2011): 64. Print.

3D Printing

This design is a patabotanical sundial inspired by the forms of mandrake roots and a *Tillandsia bulbosa* that lives in my bedroom. I designed it in Rhino (fig 1.0), and intentionally created an imperfect design with overhangs, curls, and thin ends. Because the digital interface does not operate under the same physics as a 3D printed model, i.e. the physical world, I can program and utilize these translational errors to produce an organic growth in the design.

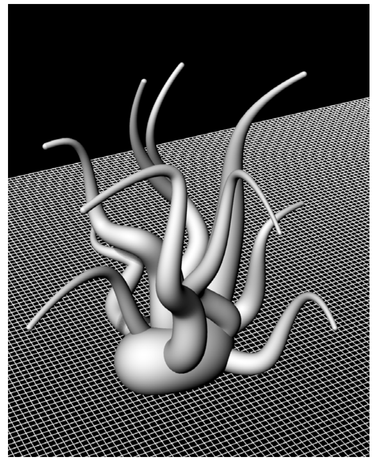


fig 1.0 .3dm 3D model in Rhino

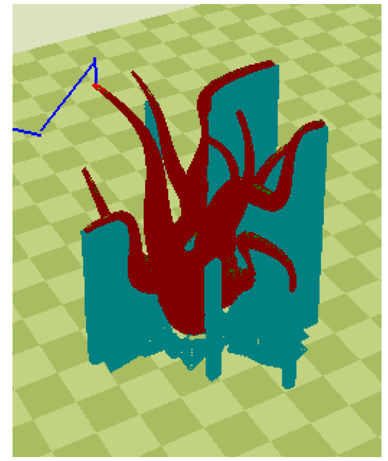


fig 1.1 .stl 3D model in Cura

When I imported this into Cura (fig 1.1), the 3D printing interface for Lulzbot, the program recognized that certain limbs would not be supported, and so suggested its own additions to the design to make the print physically possible. Red is my original design and blue is the program's scaffolding. This is a design methodology that I have been developing to generate symbiotic designs that incorporate both my intentions and the software's, often resulting in unpredicted morphologies. It is an interaction, more than just an execution of mechanical orders.

This object is also interactive in its usage. I printed this symbiotic structure with a UV-reactive PLA filament, that, when exposed to sunlight, turns from its milky-white default to a bright purple color. Similar to the elements of chromatic aberration discussed in **Flora+ Files**, this pata-plant+ interacts with the sun, and with the human user who can shift its position. The sundial also functions in a pataphysical way, as it has not been marked or measured by conventional standards of time. It is up to the interactant to form their own conceptions of time based on the morphologies, and how certain areas will turn purple, but others will be blocked and remain white.

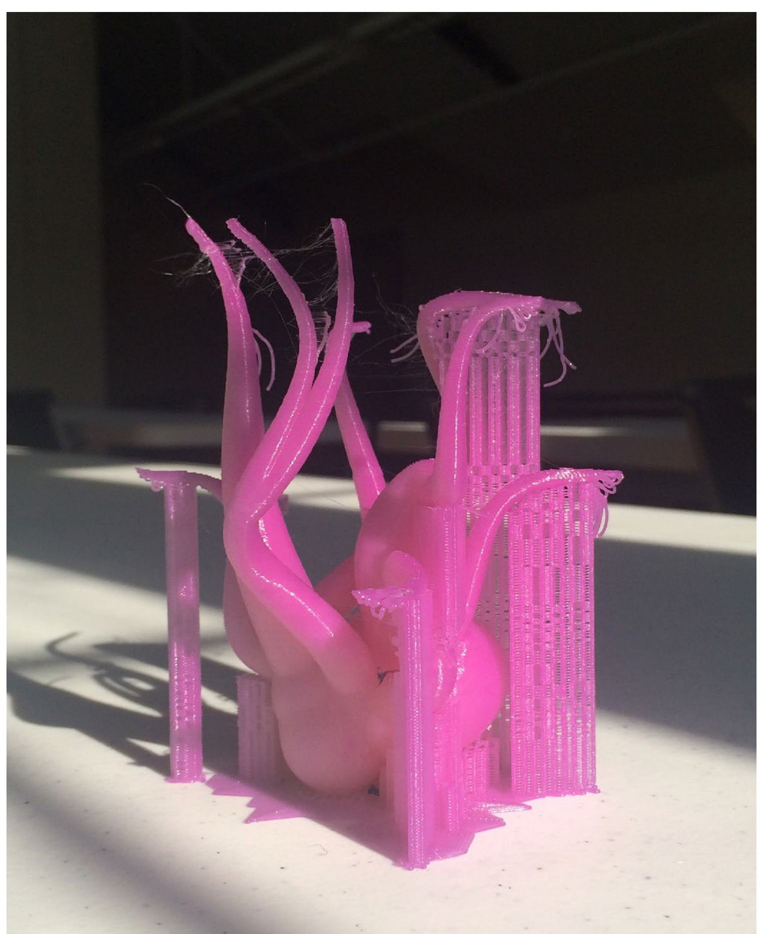


fig 1.2


fig 1.3

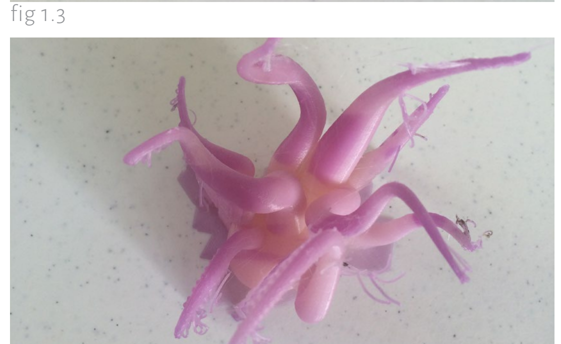


fig 1.4

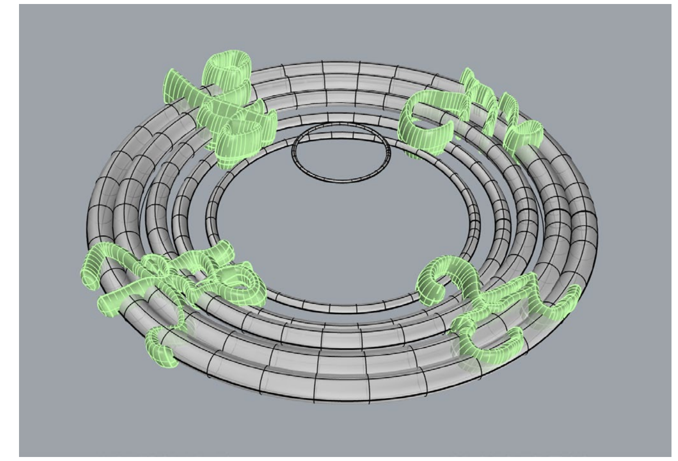


fig 2.0 .3dm 3D model in Rhino, with a 'ghosted' view

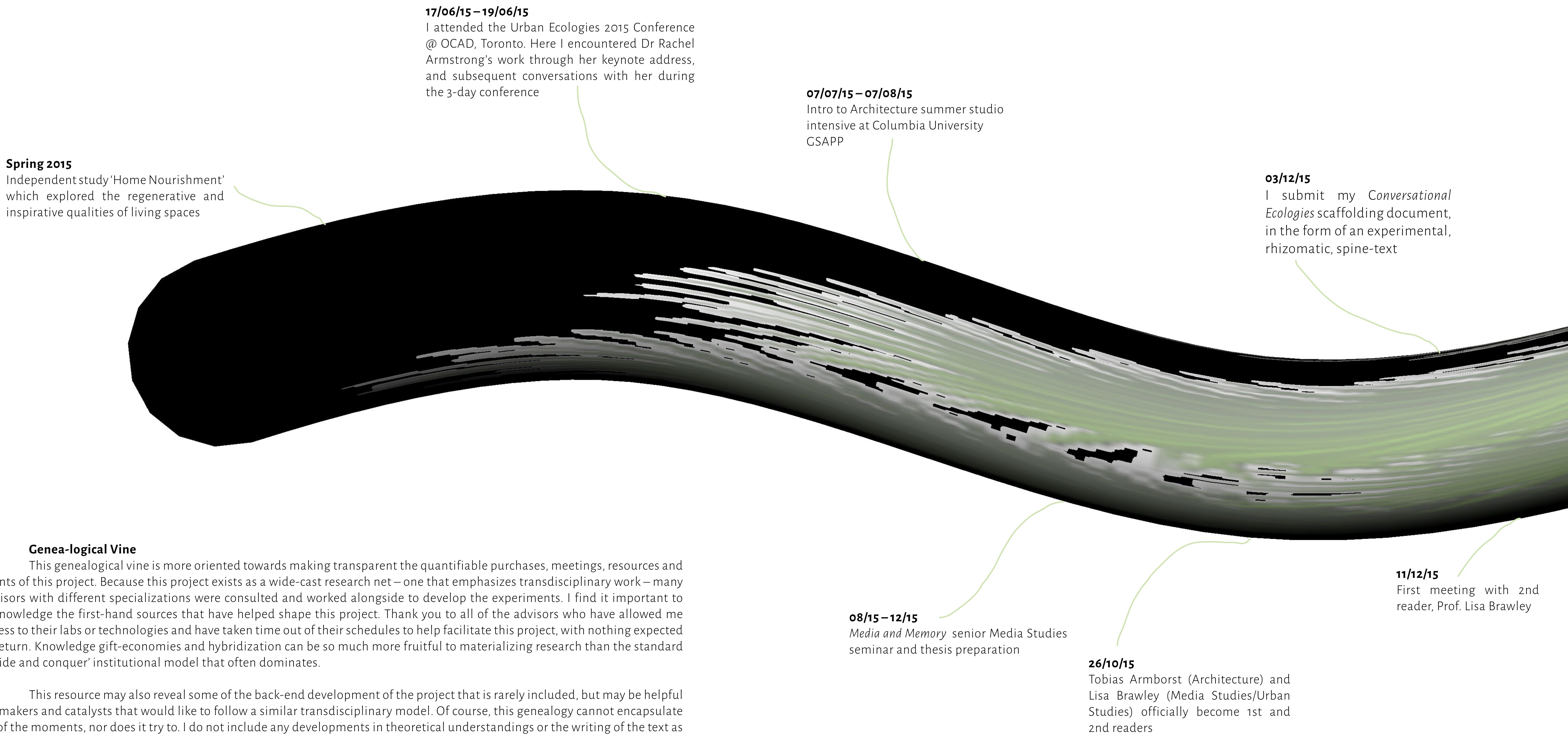
This technology, called the HexA-Morphouse, is another pataphysical device that explores the process of 3D creation through an object-ontology. It has been created using concentric rings, imagined as a sort of sonic particle collider, with cardinally-placed symbols borrowed from the *Voynich Manuscript*. Because the *Voynich Manuscript* has not been decoded for over 500 years, it has given imaginers worldwide a resource that is not determined or absolute. It is therefore the best manual for creativity, allowing its readers to imagine and reimagine its elements in their own narratives. I imagine these symbols as tactile buttons that can be played to affect the sonic vibrations emanating from the rings.

Similarly to the sundial, the HexA-Morphouse operates under my design methdolody of excavating translational errors from the remediation of the digital into the physical. I created a floating ring in the center of the design, which under digital conditions is perfectly probable, but when printed without a support structure, collapses under its assumed digital stability. Gravity instantly affects this ring, causing it to fall into the build-plate of the 3D printer. In fig 2.1 and fig 2.2. you can see the sticky, frozen strands of an imperfect and unpredictable translation – like a spider's web that has been woven into this computationally-generated object. Coincidentally, they have fallen in such a way as to tie the symbols to one another in a matrix.

Similarly to the sundial again, the HexA-Morphouse is interactive through its design process, but also through its photoreactive qualities. Charged during daylight, the device emits a strong green glow at night, and an even stronger glow in the presence of UV- or grow-lights. As with the *Voynich Manuscript*, the usage of this device has not been determined or explained. It can be used in countless situations, both tangible and imagined. For example, you could incorporate it into a plant system to attract nocturnal pollinators, trace its rings as a meditative activity, or generate an imagined alchemical soundscape.


fig 2.1 charging the device during the day with pure sunlight


fig 2.2 charging the device at night with synthetic UV light



Genea-logical Vine

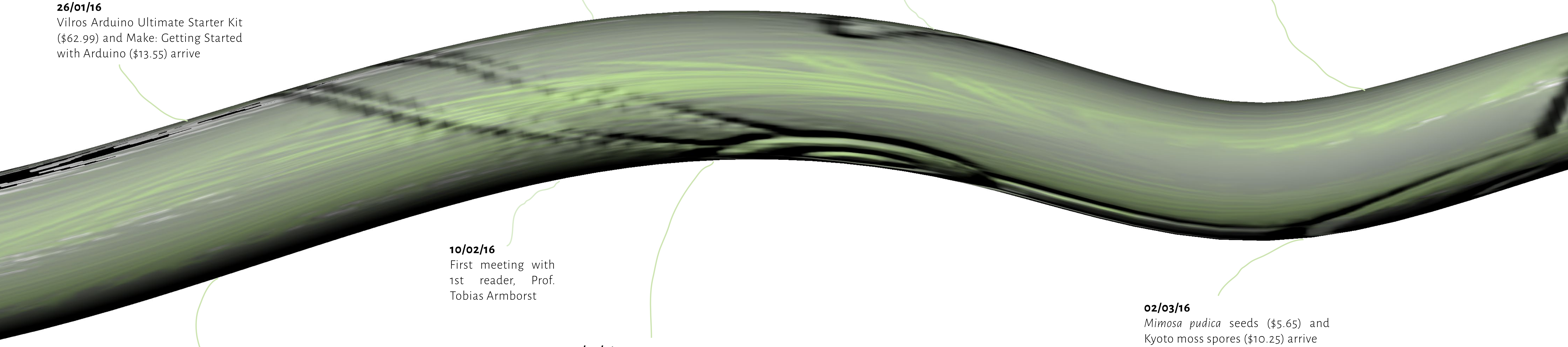
This genealogical vine is more oriented towards making transparent the quantifiable purchases, meetings, resources and events of this project. Because this project exists as a wide-cast research net – one that emphasizes transdisciplinary work – many advisors with different specializations were consulted and worked alongside to develop the experiments. I find it important to acknowledge the first-hand sources that have helped shape this project. Thank you to all of the advisors who have allowed me access to their labs or technologies and have taken time out of their schedules to help facilitate this project, with nothing expected in return. Knowledge gift-economies and hybridization can be so much more fruitful to materializing research than the standard 'divide and conquer' institutional model that often dominates.

This resource may also reveal some of the back-end development of the project that is rarely included, but may be helpful for makers and catalysts that would like to follow a similar transdisciplinary model. Of course, this genealogy cannot encapsulate all of the moments, nor does it try to. I do not include any developments in theoretical understandings or the writing of the text as this does not exist in a linear flow. These components are too rhizomatic and recursive, twisting back in on themselves throughout the entire project window. This would produce a twisted and fragmented vine, and ultimately, one that defeats itself in the relay of simple, quantifiable data.

26/01/16
Vilros Arduino Ultimate Starter Kit ($62.99) and Make: Getting Started with Arduino ($13.55) arrive

29/01/16
First meeting with Prof. Meg Ronsheim (Biology) to discuss biological features of the experimental projects

05/02/16 – 15/02/16
In conversation with Daniel Freedman and Conor Landenberger from the Hudson Valley Advanced Manufacturing Center (SUNY New Paltz) about possible acrylic lasercutting for e-terraria



10/02/16
First meeting with 1st reader, Prof. Tobias Armborst

15/02/16
Meeting with Prof. John Long (Biology/Cognitive Science/ Robotics)

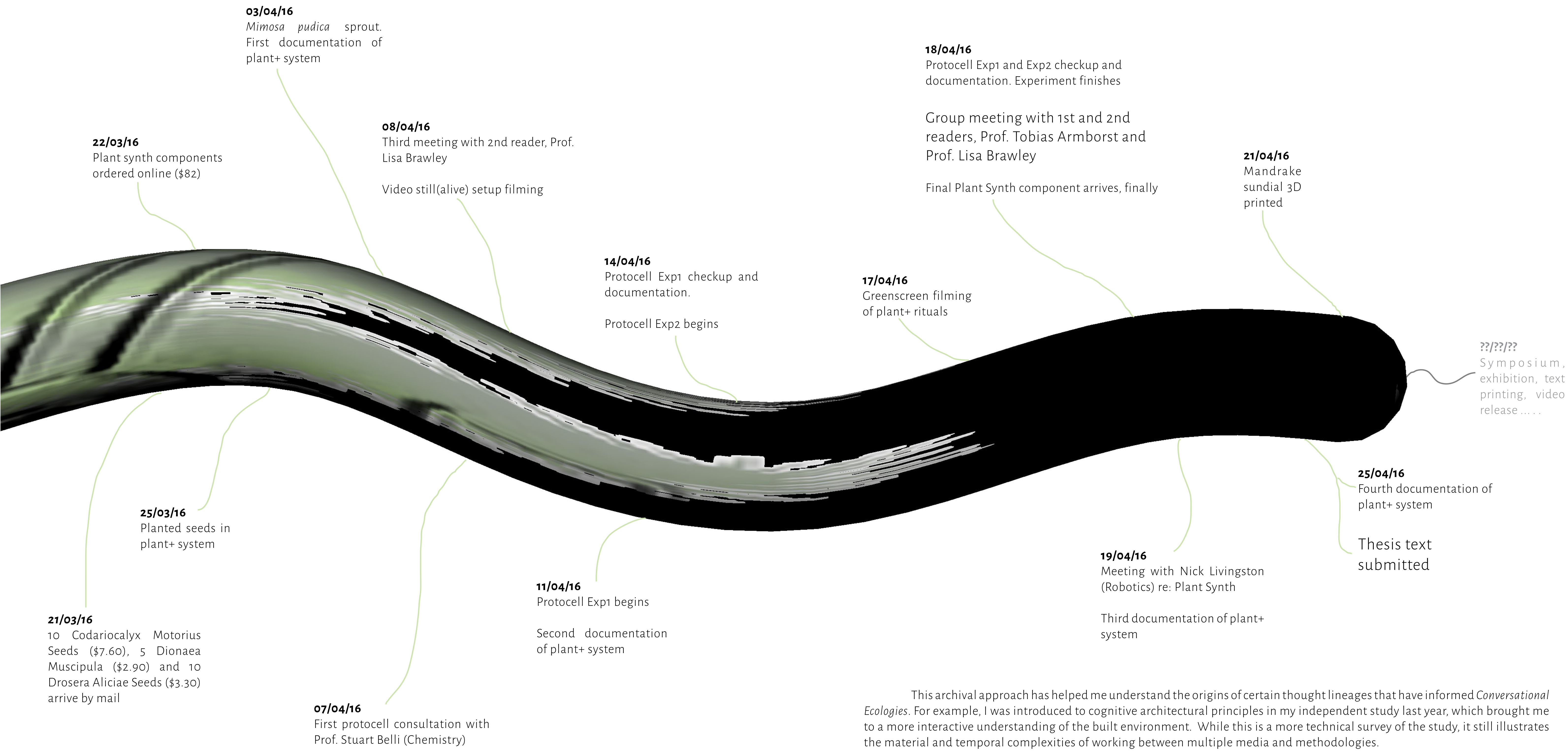
Second meeting with 2nd reader, Prof. Lisa Brawley

17/02/16
Follow-up meeting with Prof. Meg Ronsheim

02/03/16
Mimosa pudica seeds ($5.65) and Kyoto moss spores ($10.25) arrive

Hueglin Supplemental Fund of $250 received

04/03/16
HexA-Morphouse device 3D printed with Amy Laughlin (Academic Computing Consultant)



This archival approach has helped me understand the origins of certain thought lineages that have informed *Conversational Ecologies*. For example, I was introduced to cognitive architectural principles in my independent study last year, which brought me to a more interactive understanding of the built environment. While this is a more technical survey of the study, it still illustrates the material and temporal complexities of working between multiple media and methodologies.

The internet was an important tool for this section, acting as an archive to much of my arranging and scheduling. Receipts, email threads, date and time stamps, bank transaction histories, text messages and screenshot tags were helpful in reconstructing an approximate chronology of logistics . It has revealed to me that taking a comprehensive, anticipatory approach with microdetails is just as important as the main project directives. One missing component, especially for something like an electronic circuit, can delay the entire experiment and cause stagnancy. I imagine that this technique could also be used as a projective tool, imagining the weaving together of future logistics and teams, more than just recording them retrospectively.

Material Experiment Discussion

The 3D printed structures were the most instantly-engaging, as well as the most architectural of the material experiments. Although the scale of the print is quite small due to the machine limitations, multiple photoreactive models could be situated within a space to activate its interactive potential. This process is also ripe for rapid prototyping, meaning the components can be developed more efficiently and accurately. A limitation of this material is that it is plastic, and relies on mechanical production and corporate involvement. This is antithetical to the aims of creating symbiotic, life-supporting systems, but thetical to the intention of engaging people with spaces. If a sustainable biomaterial could be developed, that was also relatively affordable and accessible, this would be a prime candidate for construction.

The protocells are fascinating, alchemical, and form beautiful liquid-crystalline microarchitectures. They operate within an interesting liminal zone, somewhere between chemistry, architecture and the fanstastic, decentering the unnecessary rigidity and authority of science in favor of a more flexible approach. They have a lot of potential to be situated as living technologies, but would require a research lab with much more funding and years of development for this to be a reality. They are accessible to make on a small scale, but are not necessarily accessible to utilize as a material at this stage. However, as only one chemistry was experimented with, I am unable to make this claim for other chemical combinations which could prove to be very applicable, and very accessible.

The plant+ system is still growing, and the plant synth is still being constructed. They are both interactive technologies that require time and patience to develop, but are more likely to deliver results that are complex and evolutionary. They will accrete this complexity with time and attention to detail. These are the most symbiotic of the materials, supporting a reconception of ecologies that still includes plant+ life, and at the same time are viable for interfacing with computational methods. This was the original intention, to interface plants and computers, and still remains the most comprehensive system that operates in accordance with the *Conversational Ecologies* philosophy.

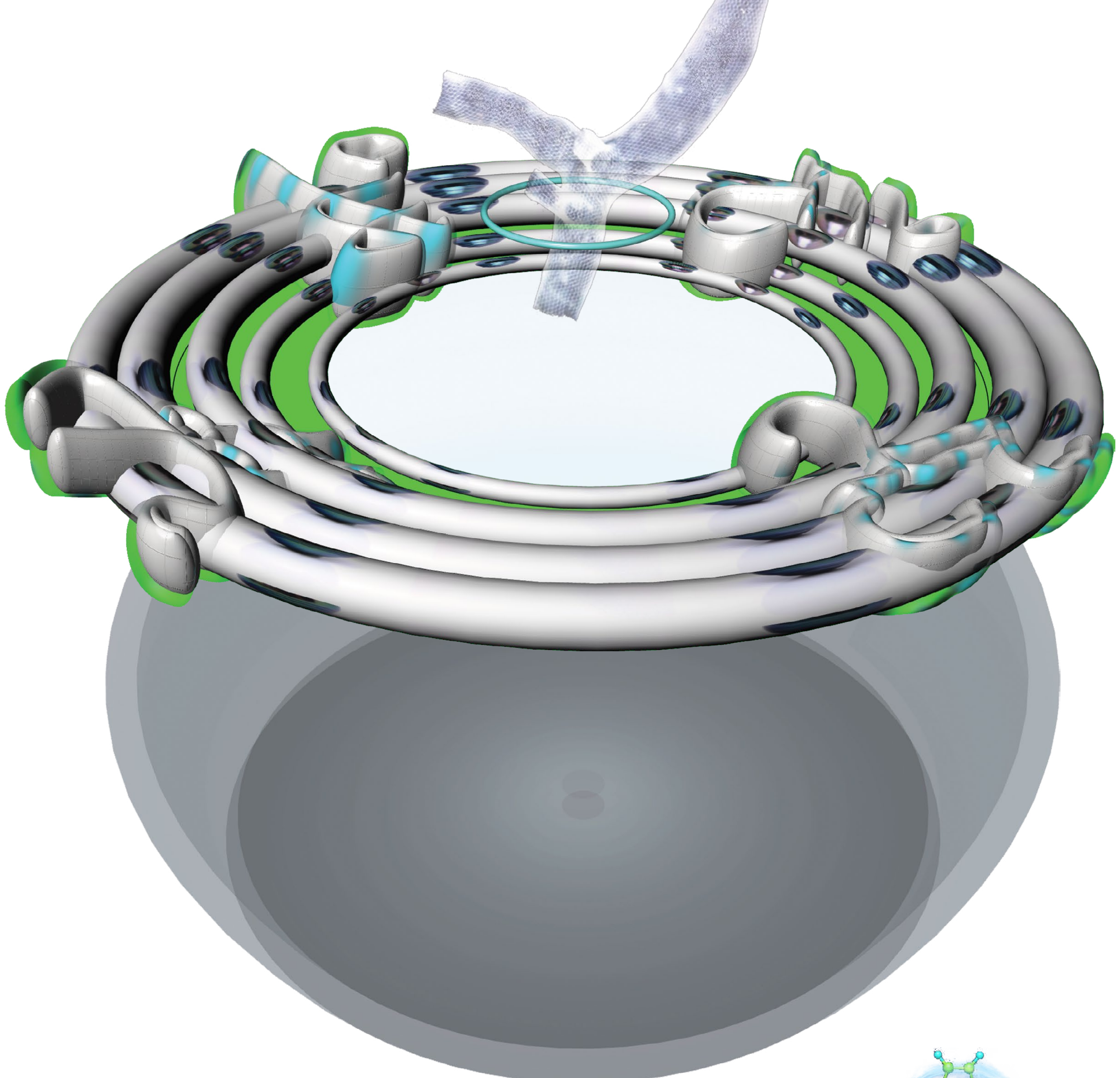
I have found these material experiments the most rewarding but also the most daunting aspects of this study so far. Because they are experiments, they offer no assurances. If the experimenter is not mentally prepared for a potential failure, and accepting of this virtuality, then they will likely avoid committing their time and energy, in favor of safer options. I found the arduino and electrical engineering aspects of these experiments the most difficult to confront because it is the immersion into an entirely different language and world that I am unfamiliar with. It requires much more committment and perseverance than I was able to give at this time, especially as an autodidact who relies mainly on self-motivation. This is an aspect of the project that I am now very seriously going to pursue in the coming months, as open-source physical computing offers so much potential for interactivity and agency. As the name of this chapter suggests, the materials and my understanding of them, are constantly evolving. This tangible experimentation with materials has given me so much more insight into their functionality, accessibility and physical qualities than learning about them second-hand, through textual or other resources. I think this is invaluable research, not just to understand their applicability , but to gain critical understandings informed by direct, interactive learning processes.

photo: http://photographicdesign.deviantart.com/art/Alien-Plants-VUE-198261440

//SPECULATIVE ALCHEMY

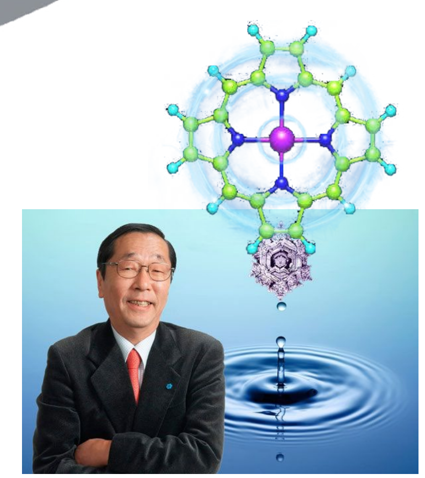
Plasmo- is a cousin of Mytho-, embracing a similar alchemical, imaginative approach. This chapter deals with speculative product and spatial designs, and suggests a future for this research. It is about the potential applications of this knowledge, and the vitality of critical play as a radical tool for reimagining our influences on the shifting earthly tides.

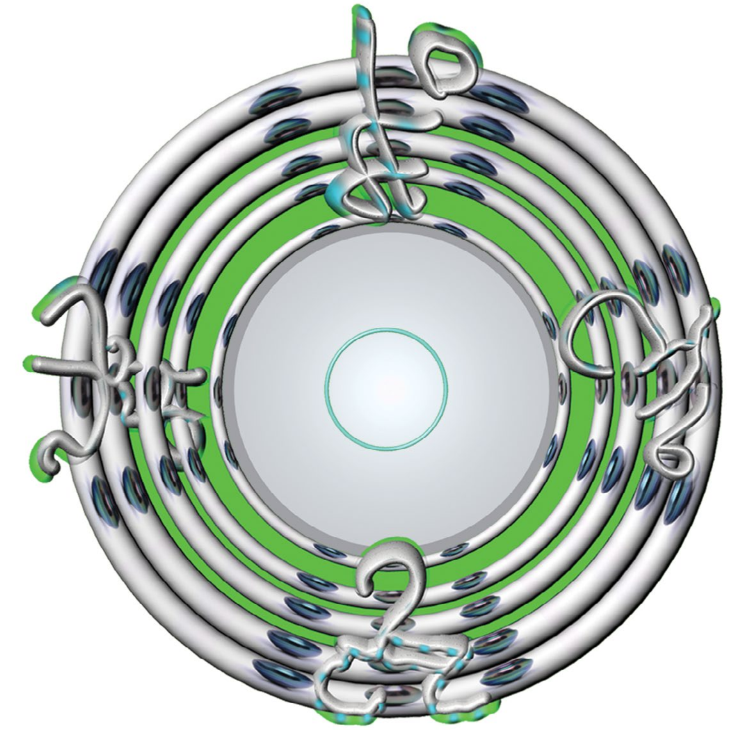
This chapter also features my conclusive remarks on all the research, experiments and theory thus far, and initiates an experimental beginning for the reader. It is a segue out of the text and into an imagined, or perhaps realized, future. As well as reflecting on what has been discussed throughout this text, I would like you to imagine your own implications in ecologies large and small. In what ways do you already interact in your everyday? Would you like to alter this fabric of interactions? If so, how will you situate the knowledge gifted in this text, or from other sources, in a conversational ecology?



Aquasonic Urn

A xylem pipe acts as a hydro-attentive spigot, able to constrict and relax based on programmable waterflow. It is guided through a hovering ring, buoyed by compact superconducting magnets (pictured OPPOSITE), embedded within each ring of the main apparatus. These rings are sonic generators, able to produce within sound ranges accessible to most living organisms. The water within the urn reacts to the sound, creating a rippling that alters the molecular structure of the water. Based on Masaru Emoto's (pictured RIGHT) research, differing forces applied to the H_2O molecules can generate a variability in molecular behavior, physiological uptake and EMF emission. Nanocomputers on the inside of the urn walls are able to analyze and disply a holograph of the water signature (pictured RIGHT). With a harmonization of molecular structure and sound, comes a potent and purified water source.



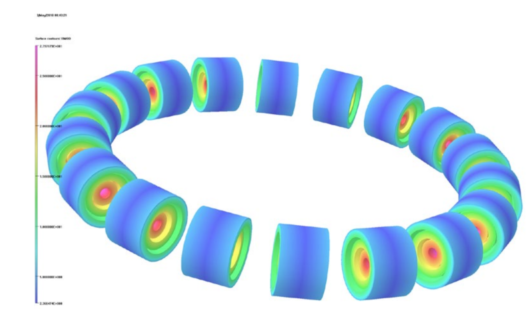


PLAN

SECTION

The symbols, derived from *Voynich Manuscript* cipher, each generate a distinct suite of tones when traced or brushed, a traditional tactile approach. Similarly, an interactant that circles the rings with a finger, antennae or prosthetic, will activate different sonic textures that resonate at varying depths within the urn. The two methods of interactivity allow a complex variability in sound to emerge.

Additionally, one can influence the aperture of the xylem vessel through their own voice, affecting the flow rate and rhythm of water into the urn.



The superconducting magnetic rings (one pictured ABOVE) power the system: drawing energy from the user interactions, they are able to magnetize and lift the xylem-guiding ring, generate sound, and power the computational identification of the water signature.

The vessel component of the urn is made out of a hydrophobic bioplastic derived from plant lipids. It maintains a water-tight seal, whilst also allowing a rippling in its skin to amplify sonic waves.

The aquasonic urn occupies multiple roles simultaneously. On one hand it is a method of water purification: it renders water as a safe consumable. In another role, it acts as an interactive instrument, engaging with critical play and imaginative water-bending. It also can become a tool for communication. As each distinct melody will affect a unique molecular patterning in the water, the water signatures of a previous user can be identified and a message can take the form of an encoded melody.

ABOVE BentoLab, a portable, affordable genetics lab for "curious makers" to engage with genetics and molecular biology https://www.bento.bio/

BELOW Eduardo Kac's *Natural History of the Enigma*, a Petunia strain bioengineered to include a fraction of his DNA

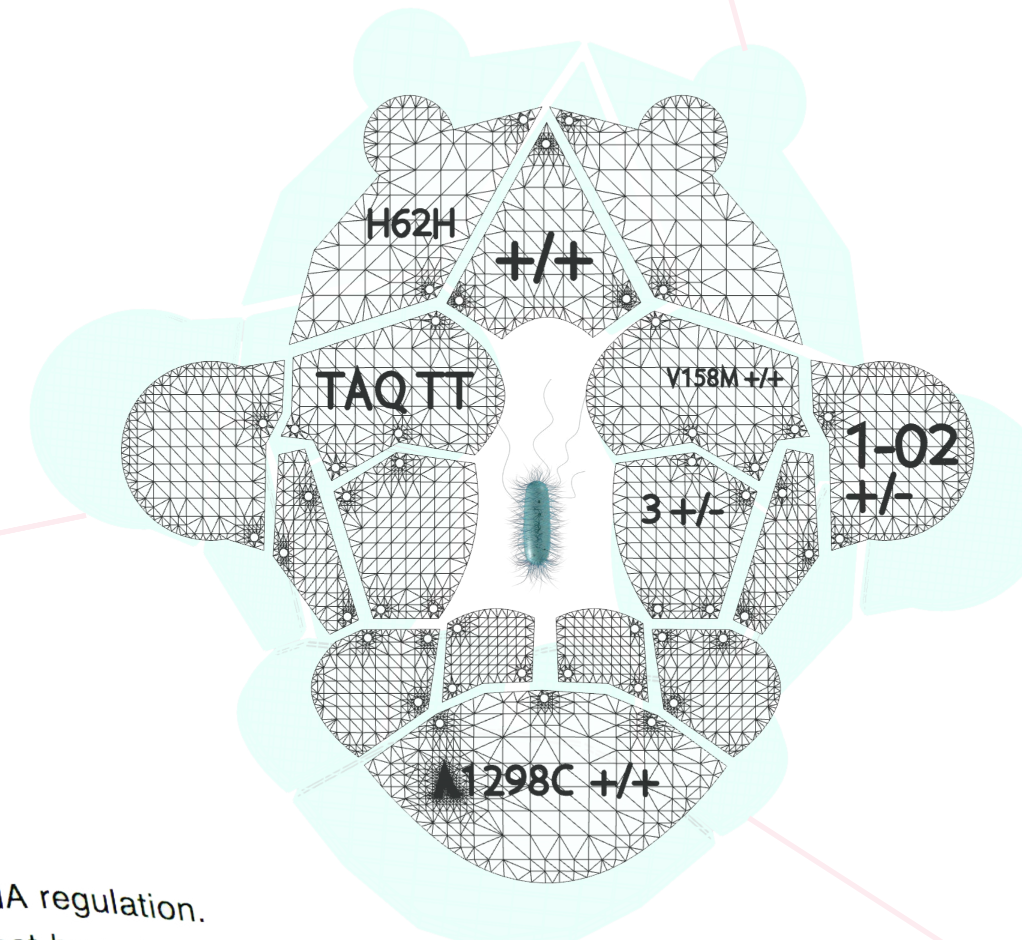
reGENeration Mask

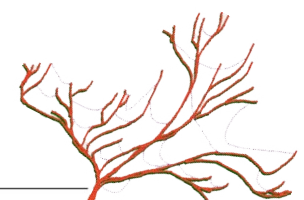
This speculative design incorporates current research being done in epigenetic expression, biotechnology and genetic engineering with targeted nutritional medicine, to produce a regenerative biotechnological face mask.

In the decaying heat of late summer in 2014, I had a short, but vital part of my DNA sequenced. The section sequenced is my methylation pathway, which is important for detoxification, nutrient assimilation, neurotransmitter regulation and the prevention of mutations in DNA expression. As you can see from my results chart below, I am quite mutated, with several vital genes having single (+/-) or double (+/+) mutations. What negative effects could this be having on my body? And what organisms are taking advantage of this genetic broken-window?.... What to do with this knowledge? Well, one option is to follow an expensive regimen of targeted nutritional support in the pursuit of nutrigenomic satisfaction. The other option, however, is more... creative. The first step is to extract a sample of my DNA and correct the mutated methylation sequence. Then once this has been tested and rendered safe, the healthy, modified methylation sequence can be snipped out using targeted restriction enzymes. This can be inserted into the plasmid of a friendly bacterium, communities of which are housed in nourished in the facial architecture indicated on the right.

Wearing this mask at night, the bacteria, through horiztonal gene transfer, would be able to insert the modified methylation sequence back into my face and subsequently my body, healing it through a bio-engineered bacterial symbiosis....

As a child, I grew up with a jade chinese burial mask hanging on the wall in my bedroom. I always wondered what it would be like to wear it. The weight.. the cooling stone... This design is partially inspired by the mythos of that childhood decor. (note: this is not the same mask, but similar)





DNA Methylation Pathway Profile; Blood Spot

RESULTS

Gene Name / Variation	Mutation Not Present	Mutation(s) Present	Call
SHMT / C1420T	-/-		G
AHCY / 1	-/-		A
AHCY / 2	-/-		T
AHCY / 19	-/-		A
MTHFR / C677T	-/-		C
MTHFR / A1298C		+/+	C
MTHFR / 3		+/-	Hetero
MTR / A2756G	-/-		A
MTRR / A66G		+/-	Hetero
MTRR / H595Y	-/-		C
MTRR / K350A	-/-		A
MTRR / R415T	-/-		C
MTRR / S257T	-/-		T
MTRR / 11	-/-		G
BHMT / 1		+/-	Hetero
BHMT / 2	-/-		C
BHMT / 4	-/-		A
BHMT / 8		+/-	Hetero
CBS / C699T	-/-		C
CBS / A360A		+/-	Hetero
CBS / N212N	-/-		C
COMT / V158M		+/+	A
COMT / H62H		+/+	T
COMT / 61	-/-		G
SUOX / S370S	-/-		CG
VDR / Taq1		+/+	T
VDR / Fok1		+/-	Hetero
MAO A / R297R	-/-		G
NOS / D298E		+/-	Hetero
ACAT / 1-02		+/-	Hetero

Minus "-" represents no mutation

Plus "+" represents a mutation

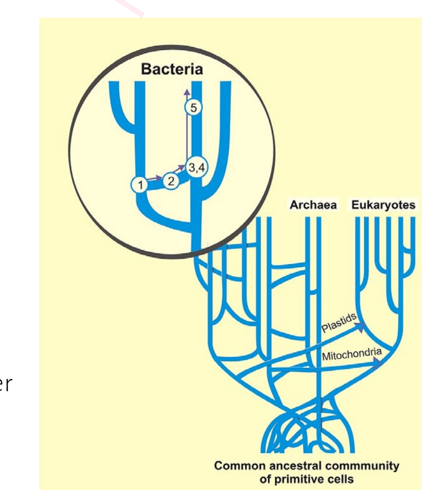
"-/-" indicates there is no mutation

"+/-" indicates there is one mutation

"+/+" indicates there is a double mutation

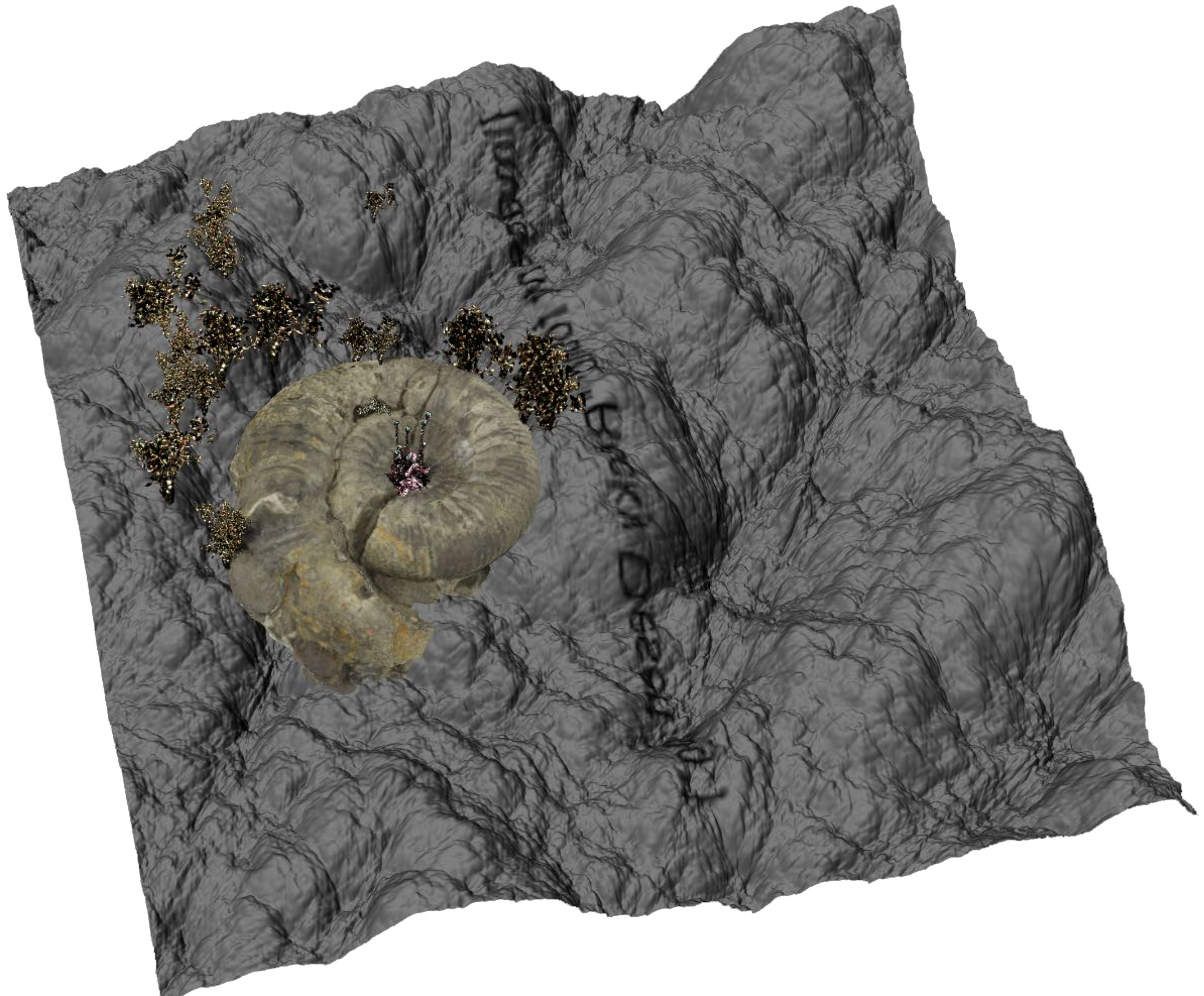
In addition, decreased levels of methylation can result in improper DNA regulation. DNA methylation is necessary to prevent the expression of viral genes that have been inserted into the body's DNA. Loss of methylation can lead to the expression of inserted viral genes such as herpes and hepatitis among other viruses.

multifactorial health issues. Methylation cycle mutations can lead to chronic infections, increased environmental toxin burdens and have secondary effects on genetic expression.



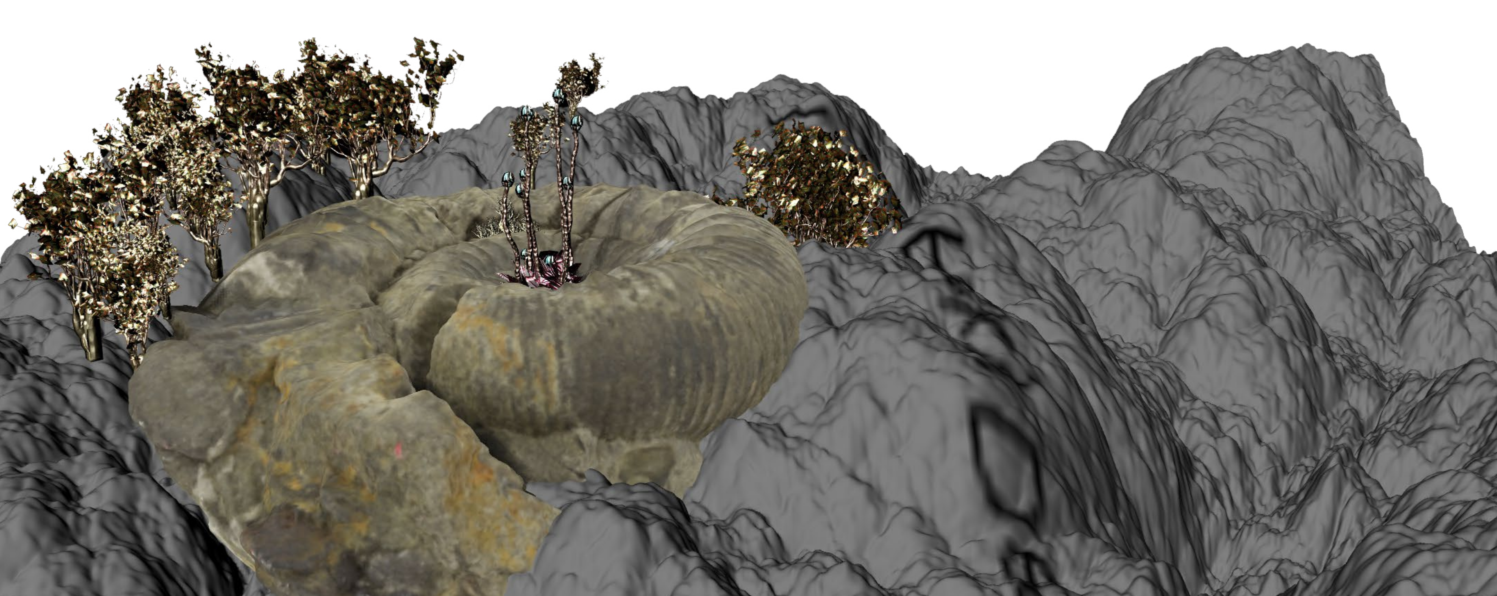
Horizontal gene transfer within the tree of life
photo: Wikipedia

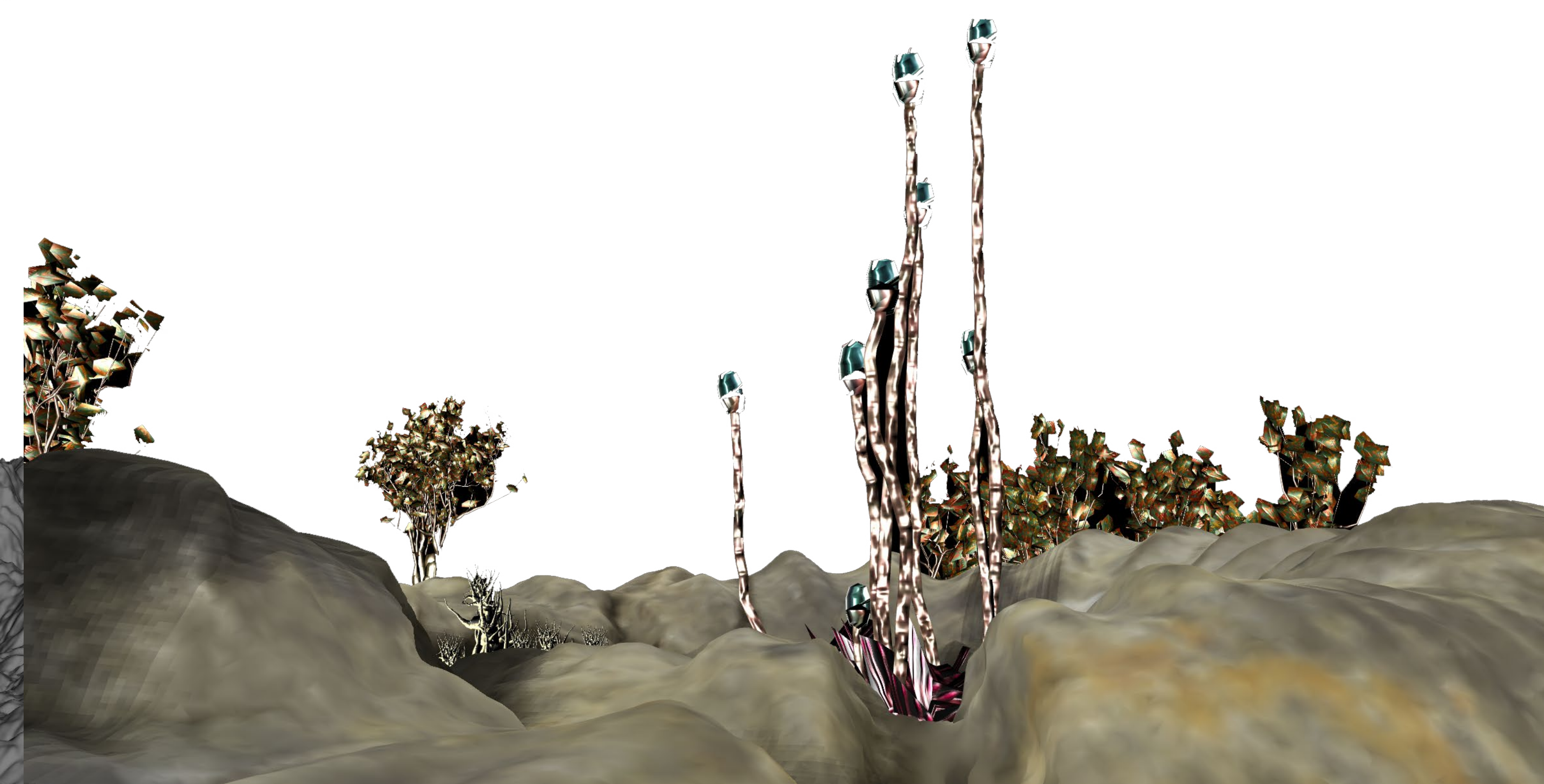
A fossil gives new life through its decay....



"softness, growth, swarm and scaffold" [78]

Soon it will just be soil, a substrate





Semi-Conclusive Thoughts

I began this study assuming that I would use my theory and research to inform the final production of an interactive spatial design, as if it would move linearly. However, I did not initially consider the importance of *material* research, in addition to the theoretical research, that would inform a physical interactive design. Theoretical concepts cannot be directly translated to a material product, without first passing through a medium of material experimentation and prototyping. The process is also slowed down because the material experiments feed back into the theoretical discourse and may alter these understandings. The protocells are a good example of this. Although the entire experiment was fascinating, I still felt that the level I was working on was very far removed from any architectural application. Conceptually I am more interested in this organic growth of an architecture than a mechanical computation of one, but Arduino systems are much more accessible and applicable relative to my skills and resources.

[78] Spiller, Neil, and Rachel Armstrong. "Protocell Architecture." *Architectural Design* 81.2 (2011): 65. Print.

The accessibility of these technologies is paramount. If they remain in the hands of a select few who are granted exclusive institutional access, they will not flourish in the same way they would if they were decentralized, open-sourced and transformable. We do need specialized research and scientific study, however, this information should also be made public for independent researchers to appropriate and work through with their own methodologies. More than just consumers of information, or observers of experiments, working with a hands-on approach allows the researcher to think *through* these objects rather than just *about* them. It decenters the authority that is inherent with exclusive knowledge economies, while demarginalizing the independent, collaborative and alternative practitioners. This brings both parties towards a more symbiotic information-sharing ecology rather than an information-capital economy. We need to be able to access these technologies, afford these technologies and implement these technologies on a local scale, and witness firsthand the effects, for these interactive plant+ technologies to become a viable (r)revolution of spatial structuring.

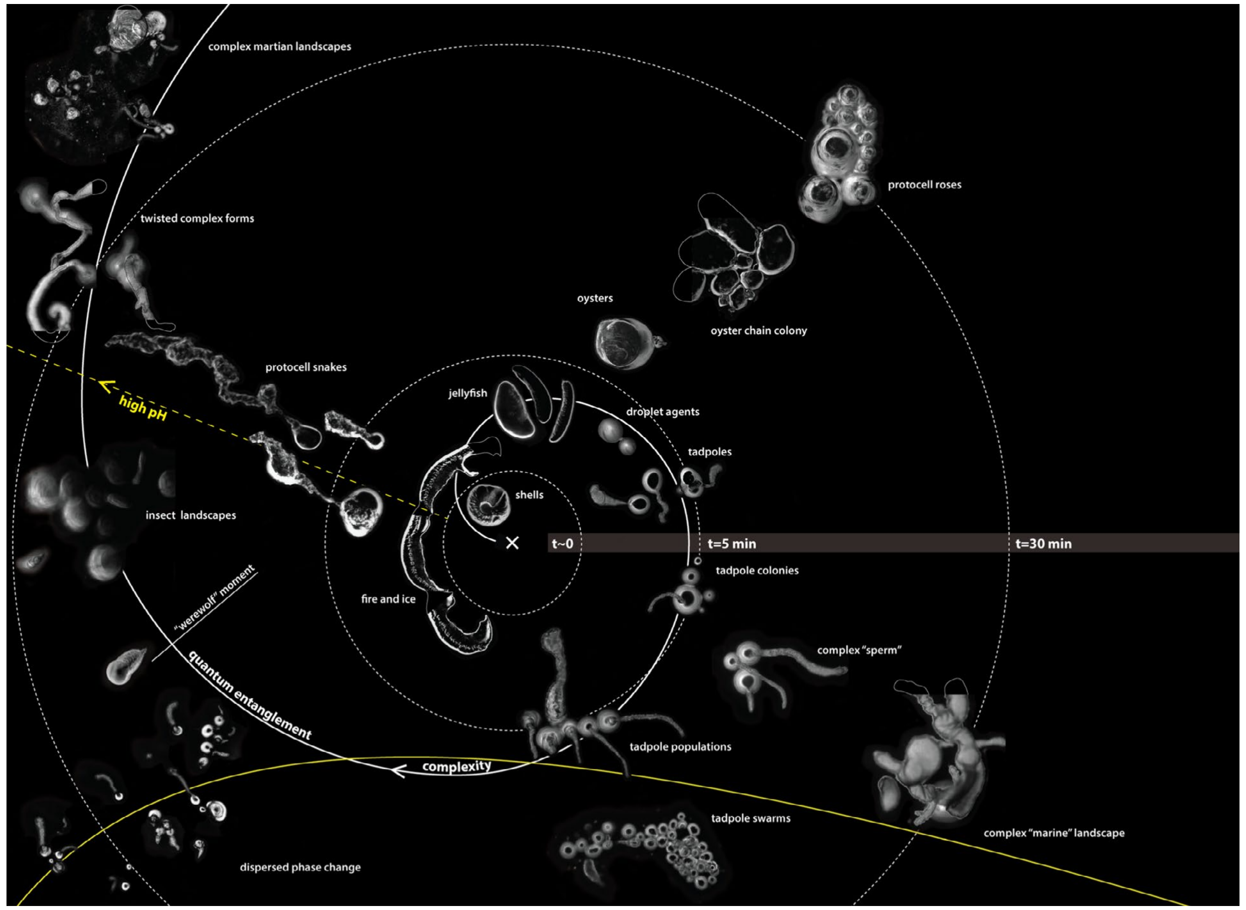
Ultimately, but not exclusively, this study has seeked to rewrite my understanding of conversational ecologies and my orientation towards space and other beings. Hopefully, this exploration will also filter out beyond myself. In Aero, I mentioned the destabilization of "speed, expansion, predation and consumption" as embedded animal survival skills that perhaps need to be decommissioned given our current world-controlling grid. The Anthropocene and Global Capitalism are already hypermagnified and compounded versions of these behaviors, and have obviously begun to turn rotten. This eutrophication of human attributes, human culture, human consumption and human waste in our global ecology has already led to the suffocation of many other species and habitats. It logically follows then, that a decentering of anthropocentric interests, and a recentering of plant+ ecologies would benefit everyone through harmonious growth. A general approach of slow growth, adaptability and ecological expansion – not just conservation or remediation although these are necessary – could be learned through listening to plant+ communities and forming a symbiotic pedagogy. Architectural and making approaches can begin this pedagogy by producing interactive, experiential and *conversational* ecologies aimed at the disarmament of mentally-embedded animal aggressions.

"It is a product of her Viriditas – greenness – making moist and green what threatens to become corrupted, mendacious, ill-used and dried out"[79]

[79] Kuzmanovic, Maja, and Nik Gaffney. "Borrowed Scenery" *The Libarynth*. FoAM, 01 July 2010. Web.

GLOSSARY

APPENDIX



ABOVE Oceanic (rather than linear or categorical) protocell morphologies by Dr Rachel Armstrong

Armstrong, Rachel. "Designing with Protocells: Applications of a Novel Technical Platform." *Life* 4.3 (2014): 457-90. Web.

RIGHT A picture I took of my sister Lucy sitting in a bird's nest fern at our home in Singapore, circa 2010/2011

RIGHT A picture I took of bird's nest ferns reclaiming the roof of an abandoned British colonial house near mine

BELOW children I met in Ta Prohm, Cambodia, crowning themselves with leaves from the surrounding temple-forests. These children were birthed and raised in an ancient conversational ecology, true practitioners...

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