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NO.4

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MATERIAL SHIFTS

I do not seek a unified theory of everything—but a diversified theory of unity.

Rachel Armstrong

SOFT CITIES

RACHEL ARMSTRONG

All that is built squirms. This is the fundamental reality that applies to buildings.

Architecture is both responsible for and can take action against the destructive environmental practices that have characterised the last hundred and fifty years—a fragment of evolutionary time. Architecture in the twenty-first century can take a positive environmental stance to secure a new way of underpinning human development, in opposition to the prospects of a sixth great extinction event.[1]

Twenty-first century society draws from a world that is less determined by objects and increasingly shaped by connectivity. The clear either/or distinctions that formerly informed experience are being replaced by a much more fluid understanding of the world. Identity is not fixed, but shaped by networks where people and 'things' can coherently exist in many states. This 'complex systems' view[2] extends to the characterization of nature, which is made up of many interacting bodies. Some of these are human, others living, and many other participating agencies are dynamic but not thought of as being alive. Yet the animal, plant and mineral kingdoms represent different kinds of organizing networks, which are seamlessly entwined and constitute our living world.

The study of complex systems has become an important scientific field, one that requires interdisciplinary collaboration to characterize a system's properties. Networks, which share patterns of organization, are at the heart of such systems. This helps us shed light on poorly understood complex systems, such as metabolic networks, by making analogies with well-known ones, such as the Internet. Complex systems are usually represented as diagrams whose points of convergence, or 'nodes', represent the various participating bodies. The connections between these active sites are represented topologically to signify the interactions between them. Structural features of complex systems are revealed as secondary phenomena that appear as a consequence of the network interactions that give rise to them. Currently, the mapping of complex systems is not deductive and cannot tell a researcher just how a network arose, or how it will behave in the future.

The temporal properties of complex systems are complicated by the phenomenon of emergence[3], but the kind of dynamic temporal changes that may occur can be grasped by studying a range of processes that can be broadly thought

1.
Ian Sample, "Human activity is driving Earth's 'sixth great extinction event,'" *The Guardian*, July 28, 2009. Accessed July 29, 2009. http://www.guardian.co.uk/environment/2009/jul/28/species-extinction-hotspots-australia.

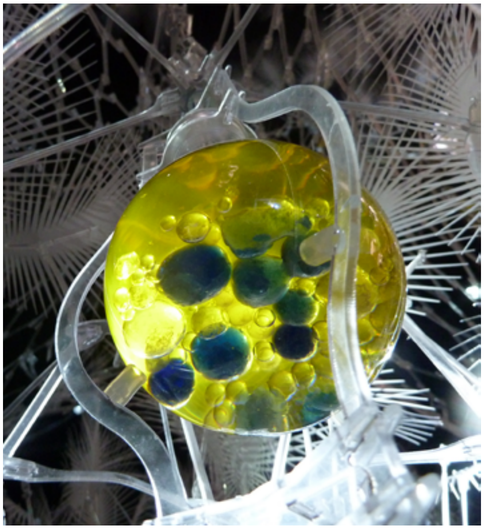
2.
Complexity Science considers the physical world to exist as the result of an interconnected set of networks, of complex and simple systems rather than as a series of objects that are hierarchically connected. Network connections are shared by different organizing systems through information flow where linkages are made and broken around sites of localizing activity. Complex systems do not acquire complexity but fundamentally possess it, exhibiting an optimized, elegant design, even when they are composed of only a few ingredients. Such systems cannot be broken down into components.

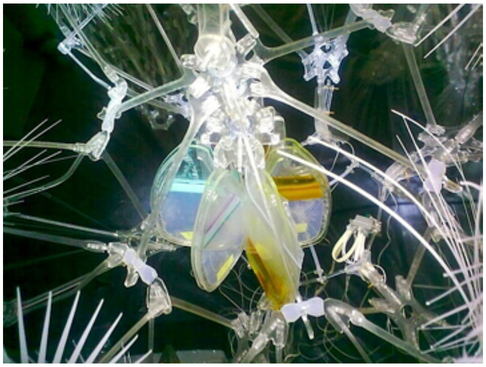
3.
Emergence is a term that proposes an alternative roadmap of organization between a mechanistic view of the world and a vitalistic one. In the late 18th century emergentists sought to describe the nature of vital substances that were composed of 'inanimate materials' yet in some sense continued to retain irreducibly vital qualities or processes. "All organized bodies are composed of parts, similar to those composing inorganic nature, and which have even themselves existed in an inorganic state; but the phenomena of life, which result from the juxtaposition of those parts in a certain manner, bear no analogy to any of the effects which would be produced by the action of the component substances considered as mere physical agents. To whatever degree we might imagine our knowledge of the properties of the several ingredients of a living body to be extended and perfected, it is certain that no mere summing up of the separate actions of those elements will ever amount to the action of the living body itself." John Stuart Mill, *A System of Logic* (London: 1882), Book III, Chap. 6,1. See also: Timothy O'Connor and Hong Yu Wong, "Emergent Properties", *The Stanford Encyclopedia of Philosophy* (Spring 2012 Edition), ed. Edward N. Zalta, forthcoming. Accessed August 15, 2012. http://plato.stanford.edu/archives/spr2012/entries/properties-emergent/.

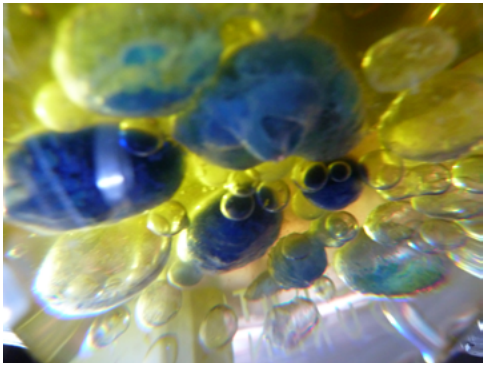
4.
William Bryant Logan, *Dirt: The Ecstatic Skin of the Earth*, (New York: W.W. Norton and Company, 2007).

of as 'evolution'. The particular structure that best embodies the transition from inert to living matter is the story of soil. William Bryant Logan notes that the earth was not 'born' with soil but has acquired it over the millennia.[4] Soils are a living web of relationships within complex bodies that will eventually grow old and die. Plants take root in the rich chemical medium and bind the particles together to attract animal life. Conversely, soil harbors fungi and bacteria that break down the bodies of dead creatures and turns them into more soil. The speed of this dynamic conversion process varies. In fertile areas it may take fifty years to produce a few centimeters of soil but in harsh deserts it can take thousands of years.

The possibility of artificially engineering soils creates the opportunity to transform artificial landscapes into places that can attract nature. Gardeners already select rich combinations of loam, compost and fertilizer to produce blooming plants, but these techniques do not evolve their infrastructures *in situ*. Rather, they transport them from other areas of soil production. So, is it possible to create a matrix using a bottom-up, complex systems approach, where interacting networks give rise to a superstructure that performs the work of soil?







An experiment that explored the possible evolution of soil matrix was conducted during "Hylozoic Ground", an architectural installation by Philip Beesley, at the Venice Architecture Biennale in 2010. Iron, the favored mineral of Ruskin, was passed through reactive gels in a chemical process called the 'Liesegang Ring reaction', which occurs naturally under certain geological conditions. This dynamic process, driven by gravity and diffusion, produced layers of complex materials over the three-month period of the installation. The process of separating the homogenous gel into layers of different colors and thicknesses was the first stage towards creating an artificial soil.

Of course, much work still needs to be done before the gel could be functionally likened to a soil. It would, for example, need to contain air filled cavities, organisms and be capable of compost production. However, these first experiments suggest that sterile surfaces can be transformed into living, complex bodies through the interactions of multiple biological and chemical agents. This synthetic matrix could potentially provide a supportive, evolving infrastructure for a web of designed life forms and synthetic ecologies, where culture and technology connect through processes that are native to the production of architecture.

Architecture has the power to become a site of ecological regeneration. Its sheer scale rivals another naturally produced body that supports life—the biotic soils. The architecture of soils promotes life, diversifies ecologies, recycles resources and propagates globally. It embodies a 'deep' ecological model[5] that may be applied to the design of the built environment.

Soils are biological cities. They house, nourish and provide the vital infrastructure for terrestrial life. Their diverse communities and the countless networks from which they are formed replenish them. The vitality of all living things ultimately depends on living, richly mineralized, vibrant soil whose architecture pertains to earth's deep history. Soil's extraordinary genesis embraces the origins of life and its own speciation and maturation—which laid the foundations for the establishment of ecosystems, the evolution of humans and the construction of the built environment. The rich complexity of soil systems provides a model and literal substrate for a built environment that can self-maintain and connect with ecological systems. Soil strategies could potentially be used to inform and embody a 'deep' ecological architectural practice that embraces Neil Spiller's 'seven continuums' of architectural design practice.[6]
Soils can be up to several million years old, though many North American and European soils date to the end of the last glacial period, around 15,000 years ago. Yet the oldest cities are only very young in comparison—a few thousands years old. Antep is the most ancient currently inhabited city and dates back to the old Hittite period (1750–1500 BC) but many modern cities are only hundreds of years old. However, their agricultural rhizomes are already in fierce competition with soils for mineral and biotic resources. Unlike soils, cities do not nutrify or replete their ecosystems and communities. Rather, they systematically consume them.

Our living soils age as a consequence of natural causes such as changes in the climate but increasingly this is also the result of artificial and biological factors, such as over-grazing and deforestation. Ultimately, soils die and when they do—they are gone forever. These acts of wanton destruction are due to our rapid expansion, technological naiveté and, as Allan Savory notes, our universal tendency to simplify the complex processes of ecosystems in agricultural management practices.[7] In these last milliseconds of evolutionary time we have globally acted upon our abstractions of the

5.
Deep ecology is a politicized view of the environment that aims to adopt a non-anthropocentric view of the natural world rather than a 'shallow' engagement with nature in which technological fixes, improve the compatibility of machines with nature according to a set of predetermined parameters without addressing the 'deep' systemic and societal issues that underpin the industrial destruction of the biosphere. Arne Næss proposed the prevailing scientific view of biology and nature could not address important ethical issues. [See Arne Næss, "The Shallow and the Deep, Long-Range Ecology Movement," in *Inquiry 16* (Routledge: 1973), 95-100]. Therefore it was necessary to develop an ethics in which a thing is right when it tends to preserve the integrity, stability and beauty of the biotic community but is wrong when it tends otherwise. Næss' ecological ethics originates in environmental wisdom that is forged through networks of relationships in nature. In a 'deep' ecology the status of objects is reduced to being of secondary importance, existing as the consequence of network node activity. By displacing the power of objects, Næss returns power to the sensory side of existence, which reconnects people with the non-human world in which they are simply one organism in an extended community of earth's systems. See Stephan Harding, "What is Deep Ecology." Accessed 15 August 2012. http://www.morning-earth.org/DE6103/Read%20DE/Harding,%20What%20is%20DE.pdf.

6.
Neil Spiller invites designers to position their work in relation to seven continuums: space, technology, narrative, semiotics and performance, scopic regimes, sensitivity, cyborgian geography, and time. Neil Spiller, "Plectic Architecture: Towards a Theory of the Post-digital in Architecture," in *Technoetic Arts: A Journal of Speculative Research,* Volume 7 Number 2 (London: Intellect Ltd, 2009), 95-104.

7.
Allan Savory, *Holistic Resource Management* (Washington, D.C.: Island Press, 1998).

world at an exponential pace and in doing so we have disrupted these ecosystems. It is impossible to say whether we still have time to turn this virulent legacy around, as ecologies are complex, brittle and as fragile as they are resilient.

A soil was not a thing … It was a web of relationships that stood in a certain state at a certain time.[8]

Modern cities share very little of their ecology with biotic soils. Yet there are many homologies between soils and our cities. In a very literal way, they are made of much the same kind of stuff. What separates a building from soil is simply time. Building materials such as concrete, brick, clay, stone, steel and wood are simply processed agglomerates of molecules that are already present in dirt and minerals. Indeed, classical building materials could be thought of as soil components that have been reverse-engineered from complex, heterogeneous systems into simple, obedient geometric forms. Nature abhors homogeneity and seeks to re-complexify these substances. So, in the same way that soils have been forged by grinding glaciers over thousands of years, the surfaces of buildings are being weathered and sheared by the same forces that created the primordial dirt. Moreover, they are invaded by microbial life that tears apart their inert infrastructure to reveal and vitalise new surfaces, which can be further colonized by living invaders and through the biological process of succession.[9] These settlers are more organised and sophisticated than those who cut the path before them. The surfaces of our buildings can be literally thought of as unfolding chemical catalysts and sites of soil synthesis—their deterioration being symptomatic of the presence of life-giving processes. Yet we resist these processes and seek to preserve our building surfaces as sterile interfaces. But perhaps this natural imperative of buildings to re-become soil can be harnessed. Perhaps the infrastructure and the agency of the urban soil-generating system can promote life while meeting human needs.

Although cities[10] and the earth's ecosystems[11] have been likened to organisms, they technically do not qualify as such. The current definition of 'organism,' or life, does not embrace the pervasive bodies that comprise soils and cities.[12] Yet the similarities are striking since the organizational principles of cities and soils are complex and share, in principle, many of the characteristics of organisms. Jan Christiaan Smuts[13] noted the degrees of agency, or 'livingness' that a spectrum of materials exhibits, ranging from crystals to biology.

8.
William Bryant Logan, *Dirt: The Ecstatic Skin of the Earth*, (New York: W.W. Norton and Company, 2007), 96.

9.
Biological succession is a directional, non-seasonal, process of change that transforms ecologies over time. Michael Pidwirny, "Plant Succession." *Fundamentals of Physical Geography, 2nd Edition*, 2006. Accessed August 15, 2012. http://www.physicalgeography.net/fundamentals/9i.html.

10.
Casey Kazan, "Is the City an 'Organism' Operating Beyond the Bounds of Biology?" Accessed August 15, 2012. http://www.dailygalaxy.com/my_weblog/2008/06/is-the-human-ci.html.

11.
In 1785 James Hutton, the father of modern geology, envisaged the Earth as a metaphorical 'superorganism'. He suggested that its circulatory and respiratory cycles were geological processes such as erosion. However, Hutton's ideas violated Darwin's theory of evolution in which living things responded to environmental conditions rather than shaping them. Yet, in the mid-'60s, British chemist James Lovelock began to develop the idea that living organisms changed their environment and their combined actions regulated the Earth's atmosphere, oceans and soils to make it habitable. In 1970 Lovelock began collaborating with Lynn Margulis, who highlighted the role of micro-organisms such as bacteria in forming links between life and the Earth.

12.
The 'Chemoton' model [Tibor Gánti, *The Principles of Life* (Oxford: Oxford University Press, 2003). See also http://www.chemoton.com/eng1.html] proposes to generate increasingly complex machineries from algorithms of chemical reactions, which, at a certain degree of complexity, transgress living and non-living states. At this transitional zone, the chemical constructions belong to the field of biology. In other words, the current definition of life is based on a mechanical worldview in which emergence can be understood algorithmically and therefore is describable according to the laws of physics. The discussions as to how emergence leads to biological cells is a deterministic one proposing that a container, metabolism and a form of heritable information are necessary. These preconditions exclude cities and earth's ecosystems from being 'life' forms. James Lovelock has contended that biologists such as Stephen Jay Gould who dismissed 'Gaia' as simply a metaphor for the earth's processes [Stephen Jay Gould, "Kropotkin was no Crackpot," *Natural History* 106 (1997): 12–21.] were not sufficiently versed with articulating complex systems and sought to describe emergence in reductionist terms. Which is exactly what is happening in the case of the Chemoton model.

13.
Jan Christiaan Smuts, *Holism and Evolution* (London: McMillan, 1926), 88.

Material Agency

There is a need to be able to discuss these kinds of systems, which are not inert but neither fully 'alive.' Their importance lies in subtle, persistent behaviours, which, without human intervention, generate infrastructures and systems for living things to thrive. It is this quality that falls apart in cities as their form is eroded with time, such as in the city of Venice which, having no living characteristics, is simply unable to fight back in the struggle for survival against the elements. To date, there is no formal way of categorizing these materials.[14] They work beyond our traditional expectations of matter and act at different scales ranging from sub-microscopic chemical interactions, like the oxidation process associated with rusting, to geological scale impacts such as the production of greenhouse gases that contribute to climate change. Living materials also change their boundaries through dynamic, physical processes that do not need genetic material to instruct them, such as crystal growth or decomposition by chemical erosion of iron through oxidation. Events such as silt deposition, which forms new fertile terrains at estuaries, or the appearance of salt crystals on concrete structures, which causes the degenerative process of secondary efflorescence on buildings, are physiological examples of living materials that are active within soils and cities. Yet living materials have the capacity to exert effects that concern humans and, from an everyday perspective, there are many substances that exist and act independently of humans. Developments in science have provided new insights into how we are related to some of these substances that we do not consider 'human'. At very small scales, molecular biology has revealed that the deep history of *Homo sapiens* is one in which our cells and bodies are actually communities of biotic networks and minerals[15] that work together with different degrees of autonomy. Some of these participants are not primarily of human origin but they have become entangled in the forty-six chromosomes that formally signify our biological identity. In other words, we are not single bodies but collaborating networks of biotic agents of diverse backgrounds—genetic analysis confirms our trans-species origins.[16] Lynn Margulis championed the theory of 'endosymbiosis'[17] using the example that mitochondria, the cell's powerhouses, were once independently-living organisms. Moreover, according to Carl Zimmer, viruses constitute 8-9% of the human genome and may play a key role in the evolution of the human placenta.[18] In the 1990s Donna Haraway anticipated the heterogeneous nature of humans by including assemblages

14.
Rachel Armstrong and Martin Hanczyc, "Bütschli Dynamic Droplet System," *Artificial Life Journal* (Cambridge, MA: MIT, In Press).

15.
Manuel De Landa observes that in the evolution of biological bones "some of the conglomerations of fleshy matter-energy that made up life underwent a sudden *mineralization*, and a new material for constructing living creatures emerged: bone. It is almost as if the mineral world that had served as a substratum for the emergence of biological creatures was reasserting itself." Manuel De Landa, *A Thousand Years of Nonlinear History* (New York: Zone, 1997), 26.

16.
See "Humans and bacteria exchange genetic material," accessed August 15, 2012. http://scicasts.com/lifesciences/1867-genetics/3458-human-and-bacteria-exchange-genetic-material.

17.
Lynn Margulis, *Symbiosis in Cell Evolution*, 2nd edn (New York: Freeman, 1993).

18.
Carl Zimmer, *A Planet of Viruses* (Chicago: University Of Chicago Press, 2011). See http://www.youtube.com/watch?v=WIZMIC5PV0c.

of non-living things, such as machines and images, in the cybernetic matrix of human identity.[19] Soils and cities also have bodies that are made up of assemblages[20] of things that are not classified within biological systems, although it is necessary to resist objectifying them according to our anthropocentric archetypes. They are not the equivalent of biological objects but they possess distinctive materialities. At first glance the living qualities of soils and cities may be attributed to the creatures that inhabit them but on further reflection, their character is shaped by the continuous, combined actions of an entanglement of a much more diverse set of actants, which leave material traces of these relationships.

The city, however, does not tell its past, but contains it like the lines of a hand, written in the corners of the streets, the gratings of the windows, the banisters of the steps, the antennae of the lightning rods, the poles of the flags, every segment marked in turn with scratches, indentations, scrolls.[21]

Both soil, which becomes mother to all organic life, and cities, which are the backbones of human civilization, resist being meaningfully reduced into their components. They are complex bodies, which act as 'wholes' forged by the myriad interactions that take place within their webs. Although soils and cities are continually shaped by human-initiated events, some of the most devastating impacts are not of human origin. The 2011 tsunami that swept through the Sendai region has changed the identity of its soils and cities. Not all of these effects have been ruinous. The natural disaster has forged a new sense of community[22] that has brought forth new acts of construction and regeneration, which are taking root in a new kind of dirt—a rubble of souvenirs that prompts visitors to weep.

Buildings are still being torn down. Red zeros are seen on buildings indicating no bodies have been found inside. Red crosses are spray painted on buildings that have been condemned and await demolition. Buildings ripped off their foundations remain sitting atop debris and wedged between other buildings. A department store with first floor lights hanging by wires from the ceiling has no walls on the first floor. Debris is sorted into recyclables and burnable piles. Heavy equipment still remains everywhere working constantly to disassemble buildings.[23]

In order to empower the generative systems that typify 'deep' ecology it is necessary to raise their status and capacity to shape events. The pervasive anthropocentrism of our classical philosophical frameworks is somewhat, though not entirely, subjugated using Actor Network Theory (ANT) to

19.
Donna Haraway, "Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century," ***Simians, Cyborgs and Women: The Reinvention of Nature*** **(New York: Routledge, 1991), 32.**

20.
The concept of 'assemblage' is normally understood to be derived from the French word ***agencement*****, as used in the works of Gilles Deleuze and Felix Guattari. The term is not considered as an isolated concept but understood through the way that new meaning evolves from specific connections between a set of concepts. "…there is a circuit of states that forms a mutual becoming, in the heart of a necessarily multiple or collective assemblage." Gilles Deleuze and Felix Guattari,** ***Kafka: Toward a Minor Literature*** **(Minneapolis, MN: University of Minnesota Press, 1986), 22. The arrangement of the connections gives rise to new concepts in creative and often unpredictable ways.** ***Agencement*** **therefore refers to a set of concepts that possess contingency and may exhibit emergent qualities characteristic of complex systems (with which they are frequently associated) that bestows new meaning, which may be radically different from their original sense.**

21.
Italo Calvino, ***Invisible Cities*****, Translated from Italian by William Weaver (Berkshire, UK: Random House, 1997), 11.**

22.
Yuka Hayashi and Juro Osawa, "One Year Later, Japan Sees Light—in a Long Tunnel," ***The Wall Street Journal*****, March 11, 2012. Accessed August 15, 2012. http://online.wsj.com/article/SB10001424052970204603004577268721386974122.html.**

23.
Tokyo Blond, "Sendai—A Year Later," http://tokyoblond.blogspot.co.uk/2012/03/sendai-year-later.html.

critique the causal bodies responsible for events. Inspired by the work of Michel Callon[24] and Bruno Latour,[25] it formulates an ecological framework in which participating communities are not centred around a single human ego—but operate through enabling networks of collaborating 'actants' such as other humans, machines, animals, where even 'matter matters.'[26] Through ANT's conceptual framework, the status of non-human agencies is raised and soils can now engage in acts of construction over geological timespans to exert effects even before the existence of *Homo sapiens*. Jane Bennett articulates this non-human agency by extending its participating community to things that are not typically thought of as being 'alive'. Bennett establishes a variety of contexts in which matter and materials possess physical force and even exert political agency. For example, she reflects on the vital power of urban material formations such as landfills, which generate 'lively streams of chemicals'[27], and city infrastructures such as electricity power grids, which are characterized by powerful assemblages of non-human actants that include 'electrons, trees, wind, electromagnetic fields.'[28] Yet if these terrestrial forces subsume human activity and claim it as their own through a pre-ordained course of evolution, then the role of cities and humans are simply equivalent to any other terrestrial event and the whole notion of design or architecture is a meaningless distinction to make. How can we make sense of the world if we don't appreciate differences between things? Daniel Dennett proposes that our ability to discriminate originates from the 'selfish' nature of matter, which establishes a position of 'me against the world' where the sensory systems of organisms are focused on defining what is 'self' and what is not.[29] Yet, our physical entwining with a complex web of biological systems does not completely subsume us. We can exert influence within our supporting networks as individuals, community members and as the authors of cities. And our natural abilities to exist in different collectives of human assemblages become even more potent when they are combined with technologies. Over the course of the twentieth century, we have become particularly adept at increasing our force through human-machine assemblages, and our modern design paradigms promote the needs of machines over diverse ecologies. Indeed, exerting excessive power has proven to be environmentally damaging to sustaining networks such as water systems, vegetation and the air around us. Our contemporary object-centered existence is being replaced by a complex model of topological organization, which can be used to support an ecological approach to the practice of the built environment. Complexity theory

24.
Michel Callon, "Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay," in *Power, Action, and Belief: A New Sociology of Knowledge?* edited by J. Law (London: Routledge & Kegan Paul, 1986).

25.
Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, MA: Harvard University Press, 1987).

26.
Lars Christian Risan, (1997) "Artificial Life: A Technoscience Leaving Modernity? An Anthropology of Subjects and Objects - With a Foreword by Inman Harvey." Accessed May 2012. http://www.anthrobase.com/Txt/R/Risan_L_05.htm.

27.
For example, the Italian 'triangle of death' has been linked to unusually high incidences of cancer that emanate from illegal hazardous waste disposal of various sources, especially from the northern Italy industries. Kathryn Senior and Alfredo Mazza, "Italian 'Triangle of death' linked to waste crisis," *The Lancet Oncology*, Volume 5, Issue 9 (2004), 525-527.

28.
Jane Bennett, "The Agency of Assemblages and the North American Blackout," *Public Culture*, Volume 17, Number 3 (2005), 445–465. Accessed May 2012. http://publicculture.org/articles/view/17/3/the-agency-of-assemblages-and-the-north-american-blackout.

29.
Daniel C. Dennett, "The Origins of Selves," *Cogito* 3 (Autumn 1998), 163-73. Reprinted in Daniel Kolak and Raymond Martin, eds., *Self & Identity: Contemporary Philosophical Issues* (New York: Macmillan, 1991).

is consistent with ANT's view of multiple, interconnected networks in which objects have been decentred and causality has been bestowed on 'systems' and centres of organizing activity. Unlike the scientific systemic view of organization, ANT enables actants to possess qualities, which are an essential ingredient for the production of architecture. The cross-pollination of scientific complexity, social theory, ANT and the 'seven continuums' of design creates profuse combinatorial possibilities or architectural experiences that are emergent and capable of producing surprises, paradoxes and can delight inhabitants. Globalized processes that act through a panoramic range of media such as telecommunications, social networking, world travel and the evolution of world markets facilitate these rich fusions and new perspectives. These opportunities for being in more than one place at once create the conditions in which once discreet boundaries are traversed: geographies, cultures, identities and even nature itself. However, these exchanges are not limitless but exist within a realm of definable probability that is contingent on a particular situation and surroundings, which obey the laws of physics and chemistry and yet cannot be 'reduced' into these elements.[30]

These observations in which the potential for an event to unfold is defined as it materialises, are consistent with our everyday experiences. Complexity confronts our object-centered world replacing its dualist paradigms (either/or) with a potentially infinite set of connections (and/and/and …). In a complex world paradoxes are not mutually exclusive but can co-exist. Indeed, we are accustomed to dealing with contradictions, both cultural[31] and physical,[32] which confront us and demand that we make decisions.

Networks do not possess intrinsic human meaning so the boundaries that form our individuality and separateness are subjectively forged. For example, we are codified by political systems and mechanical systems and reduced to the status of governable 'objects' or 'data' without inherent value. Yet, we resist this abstraction or homogeneity by 'editing' our physical and informational networks to shape our identity. We discard materials that hold no value to us as 'garbage'. Alan Turing recognized the importance of personal bias in dealing with complex systems and devised the 'Imitation Game' to address the conundrum of intelligence, which evaded an easy empirical solution. This is now more popularly know as the 'Turing Test' and is now being used more widely to fathom complex systems and to even identify 'life.'[33] This continuous process of self-identification and the creation of meaning through the production of

30.
Stuart Kauffman observes that emergent systems such as biological processes, the biosphere and human culture are ceaselessly creative in ways that are fundamentally unpredictable and presumably non-algorithmic or machine-like and cannot be 'reduced to their physics'. http://www.edge.org/3rd_culture/kauffman06/kauffman06_index.html.

31.
An example of this is the survey commissioned by Richard Dawkins' Foundation for Reason and Science, which intended to demonstrate that Christianity is a minority pursuit and assert the triumph of reason in contemporary politics. Dawkins attempted to prove that the British public were hypocritical in their religious affiliations by showing they understood very little of the texts they proposed to believe. This tactic backfired in a notorious interview for the BBC in conversation with Giles Fraser, Former Canon Chancellor of St Paul's Cathedral, who criticized Dawkins for designing a questionnaire full of 'silly little tricks' to trip people up with - before turning one of them on Dawkins who was invited to state the full title of Darwin's 1859 book [Charles Darwin, *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* (London: John Murray, 1859)]. Dawkins was unable to name the full title, but there was a deeper flaw in Dawkins' approach—that science does not offer moral or ethical guidance and most British are raised in a Christian culture, which does provide this guidance. People generally like to think of themselves as being 'good', which is a value judgment, which means their point of reference is based on a cultural appreciation of Christianity rather than an academic one. The Spectator also notes that "It is impossible to isolate those parts of your identity which belong to the religious and the rational sphere, simply because human beings aren't formed like that." See Melanie McDonagh, "Why Prof Dawkins has it wrong," *The Spectator*, 14 February, 2012. Accessed May 2012. http://www.spectator.co.uk/coffeehouse/7650038/why-prof-dawkins-has-it-wrong.thtml. So the issues are complex and impossible to dissect 'scientifically.'

32.
Technological convergences pose particularly challenging new experiences such as printed foods that taste very different to their 'unenhanced' originals. "Homaro Cantu + Ben Roche: Cooking as Alchemy," http://www.ted.com/talks/homaro_cantu_ben_roche_cooking_as_alchemy.html.

33.
L. Cronin, N. Krasnogor, B.G. Davis, C. Alexander, N. Robertson, J.H.G. Steinke, S.L.M. Schroeder, A.N. Khlobystov, G. Cooper, P.M. Gardner, P. Siepmann, B.J. Whitaker, D. Marsh,."The imitation game—a computational chemical approach to recognizing life," in *Nature Biotech* 24 (2006), 1203-1205.

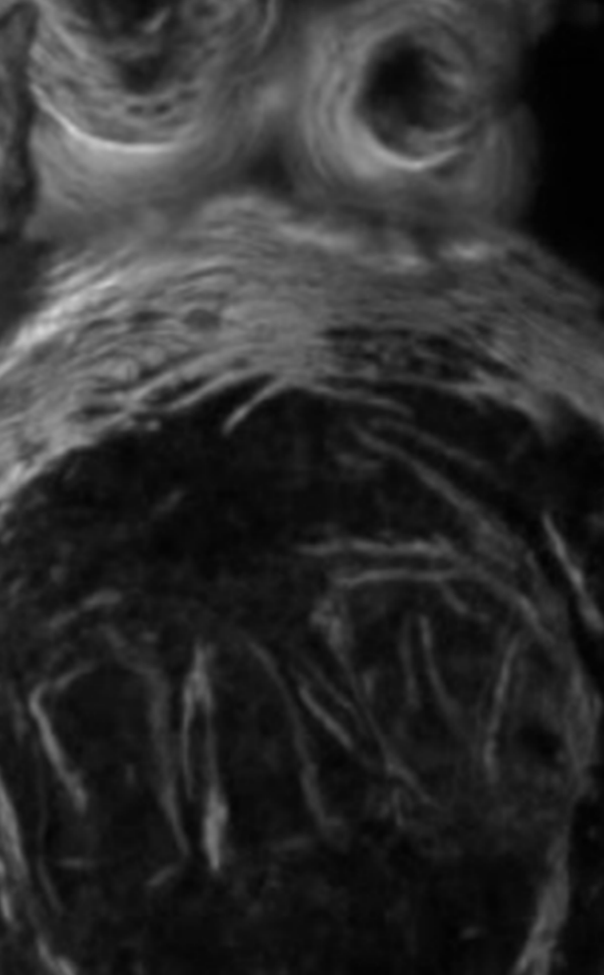
'garbage,'[34] along with the subtraction of our network connections so they become personally more manageable,[35] are the acts of design that shape our experiences, environments and communities.[36]

Rather than rendering people irrelevant to the natural world, our design practices forge meaning and precipitate events, so 'deep' ecological design practices raise questions about our agency within the biosphere and are essential in shaping human development. There are split sites and demi-spaces within the shifting boundaries of living materials that give rise to the co-authorship of cities with other non-human agencies. Here new construction approaches for human development emerge, where buildings are not 'made for' but 'evolved by' their inhabitants. With the advent of living materials, architecture is re-inhabited by techno-political-social-cultural acts of design that do not strive for the production of objects and artifacts but synthesize systems. By decentring the production of objects, the modern and post-modern obsessions that commoditize human history through industrial practices can be offset. Living matter, as a co-author in the evolution of cities, invokes a new category of architectural materials and technologies through which we can imagine buildings that are not assembled as a set of objects but are transformed by, extruded from and evolved within bodies and materials. They generate a whole new set of processes, technologies, lifespans and expectations whose performance needs a different kind of evaluation that exists beyond—but does not exclude an appreciation of—mechanical efficiency, or geometry. Living technologies work with the unique qualities of living things such as their robustness, flexibility and capacity to deal with a changing environment, whose goals are steeped in 'persistence' narratives rather than odes to 'efficiency'. 'Deep' ecological architecture does not strive for objects as its primary pursuit—but generates materials, meanings and physical traces as a consequence of the entangled web of human and non-human agencies, in which human designers can strategically act with significant force. When people and biota are entangled through mutually supportive relationships and connecting technologies, they begin to dissolve the distinction between architecture and landscape and subvert dualistic paradigms. In their place, they create systems that connect the interests of one with the interests of all through positive and negative feedback loops—which characterise natural cyclical events such as expansion and reduction, or circadian rhythms. A 'deep' ecological engagement with materials has far reaching impact on human history and the production of architecture. It questions the idea of the

34.
"Appropriation is the mother of garbage. In another guise this is seen as a human propensity for differentiation (a complicated way of saying we choose or accept something whilst rejecting something else) that inaugurates a lifetime of cutting off, disconnection and removal. Nevertheless, these activities becomes the principal means of marking off the valuable and worthy, and in this sense differentiation is what establishes culture." John Scanlan, *On Garbage* (Bath, UK: CPI Press, 2005), 15.

35.
I am specifically referring to Italo Calvino's observation that creativity is subtraction. "My working method has more often than not involved the subtraction of weight. I have tried to remove weight, sometimes from people, sometimes from heavenly bodies, sometimes from cities; above all I have tried to remove weight from the structure of stories and from language." Italo Calvino, *Six Memos for the Next Millennium* (New York: Vintage, 1988), 3.

36.
I believe that it is possible, though not empirically testable, that non-human actants will also find 'meaning' within their own network connections when they are able to do so.



construction of a building as an object—an instant 'solution' to temporary needs—and necessitates an ontological reframing of architectural intentions. A more interconnected and environmentally engaged architectural practice also requires reflection on what groups of 'actants' constitute a human body,[37] a building, a community, public and private spaces, or the city as a whole. Moreover, these questions call for consideration of the moral, ethical, political and social status of non-human assemblages within urban communities,[38] as well as our responsibility and accountability for them. Inherent to a 'deep' ecological architectural practice is the question of time itself. Cities and soils are evolved, not made, and the practice of urban planning needs consideration when emergence underpins design strategies, opening the paradox between objects, which represent closed solutions, and systems that remain open and responsive to on-going changes. While we understand that urgent action is needed to remediate the damaging impacts of industrialization on the natural world, truly sustainable effects evolve on a longer scale and are shared over generations. Antoni Gaudí's 'La Sagrada Familia' has caused wonder and inspired generations despite its incompleteness. Could the idea of a building in continual evolution offer a new paradigm for the practice of the built environment? And how do we keep youth meaningfully engaged in a vision of a longer-term development—in which cities and people co-evolve towards a common goal? Subsequent generations need to share our dreams, which means that we need to offer them our learning experiences rather than issue them directives. Moreover, when considering these processes of construction using geological rather than anthropological timescales, does it become possible to examine the construction of life-supporting infrastructures outside of architectural doctrines? From a geological time perspective we can begin to recognise afresh how the production of soils and cities embody human 'meaning' not as a totalising, or final goal, but in a manner that forges a greater biospherical narrative.

37.
Jane Bennett, *Vibrant Matter: A Political Ecology of Things* (Durham: Duke University Press, 2009), xvii.

38.
Ibid., 94.

Urban Soils

A soil is not a pile of dirt. It is a transformer, a body that organises raw materials into tissues. These are the tissues that become mother to all organic life.[39]

In applying the perspective of a 'deep' ecological design practice we are building soils to create an architectural infrastructure. Cities are the human equivalents of our biotic soils—not in a metaphorical way—but as the thing itself. The intention is to advance life-promoting strategies rather than wasteland-creating ones. Today's cities are not yet soils —they are deserts. They are as barren as the rocks of the Archean period before they were weathered and chewed by the elements, whose particles catalysed the very processes of life. Our cities need to be inhabited by networks of physical interaction and exchange if they are to make a transformation from proto-soil to mature soil, to enliven the urban environment in a similar way to electrons that flow through our cables and airwaves, continually forging 'cyberspace.'[40] From the perspective of geological time, chemical networks of exchange have enabled the proliferation of diverse ecosystems that are evidenced by the fossil record. Simple plants could only become complex rainforests when effective water-carrying infrastructures radically altered the movement of carbon through forests and drove environmental change.[41]

Around two percent of the earth is urbanised[42] and is the main site of anthropocentric injury to our biosphere—through pollution, natural resource consumption and the production of vast amounts of indigestible waste. A time-lapse film of the earth's surface over the ages would reveal that it was constantly moving. Yet when we build, we design as if the world were static. To retain this illusion we create barriers against nature or apply more mechanical power with the intention of subordinating and controlling it. Architects have selected obedient materials for building, producing and designing with materials that are not expected to surprise us. When material networks of exchange persist within our cities they are absent of formal design intention. Modernist cities are amassed as 'exquisite corpses,'[43] being forced together as sets of parts in various relationships of convenience, chance and proximity, rather than being seamlessly integrated by a shared purpose. Consequently their infrastructures are also inadequately organised to promote a diversification event comparable to the evolution of the Amazonian rainforest. They lag be-

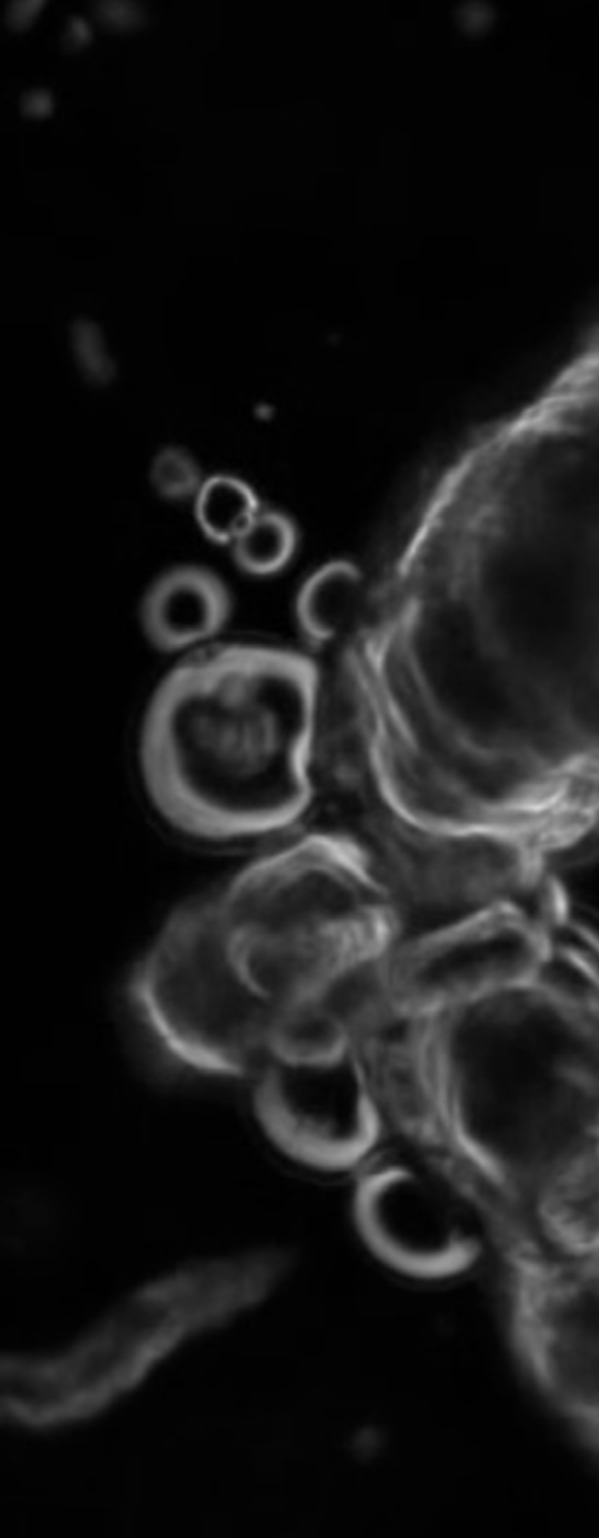
39.
Logan, *Dirt*, 181.

40.
Dynamic chemical networks of architectural dimensions are already possible through bacterial interactions that shape our bodies (see Rachel Armstrong, "Bacteria 'R' Us," http://www.nextnature.net/2012/03/bacteria-r-us/#more-21262) and our environment, with architectural impacts such as the construction of stones, or the fixation of carbon dioxide by biofilms (see Simon Park, "What Bacteria can do for your City," http://thoughts.arup.com/post/details/193/what-bacteria-can-do-for-your-city).

41.
"First rainforests arose when plants solved plumbing problem," http://phys.org/news/2011-05-rainforests-arose-plumbing-problem.html.

42.
United Nations, *The State of the World's Cities, 2001*. United Nations Centre for Human Settlements. Nairobi, Kenya. As of the year 2000, about 37 percent of Earth's land area was agricultural land. About one-third of this area, or 11 percent of Earth's total land, is used for crops. Roughly one-fourth of Earth's land area is pastureland, which includes cultivated or wild forage crops for animals and open land used for grazing. United Nations Food and Agricultural Organization, Statistics Analysis Service, *Compendium of Agricultural-Environmental Indicators 1989–91 to 2000* (Rome, November 2003), 11. To help governments with land-use planning, the United Nations Food and Agricultural Organization (FAO) developed a system called Agro-Ecological Zoning that characterizes land's suitability for agriculture based on physical parameters like climate, soil, and topography (For details, see http://www.fao.org/AG/agl/agll/gaez/index.htm). Based on current soil, terrain, and climate data, FAO estimates that more than three-quarters of Earth's land surface is unsuitable for growing rain-fed crops (i.e., raising crops without irrigation). Most of the remainder is subject to some soil, terrain, and/or climate limitations. On average, only about 3.5 percent of Earth's surface is suitable for agriculture without any physical constraints. (See *The Habitable Planet*. Unit 7. Agriculture. Online Textbook Available from: http://www.learner.org/courses/envsci/unit/text.php?unit=7&secNum=2. Accessed May 2012).

43.
The Exquisite Corpse was a surrealist tactic that explored the mystique of accident. It was based on an old parlour game where words and images were serially built upon using a folded sheet of paper that was passed between players for their contributions. The poetic fragments of text and images made by each contributor were not revealed until the end of the game, which displayed an expression of what Max Ernst called 'mental contagion.' See http://exquisitecorpse.com/definition/About.html.



hind the advancing building fronts restricting, rather than promoting, conditions of healthy growth. Indeed, the way we imagine and build our cities is at odds with the natural infrastructures that support the diverse ecologies that we share with other organisms. Regardless of our best efforts to remain at the top of a hierarchy of our own design, the radical creativity that exists within biological systems has a myriad ways to subvert our anthropocentric intentions. Grime and its allies—waste, rubbish and excrement—lurk persistently, as a soil-body in waiting, to relentlessly organise and transform spaces that have been neglected by design paradigms. Inch-by-inch, dust from crumbling walls mixes with detritus and fast food leftovers. Sticky bacteria-laden concoctions gather incongruously in crevices to lay down the infrastructure for an urban wilderness. Curious creepers, bacterial films and wandering wild flowers bloom from out of the slurry. If humans do not sanitise these weeds on sight, they unleash their radical creativity and continue their work by transforming the aseptic surfaces of buildings into new soil substrates. Natural forces urgently midwife the fledgling soil towards independence through ingenious counter-tactics such as corrosive salting and algal greening of brickwork. Tree roots upheave pavement slabs and underground springs weaken building foundations until the young propagating soil body subsumes its own networks, which yield fresh urban life forms and break open architectural shells to release a biodiverse future. As more of us move into our megacities that are founded on modernist principles and their infrastructures, we hug our cleanliness closely—reluctant to give any ground back to nature. Yet the already stressed substructures of modern cities are suffering from urban decay with its associated systemic problems such as crime, traffic congestion, homelessness, scarce resource provision, waste collection—that generate squalor and urban filth. As cities continue to struggle with these issues, there is little to distinguish self-composting modernism from the living, umbilical membrane that gathers momentum through a relentless, interconnected assemblage of bottom-up processes. Indeed, only time can differentiate between them.

Perhaps the whole world is covered by craters of rubbish, each surrounding a metropolis in constant eruption.[44]

There is great connectivity between the living and non-living worlds—we are all stardust, of different qualities, varieties and abilities. The unique condition of earth is its propensity to spew forth living materials that oozed life into

44.
Italo Calvino, *Invisible Cities* (New York: Harcourt Brace Jovanovich, 1974), 115.

existence. From a 'deep' ecological perspective architecture is more than just about humanity but shares the biospherical concerns that all life faces. At a time of ecological crisis and human discord our answers may not lie in systems of human origin but through ones that are primordial, older and wiser than the collective lessons of human history. The nature of 'deep' ecological wisdom is best embodied by the story of Aslan who comes back to life, after connecting with the deepest truths of the universe, to restore Narnia's ecological fertility and break the glittering industrial spell of winter.[45]

Her knowledge goes back only to the dawn of Time. But if she could have looked a little further back, into the stillness and the darkness before Time dawned, she would have read there a different incantation. [46]

The evolution of a city founded on 'deep' ecological practices is forged by the successive interactions of heterogeneous assemblages that differ from city to city. Architecture may no longer function as a sump of resource consumption but rather as a site of production for useful substances such as food, biofuels or precipitates that enable materials to self-repair. The sterile, inert surfaces of our modern cities provide a site and an opportunity for transformation of architectural design practice—to generate a common life-sustaining project aimed at the production of urban soil in which other systems can thrive. Non-human actants such as pollution-absorbing surfaces, lichen and bacteria, may become meaningful co-authors in shaping our shared living spaces. Dull inert building surfaces may burst into bloom with paints that 'eat' carbon dioxide and change colour when they are 'full', or sparkle with algae bioreactors that dance in the sunlight to the pulse of an iPod. Concrete and glass skins could be colonised by a variety of living materials that are designed as an architectural soil to perform a range of roles within the urban environment. These persistent exchanges and interactions provide the infrastructure for new forms of community, vivacious ecologies and an air of exuberance within the urban landscape. City inhabitants, of all constituent species and materialities, may begin to act as an expanded entanglement of participating bodies. Through continual interactions, they may act beyond the traditional notions of site and shelter and begin to collaboratively function as the architectural soil organs that will ultimately contribute to our survival.

45.
C.S. Lewis lived at a time when science was emerging as the dominant system of thought in the Western world and technological innovation was rapidly transforming society and declared "The sciences long remained like a lion-cub whose gambols delighted its master in private; it had not yet tasted man's blood. All through the eighteenth century, . . . science was not the business of Man because Man had not yet become the business of science. It dealt chiefly with the inanimate; and it threw off few technological byproducts. When Watt makes his engine, Darwin starts monkeying with the ancestry of Man, and Freud with his soul, then indeed the lion will have got out of its cage." C.S. Lewis, "De Descriptione Temporum: Inaugural Lecture from The Chair of Mediaeval and Renaissance Literature at Cambridge University", 1954. Available at: http://ia600202.us.archive.org/5/items/DeDescriptioneTemporum/DeDescriptioneTemporumByC.S.Lewis.pdf. Accessed May 2012.
See also: Edward J. Larson and Steven Layward, "C.S. Lewis on Threats to Freedom in Modern Society," accessed May, 2012. http://www.catholiceducation.org/articles/civilization/cc0109.html.

46.
C.S. Lewis, *The Chronicles of Narnia: The Lion, the Witch and the Wardrobe* (New York: HarperCollins, 2001), 176.

In a world of such incredible creativity on the many scales that nature offers, we need to rethink our approach to human development. Rather than seeking to dominate natural forces, we could regard them as co-authors of mutually beneficial environmental outcomes. Nature does not speak the same 'language' as mechanical systems. Natural systems are complex, with laws that are emergent. They require us to think in terms of context, rather than in terms of the production of objects. However, the new scientific practice of synthetic biology[47] enables the development of 'living' materials, where life's processes can be regarded as a technology. These 'living technologies' share 'the same language' of natural systems through the frameworks of complexity and the processes of emergence. Living technologies are capable of harnessing natural forces to address design and engineering challenges in new ways, even forging connections between ontologically different substrates such as computer hard drives grown from tiny magnets by bacteria[48], or producing electricity in battery cells[49]. These technologies bring new challenges to the design and engineering portfolios, as they possess agency, need sustenance, have a will of their own and change with time. Living materials require us to examine our understanding of matter, technology, life and even our understanding of reality. The categories and distinctions that we have conventionally conferred on natural systems since the Enlightenment may need reconsideration. Perhaps it is necessary that in an age of scientific 'omes' —which refer to the capacities of chemical systems to act in the course of biological development, such as the genome (genes) and proteome (proteins)—there is a need to bring forth a mineral-ome, so that we can apprehend its agency. Maybe our tendency to define also has the capacity to drive further artificial divisions and inequalities between humans and the non-human world. For example, J.C. Venter's synthetic organism 'Synthia', engineered from a fully-manufactured DNA sequence and rebooted in a 'ghost' yeast cell, has huge implications—not just for the practical aspects of biological design, but also in terms of how organisms are defined and 'classified'. Until a decade ago, scientists categorized microorganisms almost exclusively by their physical characteristics: how they looked, what they ate, and the by-products they produced.[50] Now, Venter's work implies that perhaps a better method for classifying species may be through the genomic sequence rather than the phenotype, owing to the considerable amount of manipulation that can be achieved at the genetic level of an organism. Venter's group is in the process of compiling a database of bacterial genetic codes that can freely mix and match sequences to

47.
The design and engineering with living things.

48.
"Magnetic Bacteria May Help Build Future Bio-Computers," *BBC News.* Accessed May 2012. http://www.bbc.com/news/technology-17981157. "Swarm of Bacteria Builds Tiny Pyramid." Accessed May 2012. http://www.youtube.com/watch?v=fCSOdQK5PIY.

49.
Bruce E. Logan and John M. Regan, "Electricity-Producing Bacterial Communities in Microbial Fuel Cells", *Trends in Microbiology* 40 (2006): 5181-5192.

50.
Jim Sliwa, "Genomics throws species definition in question for microbes," American Society for Microbiology. Accessed 4 October 2009. http://news.bio-medicine.org/biology-news-3/Genomics-throws-species-definition-in-question-for-microbes-2239-1/.

'crank out synthetic chromosomes.'[51]

And all this material is being put through a reduction process that brings it down to the essential, condensed, miniaturized minimum, a process whose limits have yet to be established; just as all existing and possible images are being filed in minute spools of microfilm, while microscopic bobbins of magnetic tape hold all sounds that have ever been and ever can be recorded. What we are planning to build is a centralized archive of humankind, and we are attempting to store it in the smallest possible space, along the lines of the individual memories in our brains. [52]

Yet, we need some way of signifying the changes that are taking place with the convergence of advanced combined technology.[53] Innovations that will alter the way we design and the kinds of materials that we will use are in development worldwide. They require us to work at a range of scales, spanning the nano[54] to the megascale.[55]
These are new experiences in design and architecture and will require different ways of thinking about construction processes that are discussed through new kinds of classifications that may indicate synergies rather than separations —where emergent fusions between participating systems give rise to chimeric agencies that are 'alike' since they connect. Ian Pearson' vision of a post-human future explores a nomenclature for human hybrids such as *Homo machinus* and *Homo hybridus*,[56] but there may be a need to find other ways of referring to these fusions that are not just adaptations of the Latin-based system of Carl Linnaeus. [57]
A synthetic periodic table of materials may be necessarily alluded to in Luigi Serafini's *Codex Seraphinianus*, which constructs a whole new set of taxonomies of matter in an unintelligible language and concludes with the construction of surreal, living cities.[58]

New forms of classification will invade and change the current systems of practice as they will suggest new connections and synthetic transgressions that could not be conceived of by traditional systems. Since the nineteenth century, life-like phenomena have been observed in chemistry by researchers such as Friedlieb Ferdinand Runge,[59] Otto Bütschli,[60] Moritz Traube, [61] Raphael E. Liesegang, [62] Boris Pavlovich Belousov and Anatol M. Zhabotinsky, [63] and more recently by Lee Cronin and colleagues.[64] Frequently, self-organizing properties have been correlated with some of the properties of biology.

Recently, I have been re-examining a particular, dynamic water-in-oil droplet system that was first described in

51.
Craig Venter, "Life What a Concept!" An Edge Special Event at Eastover Farm, Transcript of conversation between Freeman Dyson, J. Craig Venter, George Church, Robert Shapiro, Dimitar Sasselov and Seth Lloyd, (New York: EDGE Foundation, Inc., 2008), 53.

52.
Italo Calvino, *The Complete Cosmicomics,* Tr. Martin McLaughlin (London: Modern Penguin Classics, 2009), 366.

53.
The so-called NBIC (Nano, Bio, Info, Cogno) convergence is an innovation initiative that followed a NSF (National Science Foundation) sponsored report, which has been particularly influential in precipitating a new kind of scientific approach suggesting unification of the sciences as a common goal through converging advanced technologies, to provide the practical basis for the retranslation of humanity, in keeping with the pursuit of Julian Huxley's vision of 'transhumanism' where "the human species will be on the threshold of a new kind of existence." Julian Huxley, *In New Bottles for New Wine* (London: Chatto & Windus, 1957), 13-17.

54.
Alexis Madrigal, "Bacterial Micro Machines Turn Tiny Gears," *Wired*. Accessed May 2012. http://www.wired.com/wiredscience/2009/12/bacterial-micro-machine/.

55.
"Metabolic Venice: Algae and Protocells Anticipating Evolved Landscapes." Accessed May 2012. http://dprbcn.wordpress.com/2011/12/16/metabolic-venice/.

56.
http://www.humansfuture.org/future_post_human_futures.php.htm.

57.
Carl Linnæus, *Systema Naturæ; Sive, Regna Tria Naturæ, Systematice Proposita per Classes, Ordines, Genera, & Species* (Lugduni Batavorum: Haak, 1735), 1–12.

58.
Luigi Serafini, *Codex Seraphinianus*, accessed May 2012. http://www.holybooks.com/wp-content/uploads/CodexSeraphinianus.pdf.

59.
F. F. Runge, *Zur Farben-Chemie. Musterbilder für Freunde des Schönen und zum Gebrauch für Zeichner, Maler, verzierer und Zeugdrucker. 1. Lieferung. Dargestellt durch chemische Wechselwirkung.* (Berlin: Verlag E. S. Mittler & Sohn, 1850).

60.
Otto Bütschli, *Untersuchungen ueber microscopische Schaume und das Protoplasma* (Leipzig: 1892).

1898 by zoologist Otto Bütschli. Using potash and olive oil as reactants, Bütschli observed the genesis of an 'artificial' amoeba with pseudopodia (cytoplasmic extensions) that behaved in a life-like manner.[65] His aim was to make a simplified experimental model to explain the plasticity of body morphology and movement based purely on physical and chemical processes such as fluid dynamics and surface tension.[66]

These Bütschli droplets can be reproduced from the original recipe, which is simply a way of making 'soap'. Yet the instabilities in this system create the non-equilibrium conditions in which these droplets can be thought of as 'minimal' agents for 'life-like' behaviors. The Bütschli system is useful in depicting how a complex constellation of possibilities and events shape each other. It begins with a single drop of alkali (white) being added to an oil field (black), which is the recipe for Bütschli droplets. Tiny droplets, just visible to the naked eye (approximately 1mm in diameter) emerge from the reaction field in a sequence of events that are typical of a non-linear dynamic chemical system. When viewed under the microscope at 10x magnification it is possible to see them bursting out of one another as manifolds, like Russian Matryoshka dolls. They relentlessly push their way through interfaces and eventually become quivering, 'living' bodies that make a crystalline product of 'soap'.[67] The Bütschli precipitates suggest their own taxonomic system of classification that reveals their complex interactions and exchanges[68] and can be used as a model that deals with the classification of 'functions' within a non-linear system, without having to resort to reducing or abstracting the system.

Notably, Bütschli droplets can be 'technologized,' as the droplets provide a vehicle in which secondary chemistries can be distributed through space and time in a life-like way. This is possible by manipulating flows of chemical information in the system to produce effects that are desired by humans in a range of possible situations. For example, Bütschli droplets could be used as a delivery system for 'environmental pharmaceuticals' such as smart paints or surface coatings with the selective potential to fix carbon dioxide into inorganic carbonate in response to environmental cues.[69]

We may even begin to regard these kinds of soft new technologies and their alternative taxonomic systems as part of our most intimate communities—in the same way that bacteria and viruses have invaded our human genome escaping our everyday awareness. In this sense, our new relationships

61.
Moritz Traube, "Experimente zur Theorie der Zellbildung und Endomose." *Arch Anat Physiol Wiss Med* 87 (1867): 129–165.

62.
Raphael E. Liesegang, "Ueber einige Eigenschaften von Gallerten," *Naturwissenschaftliche Wochenschrift*, Vol. 11, Nr. 30 (1869): 353-362.

63.
Boris Pavlovich Belousov, "A periodic reaction and its mechanism," *Compilation of Abstracts on Radiation Medicine* 147 (1959):145., Anatol M. Zhabotinsky, "Periodic processes of malonic acid oxidation in a liquid phase," *Biofizika* 9 (1964): 306–311.

64.
Cronin, L., Krasnogor, N., Davis, BG., Alexander, C., Robertson, N., Steinke, JHG., Schroeder, SLM., Khlobystov, AN., Cooper, G., Gardner, PM., Siepmann, P., Whitaker, BJ., and Marsh, D, "The Imitation Game – A Computational Chemical Approach to Recognizing Life," *Nature Biotechnology*, Vol. 24 (2006): 1203–6.

65.
Bütschli, *Untersuchungen*.

66.
T. Brailsford Robertson, "Remarks on the theory of protoplasmic movement and excitation," *Experimental Physiology* 2 (1909): 303-316.

67.
"Formation of a Bütschli Droplet," http://youtu.be/ZbKyE8OkkTo.

68.
Rachel Armstrong and Martin Hanczyc, "Bütschli Dynamic Droplet System," *Artificial Life Journal* (Cambridge, MA: MIT, In Press).

69.
Rachel Armstrong, "Unconventional Computing in the Built Environment," *International Journal of Nanotechnology and Molecular Computation*, 3(1) (2011): 1-12.

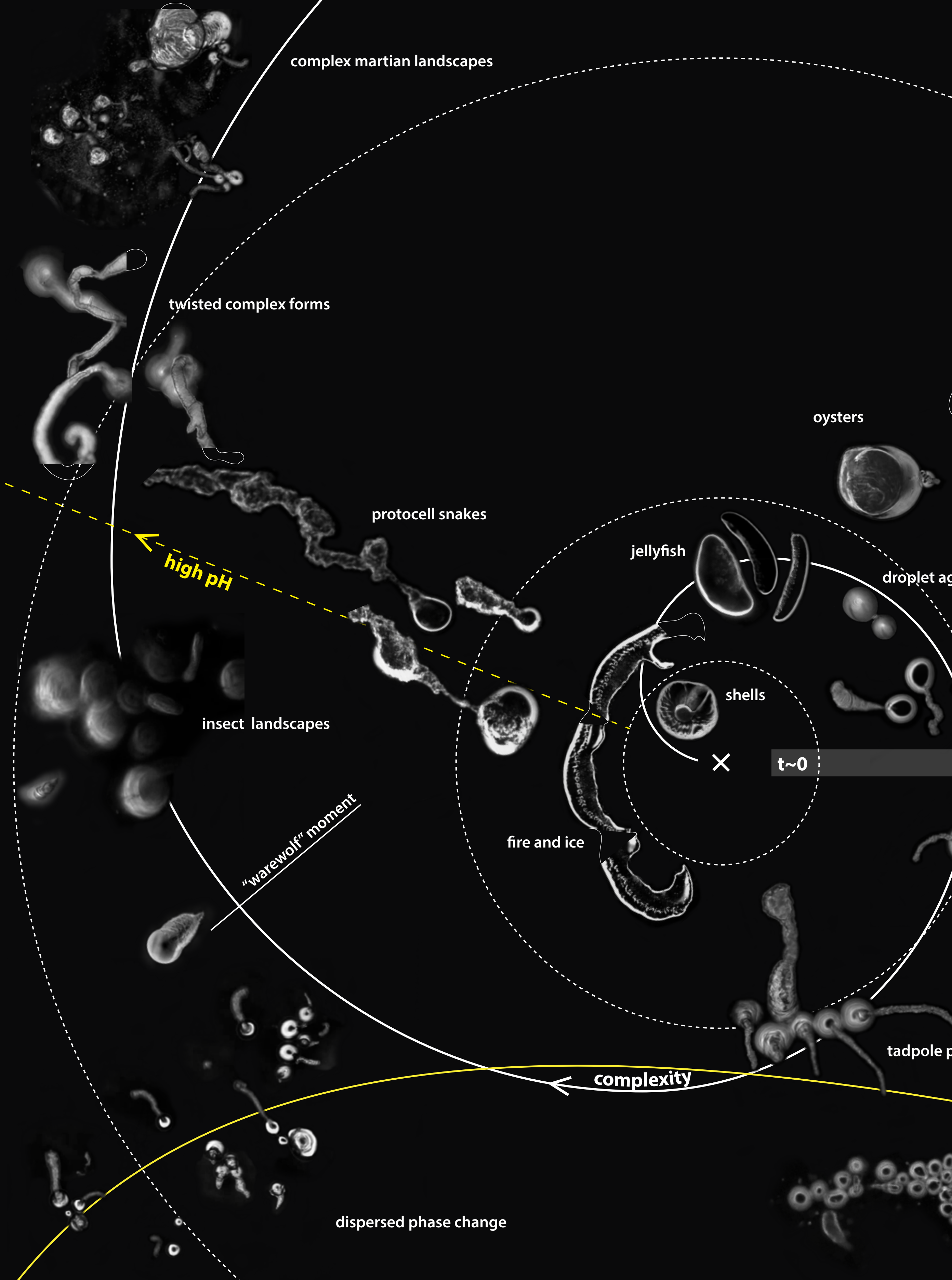
may be regarded as entirely 'natural'.[70] With our increasing familiarity and comfort in working with living materials that connect diverse communities of actors and actants, new ways of thinking about architecture may be possible. For example, we may regard our homes as literally being 'part of us' and connected to us by a series of architectural organs that are forged by a variety of living materials, each performing a different function. Our houses may not be viewed as merely a site, shelter, or barrier against the external elements but a membrane, or mycelium, that connects us with the natural world and that we nurture with the same care that we'd lavish on our own bodies. Our buildings may be consumed and reconstructed by the activities of their inhabitants and hosts of other entangled actants, and change with time. These reconfiguring relationships produce material traces that embody ecological activity, like the substances that worms produce in their networks of burrows are "… not mere excavations, but may rather be compared with tunnels lined with cement"[71] and whose architectural activities have shaped human history by causing poor soils to become fertile, enabling the global spread of agriculture. 'Deep' ecological architecture may be viewed as being as natural to our existence as our immune systems, which work with similar degrees of complexity, recognizing which substances are 'wanted' and which should be rejected. These organs may have structural similarities with the soils in terms of their local variations, complexity and ability to influence biospherical systems. Soil, rather than being the horizontal, geometrically defined amount of dirt we have beneath our feet, is transformed into a living system that nurtures our emerging 'soft' cities. Human development is now enabled to synergistically evolve with the biosphere and help us co-author an ecologically engaged future—in spite of, not because of, the odds. Our future is neither determined nor predictable, but there are countless possibilities within the physical constraints of our possible futures. Soft cities offer a new vision of human development, one that flows within a physical infrastructure of interactions that are built through our participation with non-human communities. Together we can address the significant challenges that we face in the advent of a sixth great extinction.

70.
Koert van Mensvoort proposes that nature and culture evolve together in a fusion he describes as 'Next Nature'. See "What is Next Nature?". Accessed May 2012. http://www.nextnature.net/about.

71.
Charles Darwin, *The Formation of Vegetable Mould, through the Actions of Worms, with Observations on Their Habits* (London: John Murray, 1881), 112. This substance has now been identified as a calcite silica mix, which is a cement-like substance. See Mary Caperton Morton, "Earthworms Churn Out Calcite Crystals," *Earth Magazine*. Accessed May 2012. http://www.earthmagazine.org/article/earthworms-churn-out-calcite-crystals.

I have also thought of a model city from which I deduce all the others … . It is a city made only of exceptions, exclusions, incongruities, contradictions. If such as city is the most improbable, by reducing the number of abnormal elements, we increase the probability that the city really exists.[72]

72.
Italo Calvino, *Invisible Cities* (New York: Harcourt Brace Jovanovich, 1974), 69.

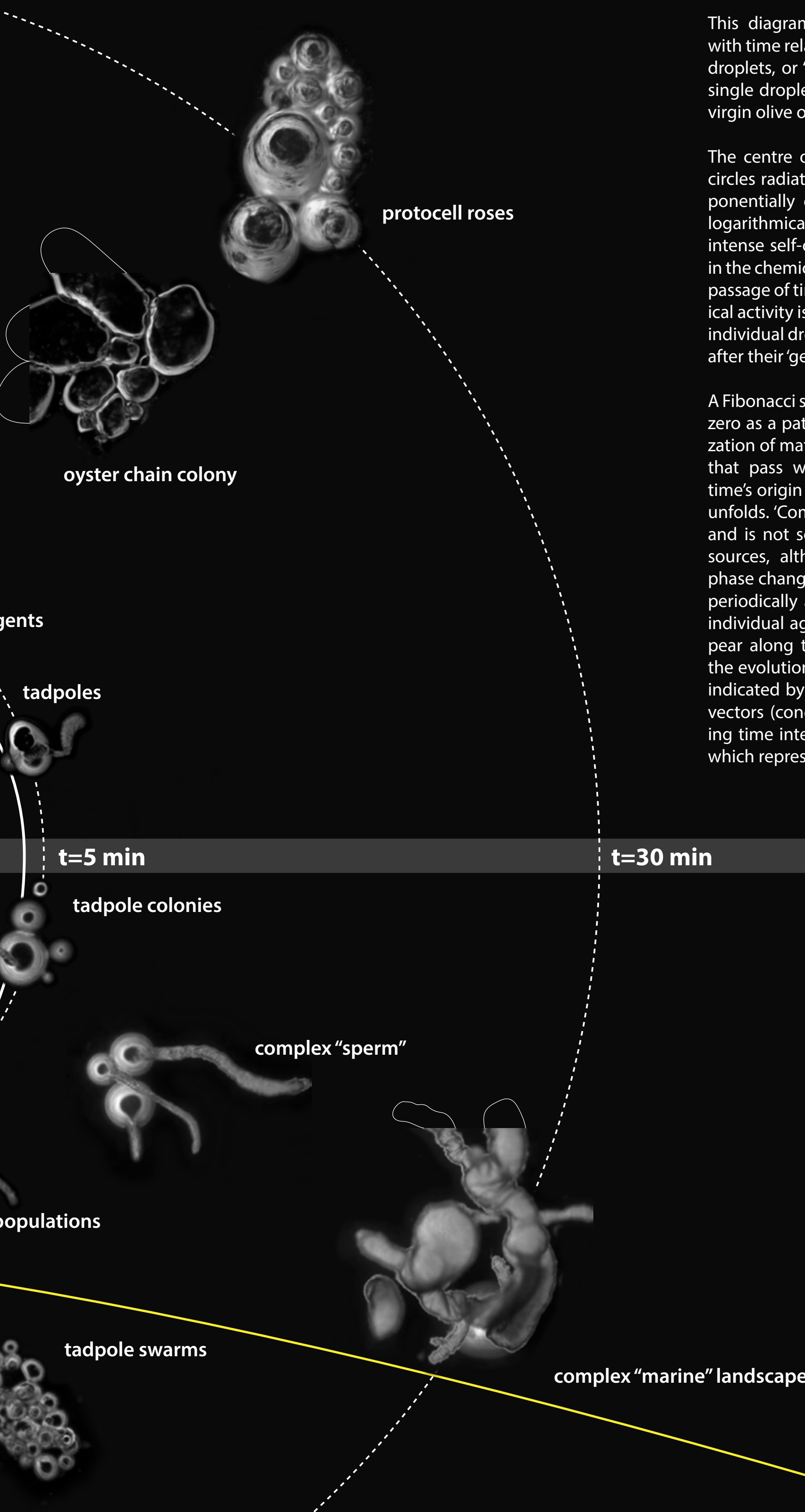

complex martian landscapes
twisted complex forms
oysters
protocell snakes
jellyfish
high pH
droplet ag
shells
insect landscapes
t~0
"warewolf" moment
fire and ice
tadpole p
complexity
dispersed phase change

TOPOLOGY OF PROTOCELL EVOLUTION

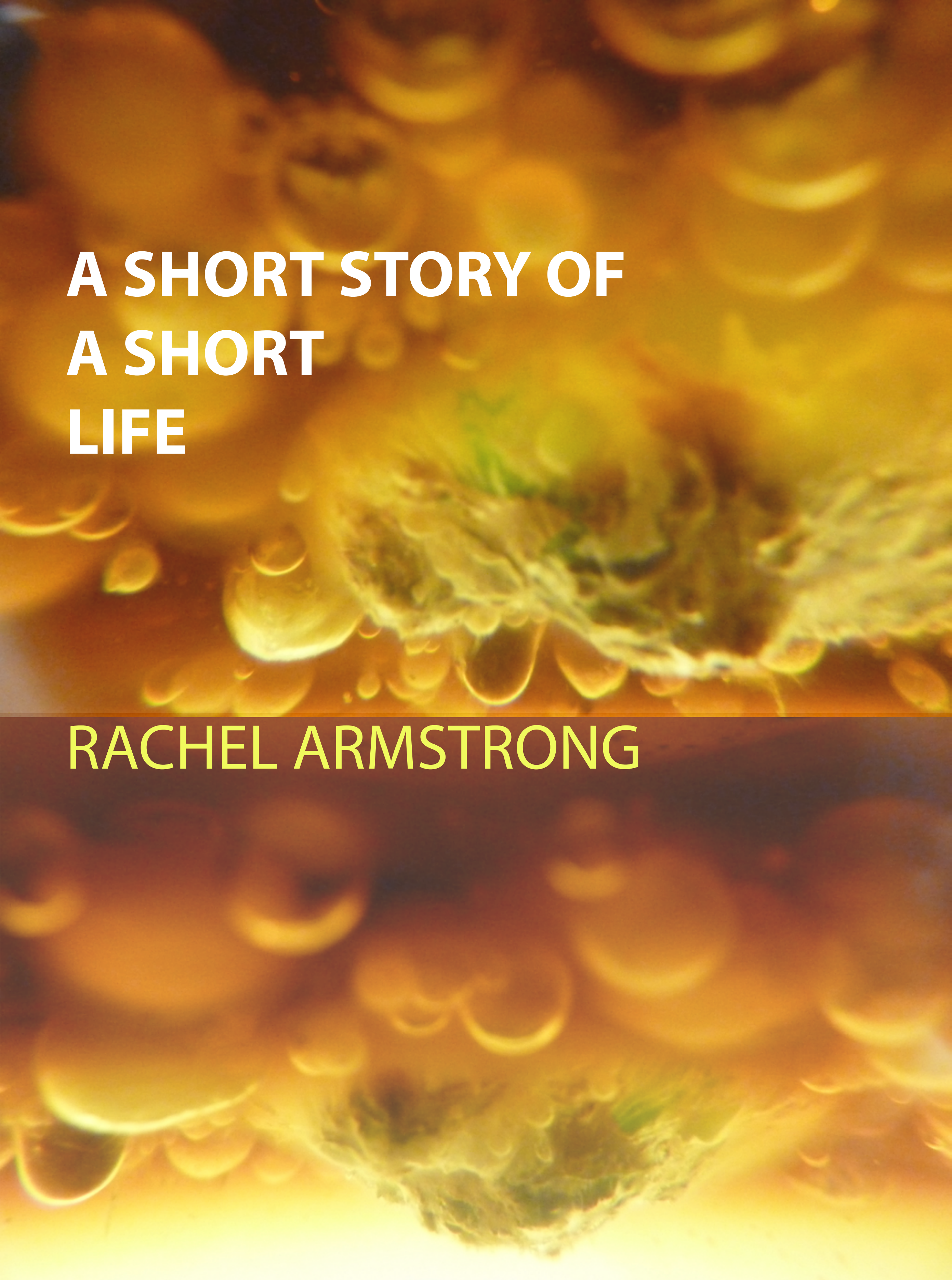
This diagram represents the change in complexity with time related to the evolution of 'Bütschli' oil/water droplets, or 'protocells', traced from the addition of a single droplet of sodium hydroxide to a field of extra virgin olive oil.

The centre of the page is time zero, and concentric circles radiating out from this centre represent an exponentially decreasing series of time intervals. This logarithmically decreasing function encapsulates the intense self-organizing activity that happens early on in the chemical reaction, which falls off rapidly with the passage of time. An estimated ninety percent of chemical activity is completed within five minutes, although individual droplets have been active as long as an hour after their 'genesis'.

A Fibonacci spiral of complexity also radiates from time zero as a pathway that indicates the enriched organization of matter, which also, like the number of events that pass with time, is most concentrated around time's origin and is progressively less complex as time unfolds. 'Complexity' is innate to the evolving system and is not something that is acquired from external sources, although when droplets start to interact, phase changes in the degree of complexity may occur periodically and unpredictably. Interactions between individual agents occur as a function of time and appear along the complexity spiral, and disruptions in the evolutionary topology of the Bütschli droplets are indicated by tangents that intersect the fundamental vectors (concentric circles of logarithmically decreasing time intervals and spiral increases in complexity), which represent the progression of the system.



Images by Rachel Armstrong.
Topology diagram by Rachel Armstrong & Organs Everywhere.



A SHORT STORY OF A SHORT LIFE

RACHEL ARMSTRONG

Women don't work in artificial life as they can already make it.
Bruce Damer, guest speaker at the British Computer Society in London on July 11, 2008.

The tiny droplet crawled almost imperceptibly over the base of the petri dish. Rendell Stone wondered just how long she had now been watching it through the microscope lens. These droplets were a couple of millimetres big and extremely simple, being made from an emulsion of oil, water and an alkaline salt. When the initial chemical field broke up, this simple combination gave rise to an extraordinary result: droplets that exhibited life-like behaviour. Admittedly, the apparent vitality of the system was relatively limited, but the droplets had an uncanny character and were able to move around their environment. The constantly squirming fluid beads could seemingly 'sense' their surroundings by following invisible trails of unidentified chemicals in the medium. When they collided, they exchanged a strange kind of 'kissing' action. Usually the rather gregarious and somewhat affectionate beads of fluid had a life span of several minutes. When she was at the microscope, though, Rendell felt as if she had been observing them for hours, intruding upon their limited, private existence. Should she be disturbing them?

'Pull yourself together! This is a science experiment!' she muttered, irked that the compelling and rather 'familiar' behaviours of the droplets had somehow disarmed her objectivity. She reminded herself that these so-called 'life-like' properties could be explained using the language of fluid dynamics and principles of self-assembly. It was no use. The droplets gleamed personality back at her no matter how hard she tried thinking about them in 'simple' material terms. Sighing, Rendell realised that she had missed the droplet she had been tracking. Droplets could be surprisingly tricky to follow, and when they began to shed a crystal 'skin' they had a tendency to suddenly speed up—which was another one of those endearing life-like properties they exhibited. This transformation was rather characteristic, causing the agent to change from a spherical to a 'tadpole-like' configuration. After a short, systematic search, Rendell returned the droplet to the field of view, where it was still heaving and pushing its way to an unknown destination. This time it was moving with a 'swimming' action caused by the addition of a 'tail,' which made the whole complex sway from side to side. For a fleeting moment, Rendell wondered how she knew that she had retrieved the 'right' droplet, but grew distracted by a conversation about lunch that was taking place in the corridor. Now she wished she had been content to let it disappear from view. As the tiny tail-bearing prodigal bead of fluid glittered and pulsed at her through the lens, she grew impatient at its persistence and decided to follow the fading voices before she perished first from lack of food. She left the digital video recording system 'on' to capture the droplet's demise and trailed the others down to the canteen.

'Hey Rendell! How's it going?

'I've been watching droplets travel around a Petri dish.'

'That sounds like science! You're only doing real science when it's tedious or if it doesn't work!'

'I'm having a great day then!

The laboratory was on the first floor by an open courtyard where most of her colleagues went to light up cigarettes after lunch. On returning to the microscope, she could smell the smoke filtering its way through a leaky window seal. She drew the curtain around the microscope to keep out the brightening sunlight and prevent the fumes from 'poisoning' her experiments. Rendell decided to save the movie file that had been left running during lunch before the computer ran out of disc space. She hadn't considered there was anything unusual about the abandoned droplet, but as she glanced into the viewer she was surprised to see the droplet still throbbing at the centre of her field of view. Its tail had expanded so much that it now resembled a barnacle shell and was anchored to the bottom of the Petri dish. Rendell stared through the viewer waiting for the droplet to stop pulsing whilst the files were loading and converting. The droplet's oscillations appeared less frequent and vigorous than before, so Rendell concluded that the changeling droplet would soon 'die'.

It didn't. The tiny droplet continued to glare back at her, defiantly moving in its new casing, slightly but regularly as if quietly 'breathing'.

Rendell glanced at the clock on the wall, which appeared to be holding its bored institutional face despairingly in its hands. A couple of hours must have passed since the start of her experiment—she thought wishing she had made a proper note of the time. It took another twenty minutes for the movie that she'd taken during lunchtime to render. When the software finally stopped spitting out lines of 'dots' that promised a calculation was 'in progress,' she started the camera recording again and went to find her supervisor.

'Do you have a moment?'

Massimo Hyundai's back was visible through the open door of his study. She was aware that her supervisor had developed a protective mechanism against persistent interruptions by students. He simply did not acknowledge them. Determined to secure a second opinion, Rendell took several loud steps into his room, and tried a different approach.

'Would you recognise synthetic 'life' if you saw it, sir?'

Massimo's back drew a deep breath and spun around in a chair that turned twice, once at the pivot under its seat and again on the wheeled base. He leant forward. 'Would you?' he challenged.

'I'm not sure! But I'd like your opinion on something. I'm chewing up lots of disc space making a recording of a droplet that just won't … well … die!'

Massimo laughed. 'Are you telling me that you've already created life in the lab from scratch?'

'Well. I don't think I 'created' it! The system assembled itself and I've been observing it for hours now. This particular chemical system is usually completely spent after ten minutes so I know what is happening is out of the ordinary!'

'Okay! Now that I am interrupted, let me take a look!'

Rendell picked up a pace on her return to the microscope bench. Although she'd spent most of the day wishing that the tediously persistent droplet would stop moving, she was now concerned that all she might have to show Massimo would be inert chemistry. She shut her eyes as she approached the viewer, willing the droplet to 'live'. When she finally opened them, she was relieved to find the droplet winking at her right at the centre of the field of view. It was smaller than she remembered and had broken free from its broad based 'shell.' It lazily circled the base of the mineral deposit in a way that reminded Rendell of glimmering fairground goldfish territorially patrolling their plastic bags.

'It's still there! Thank goodness!'

Massimo squinted into the lens and changed the fine adjustment on the eyepiece.

'Mmmmmm!' he observed.

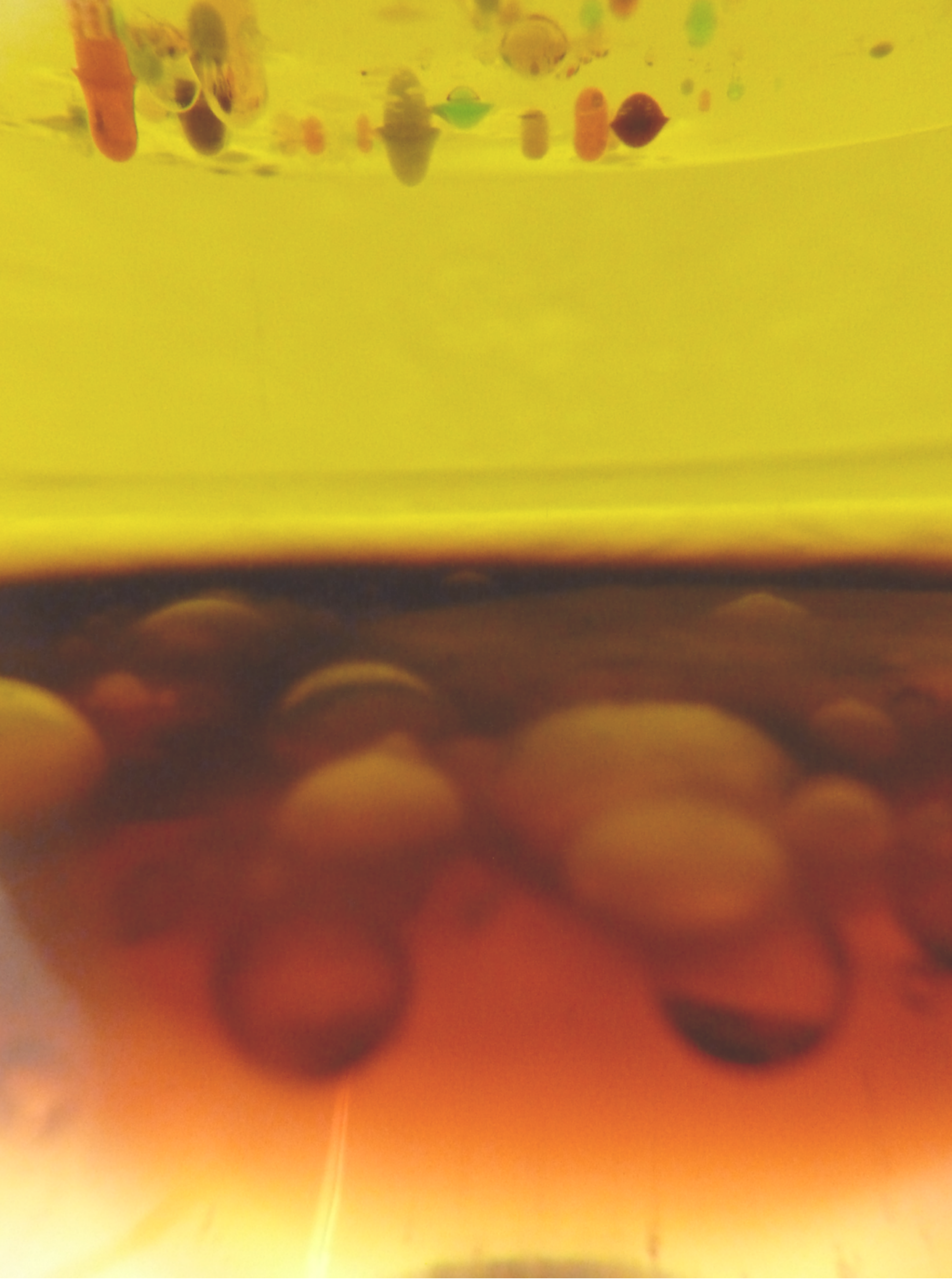
'What do you make of it?' asked Rendell eagerly.

'How long has this been moving for?'

'Around two hours now.'

'Okay. It's hardly 'evolution' but it's interesting. There must be something different about this droplet from the others.' Massimo became engrossed in surveying the details of the Petri dish, deftly moving the fine focus and microscope stage.

'How could I measure its difference?' Asked Rendell.



'Well, that's the problem. What exactly is it about 'life' that is worth measuring?' Massimo muttered as he studied the mineral traces.

'It's …' Rendell paused, realizing that she hadn't thought that particular issue through. She needed to.

Massimo continued. 'The next problem is that the techniques we use to measure 'life' in science require us to 'kill' and process first.' His hand momentarily splayed whilst he appeared to be taking note of something.

'But the chemistry of the system must change when it is killed!' objected Rendell.

'Correct!' Massimo added changing a lens setting.

Rendell rolled her eyes in exasperation. 'So what should I do?'

Massimo smiled and tilted his head thoughtfully. 'Well, if I were you, I wouldn't rush to make any measurements. Not until you really know what you're looking at. Why don't you start at the beginning?' He returned the microscope back to the magnification setting that Rendell had been working with.

Rendell was puzzled. 'The beginning of what?'

Massimo stood up straight and stretched his back. 'The beginning of scientific experiment, of course! You must establish what you're doing by trying to prove yourself wrong. If you fail to prove yourself wrong, you'll be right!'

Rendell hated these riddles and wanted clarity. Annoyed by his apparent equivocation she demanded practicality, 'So, how do I do that?'

Massimo's back replied. 'Oh, for example, you need to be sure that the movement you are seeing isn't due to mixing of the oil and water layers under the heat of the microscope lamp. You also need to prove that airflow across the surface of the fluid isn't causing the droplet to move.'

Rendell sighed deeply. She wanted to ask her supervisor that if 'life' wasn't something that could be objectively 'measured,' then what was the point of taking these ridiculous 'control' measures in the first place? Instead she inquired, 'So, what should I use?'

The back was already leaving as it announced, 'you'll figure that one out yourself! I have a grant proposal to write. Keep me posted!'

Realizing that the camera had been left recording all this time, Rendell decided to save the data and started to convert the file so that it could be exported. At least this would release some working memory on the scratch disc whilst she figured out what to do next. Peering into the viewer, she noticed that the droplet was weak and almost stationary. Yet it continued to throb at the foot of the shell-like deposit it had grown earlier in the day. If it had been 'alive' then she might have described it as being 'exhausted'.

Where on earth could she find a suitable marker to follow through on Massimo's suggestion?

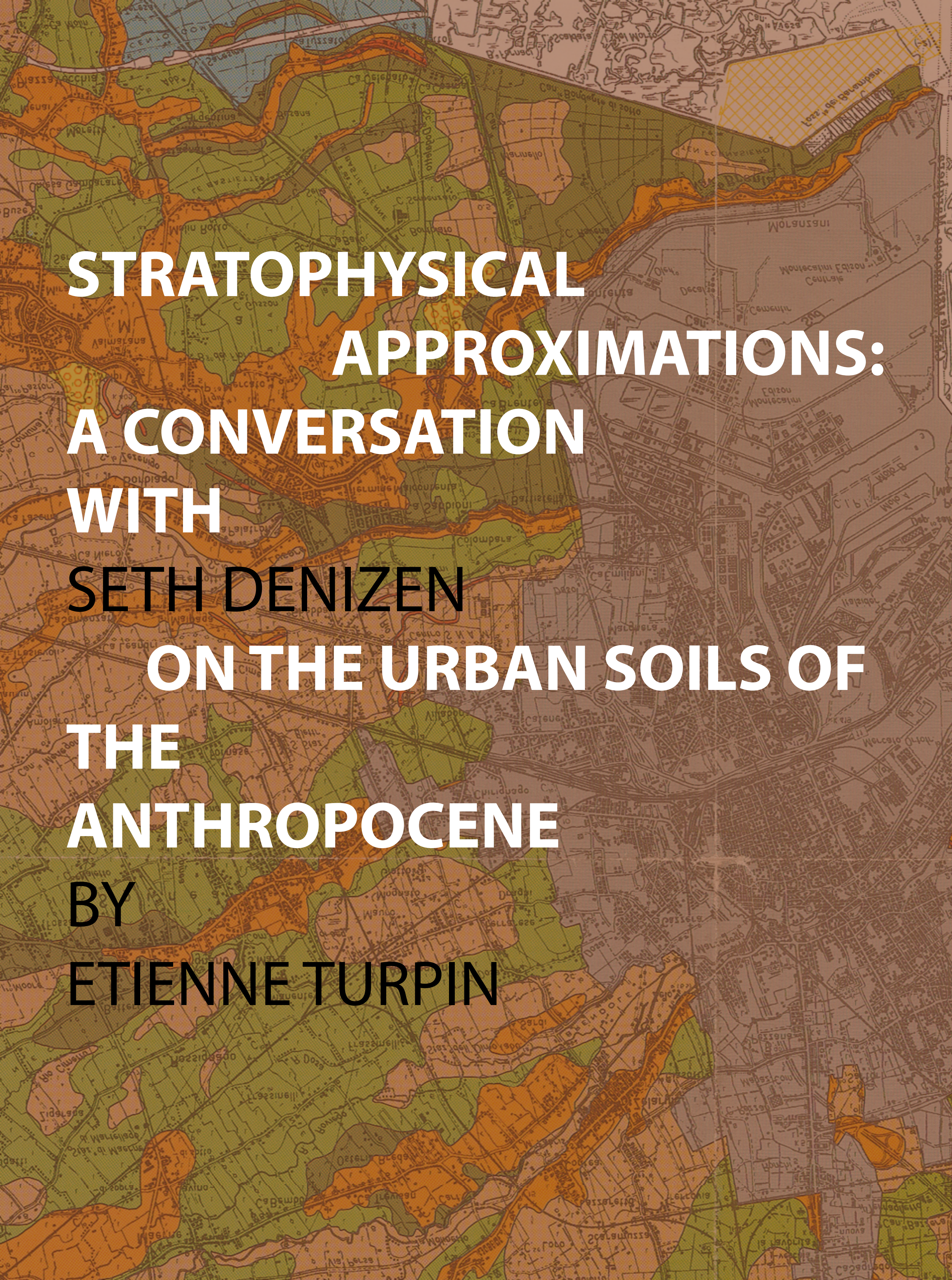
Golden afternoon rays started to lick their way across the microscope bench. Rendell wandered over to the window and stared down into the courtyard, where a group of smokers were huddled around a door that opened out to the courtyard. The sunshine created a false impression of warmth on this late autumnal day, as it seemed that the smokers were trying to protect their cigarettes from being extinguished by the wind. A burst of dandelion seeds was stirred upwards past the window, where a few of them settled for several moments before being hurried on again by the wind. Rendell realized that these seeds would be a perfect indicator for any airflow taking place on the surface of the liquid, and she raced outside to try and catch one. Although there were many weeds between the cracks in the concrete, scattered throughout the poorly tended courtyard, the task of gathering seeds was not so easy since none of the dandelion clocks appeared to be ripe enough to pluck a supply from. Rendell finally secured a fluffy parachuting seed that was trapped by the roughness of a wall in one corner of the quad. Approaching it carefully she pounced, and triumphantly brought the precious structure back to the lab.

She placed the downy seed on the surface of the liquid, where it floated like a water boatman. But when she looked for the droplet under the microscope viewer, it was nowhere to be seen. She tried a systematic search, hoping that she'd just misplaced the droplet, but only found trails of crystal skins. Rendell anxiously scanned the Petri dish hoping that the droplet had strayed. She wanted the droplet to have found new energy as part of its series of strange transformations, but although she looked repeatedly, the Petri dish was barren.

Oddly shaken by the loss of her 'pet' droplet, Rendell searched for evidence in the video footage that she had just taken. Sadly, this suggested that the droplet had turned into a tiny crystal skin deposit. Rendell stared at the enlightening frames in disbelief that such a stubborn entity could ever be extinguished. The dynamic, pulsing, winking droplet had gone and had been replaced by a small inert barnacle standing on the foot of a bigger barnacle. There was no sign of anything throbbing or moving.

As Rendell sadly cleared away the Petri dish remains wondering what on earth she was going to do next to explore those questions that currently beset her, she overlooked, on the underside of the microscope platform, a tiny, winking droplet that was tethered like a barnacle by a shiny crystal skin.

Images by Rachel Armstrong



STRATOPHYSICAL APPROXIMATIONS: A CONVERSATION WITH SETH DENIZEN ON THE URBAN SOILS OF THE ANTHROPOCENE

BY ETIENNE TURPIN

Introduction

Recent research regarding the significance and consequence of anthropogenic changes to the earth's land, oceans, biosphere and climate have demonstrated that, from a wide range of scientific research positions, it is probable to conclude that humans have entered a new geological epoch, their own. First labeled the Anthropocene by the Dutch chemist Paul Crutzen, the consideration of the merits of the new epoch by the International Commission on Stratigraphy and the International Union of Geological Sciences has started to garner the attention of philosophers, artists and designers, legal scholars, as well as an increasing number of researchers from a range of scientific backgrounds. Recently, I curated the symposium, *The Geologic Turn: Architecture's New Alliance*, as a way of bringing architects and landscape architects more thoroughly into this conversation.[1] Among the participants invited for the symposium, the landscape architect Seth Denizen brought up several key issues regarding the relationship between evidence, design, and taxonomy that arose from his recent research.[2] Following an invitation from *Organs Everywhere* editor Simone Ferracina to contribute to this issue, I asked Seth to have a conversation that would further explain his recent project, *The Eighth Approximation*, as well as its relationship to the history of land use practices, and its orientation among other research on the Anthropocene. What follows is a transcript of our conversation, conducted in August, 2012.

Stratophysical Approximations

ET Your recent thesis, *The Eighth Approximation*, was completed at the University of Virginia as part of your Master of Landscape Architecture. Can you explain where this research came from and why it is the "eighth" in a series?

SD The thesis was called *The Eighth Approximation: Urban Soil in the Anthropocene*, and this is what I imagine to be the unwritten update to the *Seventh Approximation*, which was published by the United States Department of Agriculture (USDA) in 1960.[Fig. 1] When it was published in the 1960's it was a radical new approach to classifying soils, that came from twenty years of work published as "approximations." Now it's become the dominant methodology for classifying soils around the world.

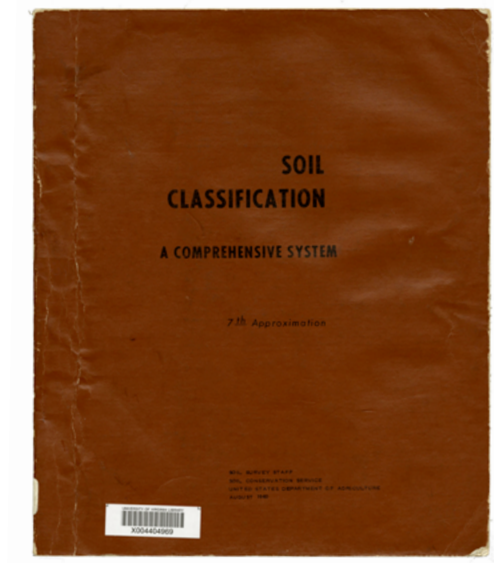


Fig.1 The well worn copy of the *Seventh Approximation* from the University of Virginia Library.

ET When did the USDA begin approximating soil with their new taxonomy? Was this following the dust bowl in the US?

SD There's a helpful timeline on my website.[3] The *Seventh Approximation* was not released until 1960, but certainly the dust bowl caused a major reassessment of our understanding of soils. Basically, you have Milton Whitney in 1909, George Nelson Coffey in 1912, and Curtis F. Marbut in 1927, all putting together schemes for soil classification, with the Marbut scheme being the most genetic of them. Significantly, Marbut read Russian, and he was reading the publications of the Dokuchaev school, named after Vasily Dokuchaev, a Russian geologist who is credited with founding the discipline of soil science in the 1860's and 70's.

Dokuchaev basically begins the entire discipline of soil science by describing soil as a body, in the biological sense of a whole, a body with organs. You can imagine that before Dokuchaev, soil was really understood as just inert stuff that came from rocks.

Agricultural Imperatives

ET Even in the Italian geologist Antonio Stoppani's 1873 argument for the Anthropozoic, among his comprehensive accounts of human activity on earth, he remains convinced of the pure virtues of "mother earth," who opens herself, or is opened by man, to receive the gifts of agriculture.[4] What is it that gives rise to these more speculative concerns about soil in Dokuchaev's work?

SD Agriculture. It was a moment at which the science of growing food was important and becoming increasingly important. If you start to look at soil from the point of view of agriculture, you realize quite quickly that some soils are better than others, and when you apply the knowledge and disciplinary training of a geologist in the 1860s to this problem, you realize that soils don't just appear *ex nihilo*. What makes soils rich and fertile for agriculture is actually the living things in the soil, and this led Dokuchaev to the idea of soil as a kind of body, which is an understanding with an important consequence: all of the complex differentiations, and all the distributions of matter in the soil, and all the irreconcilable differences that appear in the soil profile, in the layers that have nothing to do with each other, can be understood as one thing—all of this is soil—and it is one thing because it is found in other places, it is repeatable, and thus, the "soil body" can become the basis for a taxonomic classification.

ET So, is there also, in addition to this geological line, a biological line that enters the discourse, where the microbiology of the soil puts life to work and begins to capitalize on this realization? A biological line that wants to tap a kind of internal vitality to maximize and standardize, not just inert stuff, but as a body to be worked on?

SD Yes, soil begins to be seen as a kind of standing reserve.[5]

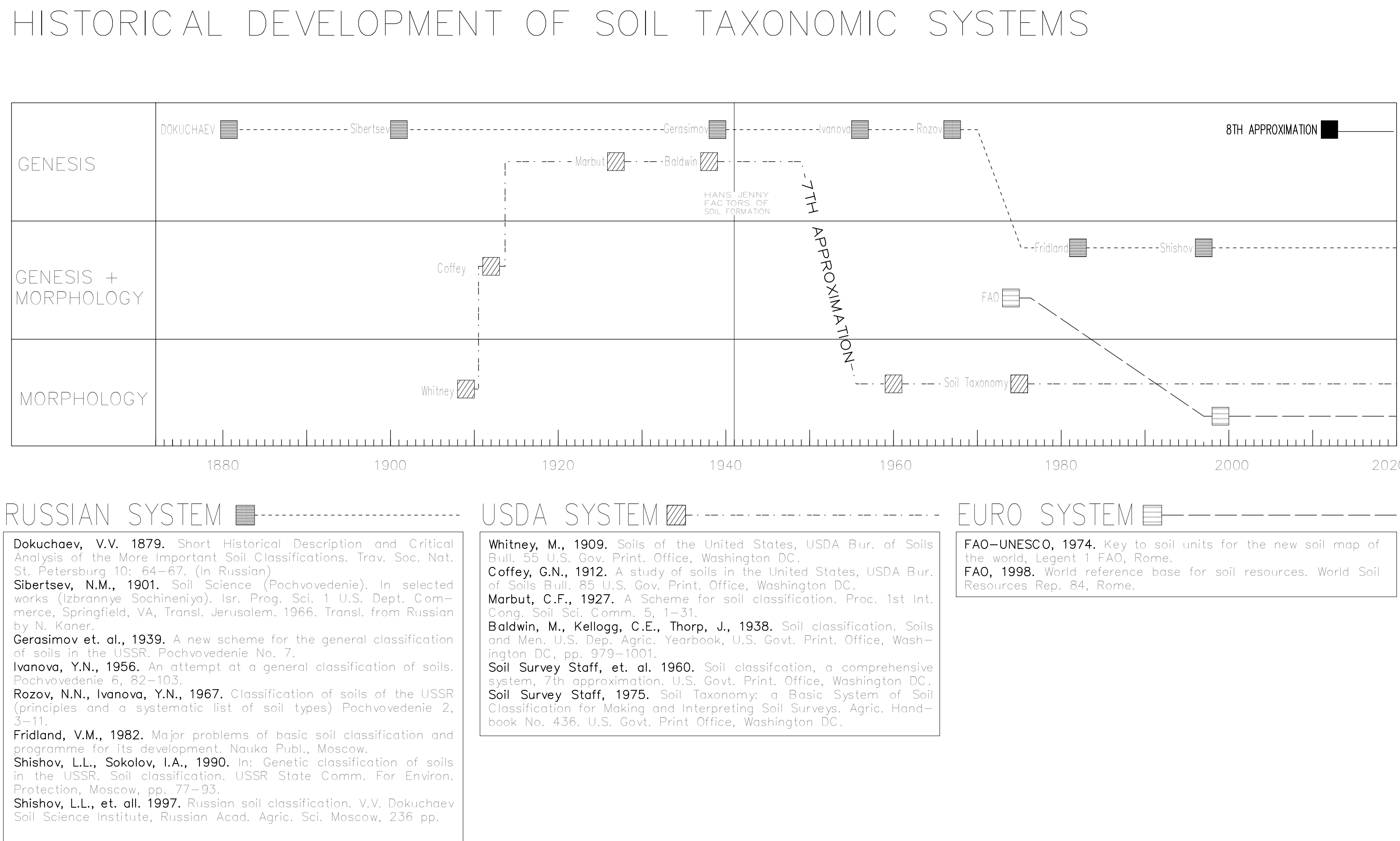
ET How does this compare to the previous systems of soil classification? Your research develops a comparison to these previous systems as a means to show some of the limits and the ways in which your project attempts to overcome them. Can you start by explaining the history of these other systems of soil classification?

Early Soil Classifications

SD Previous systems of soil classification can be differentiated into three groups, with two poles: genetic taxonomies, morphological taxonomies, and a mix of both.[Fig. 2] Dokuchaev, as a geologist, creates a taxonomy of soils that is genetic; that is, when you ask, "what is a soil?", the answer is always, "where did it come from?" This requires that you know where a soil came from in order to classify it—you have to know your geology. So while Dokuchaev understands soil as a living thing, and not just the residue of rocks, his taxonomy of this body is still based on the observation that certain rocks produce certain soils. It's a phylogenetic move, in the same way that what makes dolphins distinct from fish is not their ecology, it's that they used to be a kind of deer. The system is actually pretty convincing. If you look at the geological map of any country, or, even more specific to my research, if you look at the geological map of Virginia, and you overlay it with the soils map, it is almost identical. At the scale of a state, the difference between soil and rock does not really exist: in Virginia, you have Triassic basins that map to the soil survey perfectly. The problem with this is that you end up with a taxonomy in which every soil classification becomes an argument about geology, or geological history, and this leads to any number of differences of opinion on how to classify a soil.

ET The origins that the soil expresses are not necessarily agreed upon?

SD Exactly, because geology is in a state of constant revision. The history of the earth is constantly being revised. This seemed like a problem for geologists and soil scientists, at least in the U.S., up until the dust bowl. Then, you had the dust bowl, and what we realized is that this is not a problem for geologists and soil scientists, this is



Source: Bockheim, J.G., Gennadiyev, A.N., 2000. The role of soil-forming processes in the definition of taxa in Soil Taxonomy and the World Soil Reference Base. Geoderma 95 (2000) 53-72.

Fig. 2 All major contemporary soil taxonomies that classify at a global rather than local scale tend towards morphological descriptions.

a problem for everyone! The major, fundamental misunderstanding about soil in the dust bowl was the role played by the living things in a soil that are required to keep the soil in place. There is a critical threshold after which the soil becomes extremely fine and particulate, and at that moment it is carried away by the wind with relatively little force. So, from that point on, all subsequent understandings of soil will focus on how soil forms clumps, basically. They are called "peds," and there are multiple important scales to consider when you want to prevent soil from becoming a microscopic clay particle that can be blown across the country.

ET So by the end of the dust bowl, the loss of topsoil had reached nearly a billion tons.[6] It was just blown away—and it wouldn't be easy to replace! So the goal of soil science becomes how to deter, urgently, the processes that allowed this to happen.

SD Exactly, because an inch of topsoil can take five hundred years to form, so the soil that is lost is not easily replaced. It is a catastrophic moment, and, in fact, we are still in that moment. There are some pretty dark statistics about top soil loss worldwide.

ET Not least the statistics relating to the current drought in the United States.

SD You can see from Google Earth just what kind of top soil loss we are taking about. Take Panama, for example. If you look at high quality satellite images, you can see the top soil literally shooting into the ocean. This is due to land use practices, and the lack of understanding of how to keep a soil in place through fairly complicated processes.

ET The drought, when it ended in 1939, was brutal enough to generate concerns about how to prevent that level of damage from happening again, but is there really a concern about the practices, or the causes of it? I can't really speculate on this, but, presumably, the extensive use of fertilizers and pesticides, as well as industrial crop production, suggest that we do know why, in part at least, it happened, but we continue to aggravate the soil nonetheless. We just add greater compensatory techniques of management and control, don't we?

Technical Responses for Continuous Growth

SD It was not a total mystery why this was happening. If you look at some of the documentation I have put together from the Library of Congress, you can see that some of the things the USDA was doing to educate farmers about soil contain striking images that argue for the use of new techniques, for example, the planting of rows of trees to help fight wind erosion.**Fig. 3** The USDA also introduced techniques like plowing on the contour, so, instead of just plowing a grid on a field, farmers were taught to follow the topographic contour with the tractor, so when water hits the top of the hillside on your land, it doesn't just shoot down the rows of planting, but is slowed by successive terraces of crop rows. This was another important aspect of the USDA educational campaigns. **Fig. 4**

ET The Walker Evan's photographs you have identified in *Soil and Shelter* are also quite amazing, but I want to return to the question of industrialization. The development of the McCormick Reaper in the late 19th century had an incredible influence, even though it remained a horse-drawn technology. But the tractor introduces an important, unprecedented new feedback; that is, the ability to collect more crops on a given farm means we can also try to grow more as well. The technological demand for increasing yield is also about the capacity for harvesting. So, while the response to the dust bowl is the USDA's implementation of these educational means, new means to reduce erosion were also competing with technological advances …

SD … But, this also meant that agriculture is now a question of national security. It always was, to an extent, but after the dust bowl there was a whole new emphasis that went all the way from the farm to the academy.

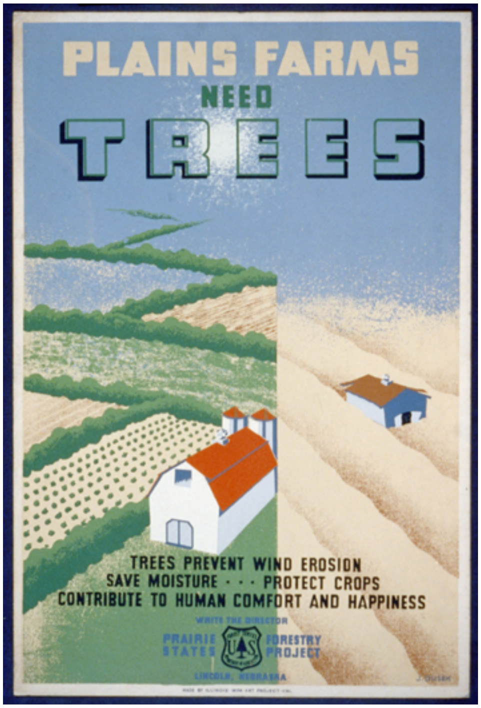


Fig. 3 Plains farms need trees, J. Dusek, 1936-1940.

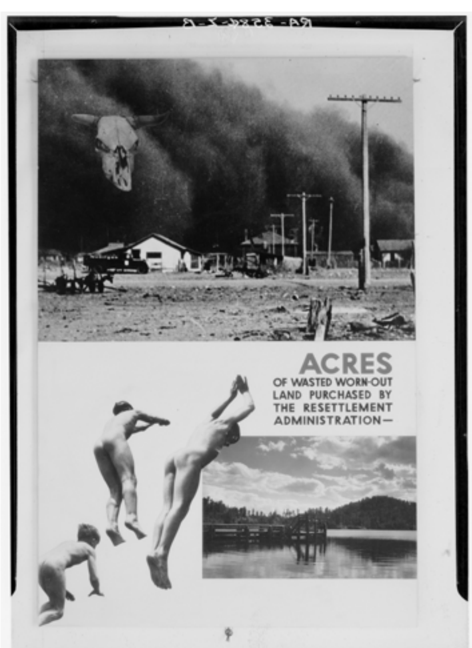


Fig. 4 Soil and Shelter exhibit, US Resettlement Administration, 1936.

ET And this is why John Gerrard and Michael Morris talk about the fight to secure nitrogen reserves in South America so that Britain and America can ensure that they can grow more food. The question of national security is also a question of the attendant chemical resources that go into these practices.[7]

SD Floyd Bennett Field, a specific site of my research, was the place in New York City where horses were being boiled for nitrogen, which took place at least until 1905. When New York was a horse-powered city, what is now Floyd Bennett Field was a site for the production of nitrogen fertilizer for agriculture. So, the kinds of economies that developed around these rural concerns were also very urban because every major city in the US had factories that were transforming biological waste into fertilizer.

We should add here as well that the immensity of the change that is made possible by the Haber-Bosch process is usually quite understated. You have to realize that for the last billion years there has been a tendency for nitrogen to become an inert, atmospheric, biologically-unavailable gas through the metabolic processes that defined life on earth. The technology to produce the reverse reaction was held only by bacteria. Only bacteria had the Haber-Bosch process.

ET Which is quite significant in light of the biologist E.O. Wilson's comment that human beings, in the Anthropocene, have reached a rate of biological reproduction that is more bacterial than primate. It is precisely by fixing nitrogen through the Haber-Bosch process that begins the asymptotic ascendency of the so-called "great acceleration" following WWII.[8]

SD This is a much better way of clarifying what Wilson meant. We are not talking about the division of cells here; we are talking about a reorganization of the world's resources to support an extremely energetically-costly reproduction model, which is a whole other thing.

Redefining Soils

<u>ET</u> So, we have these precarious but somewhat stable processes that allow us to increase production. We have faith in these processes to continue to produce for us, but what does this do in terms of taxonomies of soil?

<u>SD</u> The question is: "how are soils formed?" With the dust bowl, what we have is soil blowing away, but what is really happening? We can say that soil is ceasing to be soil, soil is dying and becoming rock, particulate rock, and blowing away. There is a very famous soil scientist named Hans Jenny who created the five factors of soil formation. For him, there are five things that make soil: climate, organisms, relief, parent material (i.e. rocks), and time. This was, and still is, the best description of what a soil is, although it has one key problem for soil science: it is unquantifiable. Although Jenny was trying to create very qualitative equations with very strange conversion factors and arbitrary multipliers that could quantify each of these five things—you would get a number that was supposed to mean something very precise about soil formation—this was useless because it was far too arbitrary. Interestingly, it was Jenny that was responsible for introducing the vocabulary of "approximations" into soil taxonomy. Jenny was still giving a genetic account that tried to show what formed a soil, but instead, the USDA tried to rethink the taxonomy altogether. Rather than asking how a soil was formed, or, like Dokuchaev, where it came from, they started to describe soils in terms of pure morphology. At this point, it did not matter where the soil came from, or what happened to it for the purposes of taxonomy. Instead, the USDA boasted, after the release of their *Seventh Approximation*, that they could parachute a USDA soil scientist blindfolded into an area, and armed with only a pick ax and rudimentary tools, that scientist would be able to accurately classify any soil according to this new taxonomy.

This is also where the chemistry of soil becomes the description of soil—it is pure chemical morphology, and the chemistry that is most important for classification comes from the chemistry of plants. But, if you are wondering about history you have to realize that the USDA is approaching this from another angle. Once you have the morphological description, they believe you will be able to see in that description the historical reality. History is not exactly given up—trends and patterns in soil classification certainly require genetic explanations, so they are not throwing out the genetic—but the only taxonomic features under consideration for the Seventh Approximation are morphological.

Towards An Anthropogenic Approximation

<u>ET</u> So, given that there is still an explanatory value that leads to the genetic, what is the role of the *Eight Approximation*? Was the *Seventh Approximation* just an epistemological trade-off that favored the morphological? How does your project act as a corrective to this?

<u>SD</u> There is an important implication that we need to discuss first. A morphological taxonomy is essentially forced to assume that there are no humans on that planet, or at least that they are the exception rather than the rule. Admittedly, the *Seventh Approximation* did have certain taxonomic groups that dealt with the impact of agriculture on the soil, things like if your plow is a foot and a half deep, you will get a hard, compacted pan a foot and a half deep, etc. They were sensitive to that.

But, essentially, to identify a soil that has a very complex morphology—it's got seven distinct layers down to the regolith—and take all the difference and distinction that has taken thousands of years and collapse it into a single taxonomic category … well, how can you do that? Because you can say that the same things happened to all these soils, as they all experience the same chemical history. Basically, this USDA taxonomy has a tremendous utility when we are talking about undisturbed, or relatively undisturbed soils because you have hundreds or thousands of years of history intact to solidify your taxonomic system

—a thousand years of climate, a thousand years of time, a thousand years of organisms, have acted uniformly on a soil body. According to this taxonomy, you must rely on that consistency for the system to work. The result is that when you look at soil surveys, even today, you still find these very strange dark holes in the maps, drawn along very sharp boundaries, which correspond to the city limit.

You are looking at an immense project—to survey every soil in the continental US— that has taken much of the last century to complete, and you realize that every single city on the USDA survey is just a void. So, my project began with the question, while looking at these maps, of *what is in there*? Surely, the soil doesn't stop; surely there is soil there where the city begins. This is especially apparent when looking at, for example, the soil survey of Venice. In Venice, you see this incredible, immaculate system of rivers that produced the Venetian lagoon, and every time they flood they deposit very particular sediments depending on the very particular geological origins of the rivers, and so you have this beautiful soil survey of fingered, sprawling difference, with soil from all over the Veneto and all over the Italian Alps, and then you see that there is a dark hole, where all the rivers enter the lagoon, as if history ends at the periphery of the urban settlement of Venice. **Fig. 5** You can also see in the soil survey a millennium's work of forcibly redirecting the rivers that enter the lagoon, so there are soils that exist from deposition where there is no longer a river, but you still see where they were. But, what we have on the soil map is a void, an absence … nothing. The question my research asks is simple: *what's there*?

ET What is in the void of the map? But first, as a quick aside, are these voids there because soil science has always been marshaled toward building new farms or developing farmland, and the imperial expansion of agriculture into the hinterland? And, this also begs the question of what soil science is ultimately responsible for, or what it could contribute to other than an expansionist agricultural project.

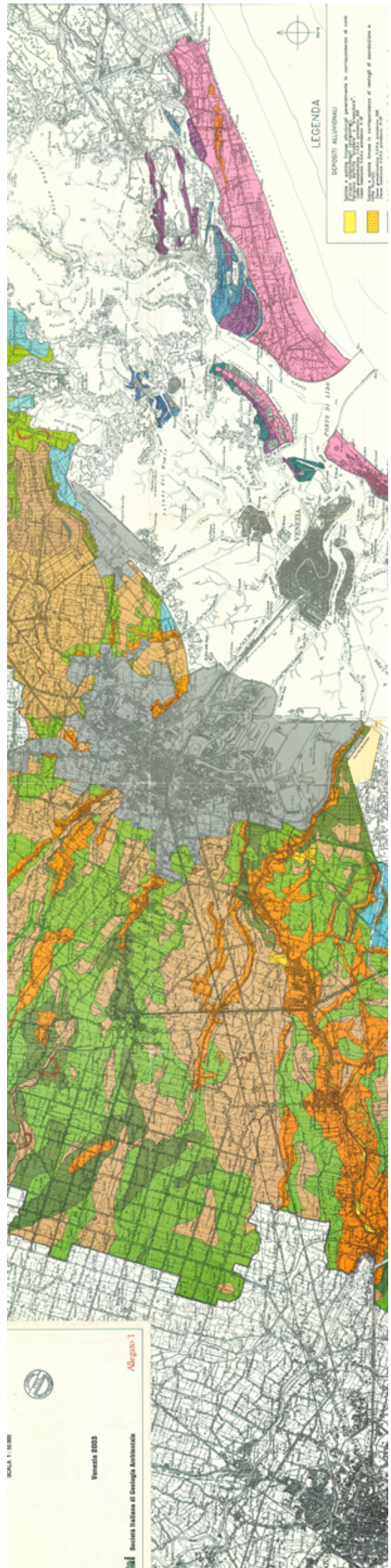


Fig. 5 Soil Survey of Venezia 2003, Società Italiana di Geologia Ambientale.

SD It is important to explain first that the black hole in the map is not just because of an emphasis on agriculture; it is also because the taxonomic system simply doesn't work there. It doesn't work there because the soil has been turned over, basically, and this destroys the system of horizons that is used for this form of classification. Then, of course, a lot of other things happen to the soil of cities: things are added, burned, dumped, and leaked, which have no known effect on the soil. We can specify the effect in terms of pollution, in specific ways, but in terms of the kind of soil that roads or cemeteries make, it is not known, and, it is still in formation. And if we don't know what soil it makes, we don't know how to classify it. So, it is a point at which the USDA taxonomy becomes less useful for classifying soil because it solely operates on morphological properties, and the force behind a morphological classification of soils is the consistency of history that forms the morphologies. Here, in the city, we have a total breakdown of this consistency and history, at the scales of time that it takes for soils for form, and so it becomes very difficult to classify a soil morphologically. What you end up with instead, are engineering taxonomies that specify if a soil is good, or not good, for a specific function, a subway, a road, etc. So, we don't know what it is, we don't know what will happen to it, it's just classified in terms of certain properties related to use. Soil as standing reserve once again.

Soil in the Future of the Anthropocene

ET The absence of temporal consistency is quite interesting for soil science, not least because it repeats, in a way, Stoppani's argument in the *Corso di geologia*, which was basically that although humans have been around for a relatively small amount of time, geologically speaking at least, their impact is epistemologically consequential, or not negligible for science, and this initiates his argument for the introduction of the Anthropozoic as an epoch. So the question of adapting a morphological system to account for an intensive moment that challenges the previous historical consistency is quite important in the longer history of the Anthropocene.[9] How do you work with that in your research?

SD It means that, in the city, history is the organizing force of soil formation. So, the urban condition calls for a return to genetic classification in order to understand the relationship between the soils that we make and the cities that we build. For me, the moment at which you disconnect, in a taxonomy, the relationship between the history of a soil and its morphology you cease to be able to see these in their real relationship. In the *Eighth Approximation*, I am arguing that urban soils call for a return to genetic taxonomies. My thesis was the project to built this taxonomy and see what it would look like.

The system starts with a series of questions.[Fig. 6] The first question, the highest taxonomic level, is: *what was deposited*? This makes a statement that, in a city, all urban soils are the result of a process of deposition. So, in the highest level, we answer the question of the mode of deposition responsible for the material. There are five groups: first, *citified*, or soils which are the result of the deposition of a medium previously available for plant growth, basically stuff which we commonly would recognize as soil, and maybe use in our gardens; second, *gentrified*, or soils which are the result of the deposition of mineral soil or regolith, which basically has no organic matter, or what we think of as non-soil, like mined rock or asphalt; third, *commodified*, or soils which are the result of the deposition of materials previously subject to a process of manufacture, and this is a category in and of itself because we have to understand the cycle of commodities inherent in the mode of deposition, which means we have to see the cycle of our economy as producing materials that, as waste, are incorporated into the physical fabric of our cities, like garbage, dead bodies, incinerator ash, construction debris, etc.; fourth, *mortified* soils, in which the mode of deposition is removal. This happens when the side of a mountain is scalped, leaving whatever is there underneath to form a soil; and, finally *beatified* soils, which are those soils that are pronounced to be undisturbed. Those are the categories at the highest level, and then beneath that, for example, in the

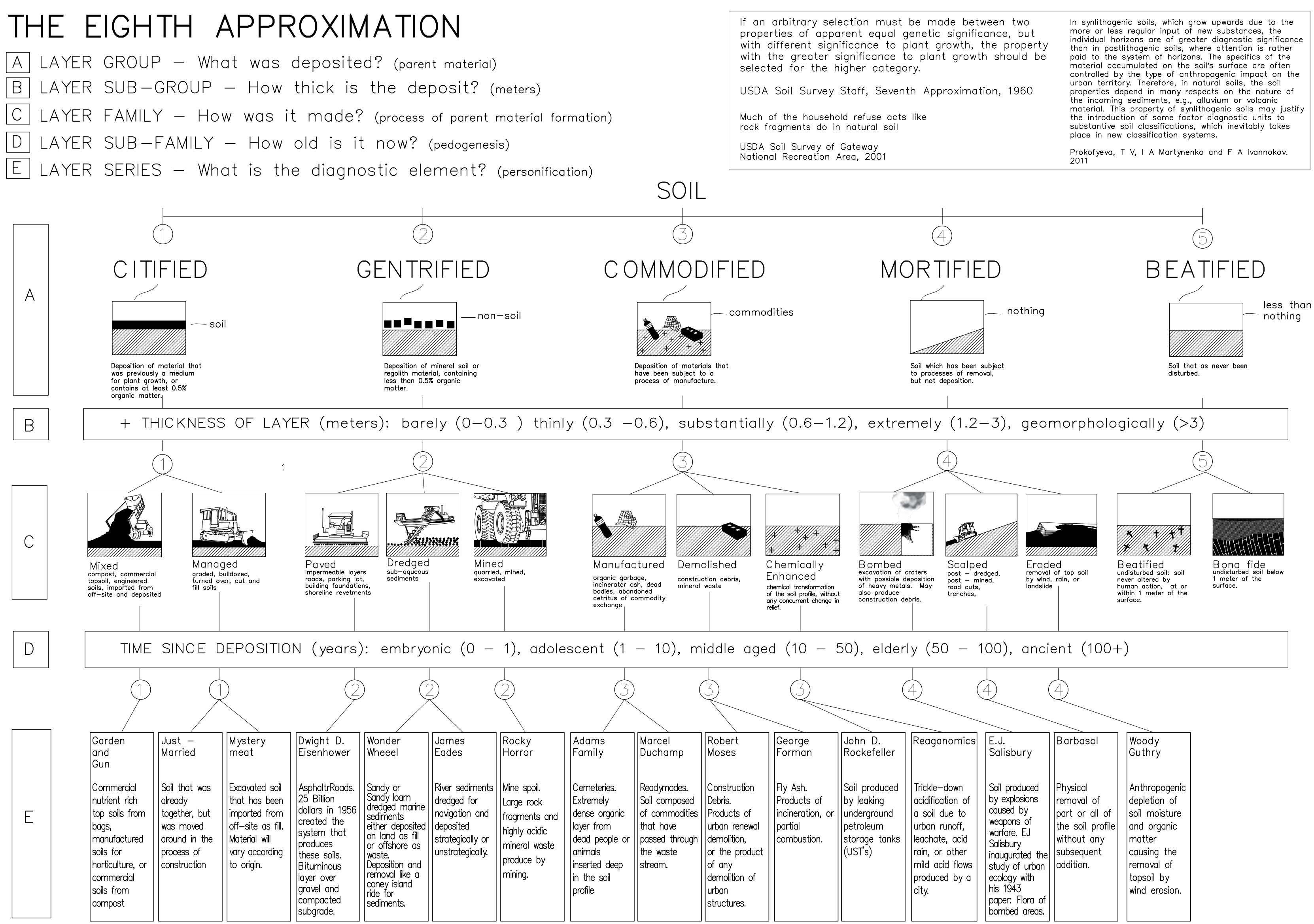


Fig. 6 The Eighth Approximation: Taxonomy of Urban Soils.

commodified category, we have *manufactured* soils, distinguished from cemeteries, which are the deposition of human bodies usually placed below the zone in the profile where aerobic decomposition is possible, accompanied by an assortment of heavy metals in the form of coffins and tooth fillings.[Fig. 7] Also here are the *chemically enhanced* soils, which are entirely intact in their structure, just polluted in some way. So, in the first three levels the taxonomy is identifying the mode of deposition, the thickness of the deposited layer, and the material that was deposited. Finally, at the fourth level you ask, *what is the diagnostic element of this soil*?

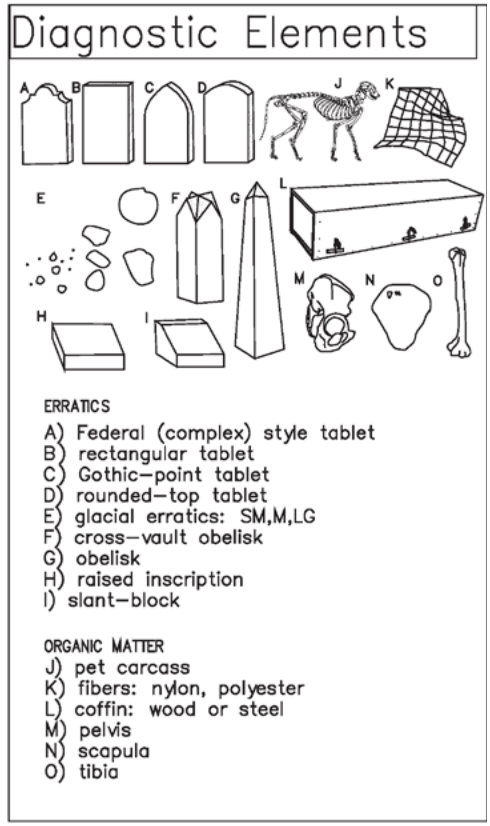


Fig. 7 Soils formed in Cemeteries a.k.a *Commodified* thinly-to-extremely.
Fig. 8 Soil Textural Triangle for Robert Moses.

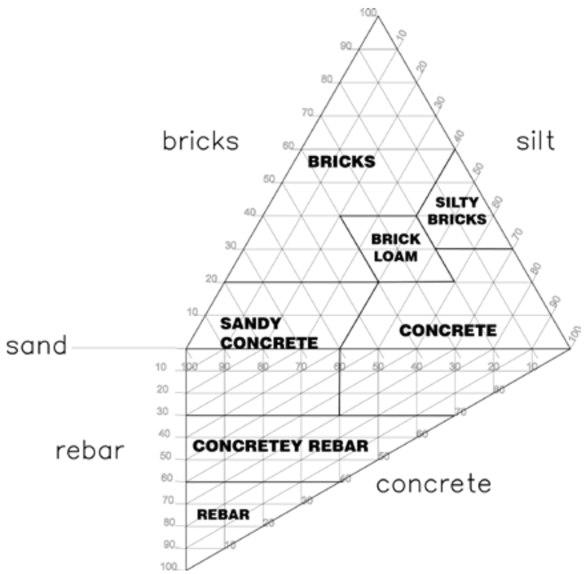
Here, at the fourth level, I have used names that might mean something in the diagnosis, for instance, the paved soil in the *Gentrified* group is called Dwight D. Eisenhower, because Eisenhower created the system that produces these soils, in 1956, with the implementation of the Federal Highway Act. It is a way of personifying the soil that has a certain character. But, at this level, of course, the taxonomy could never be complete because it is connected to the processes of the city, as the city is continually making itself, so at this level the identity would be quite local.

Again, for example, I have a Robert Moses soil in New York City, where this soil is connected to the practices of urbanism implemented by Moses, but in relation to very particular materials connected to their historical and geological past, which is quite local. [Fig. 8] So, I am giving things local names at this lower level of the taxonomy.

ET I'd like to ask about the *chemically-enhanced* designation because it brings up another point we should address. What about the role of drift, or the ways in which the circulation of materials that have been accumulated and disposed create aberrant forms of deposition? Is this addressed in the *Eighth Approximation*?
And, can you speculate on the role of the *Eighth Approximation* for research today? If, in a previous epoch, the USDA and soil science was directed toward agricultural expansion, efficiency, and consistency, in a way that is similar to how the USGS played its role in the development of mineral extraction, what does your research try to do in the context of urban soil that makes it different from the engineering profile of soils?

SD In some ways, the most imperialist thing that early soil scientists did was to define soil according to its function for agriculture. When I am talking about soils that are formed by construction debris and fly ash, it is difficult to get a soil scientist to actually even consider this as a soil, because, in a classical USDA mode, they would insist it is not a soil.

ET There is also an important stratophysical limit of the USDA soil science research, that is, they only concern themselves with the soil to a depth that typical plant life, or, perhaps, consumable plant life, requires for growth and maturation prior to its harvest. It is a kind of 'root-down analysis,' but then, the USGS doesn't concern itself with these layers either, so there is a missing aspect of soil analysis for cities, which is actu-



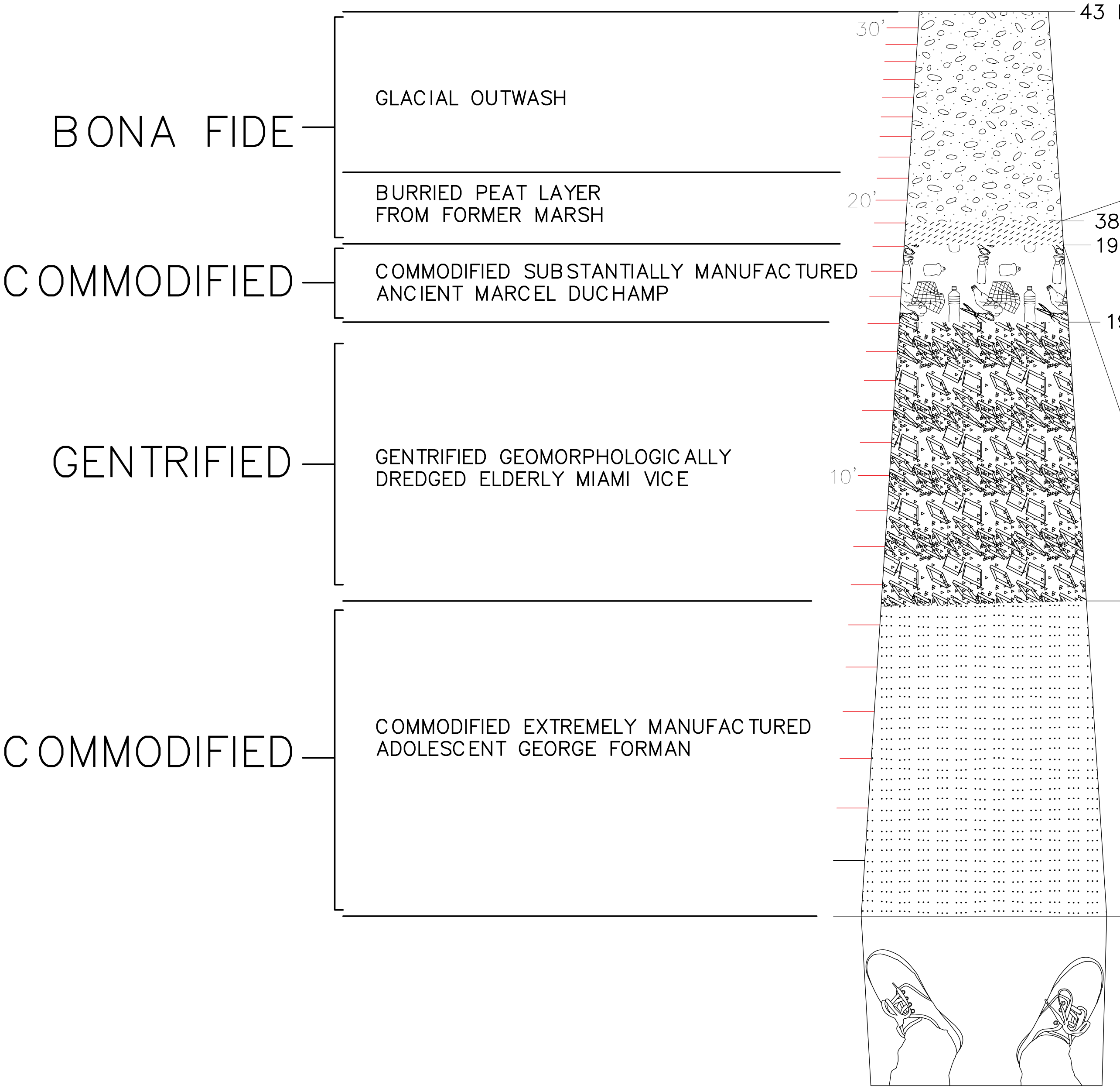
ally where cities really are, given the role of the subterranean infrastructures that constitute large parts of contemporary urbanism.

SD I would also say that plants do grow in these things, and deeper than the USDA is concerned with. Also, the fact is that plants grow in many things the USDA would not consider a soil. You only have to spend a few days in New York to realize that there is all kinds of shit growing out of this stuff! The people whose problem that really becomes, and this is one of the most interesting things that is happening right now, is the National Park Service (NPS). The NPS inherited Floyd Bennett Field as part of the Gateway National Recreation Area, which is made of nothing but dredged sediments, fly ash, WWII bunkers that were used to store warheads, construction debris, and all of the 18th century offal factory waste and dumps that are still clearly discernable layers in the profile.[10] The NPS doesn't have the luxury of saying that this isn't soil because they want to have a nice, pretty park where things grow, and so they need to understand this soil as part of the project of cultivating the park. They are in the position of trying to do the kind of work that the *Eighth Approximation* does, which is to make classifications of these soils. Whereas my taxonomy is trying to create a structure which explicitly links processes of urbanization to soil formation, their taxonomies are more specific and local, and remain morphological in their descriptions. So, the NPS, working with the USDA, will have things like the "Freshkills" series, which is described as containing over 40% fly ash. But, why isn't it just called the "fly ash" series then? I asked a USDA soil scientist responsible for the recent soil survey of New York City where the name "Freshkills" came from and why it was connected to fly ash, and he said that he didn't know. There is also a "Big Apple" series and a "LaGuardia" series, which is vaguely related to the LaGuardia area of New York, but creating these series based on locations in New York isn't very helpful and doesn't work because those soils are also quite diverse. So, the NPS still ends up with arbitrary categories, but, if you read further down into the morphological descriptions, you can find interesting facts that reveal genetic aspects.

ET I know you haven't been in Hong Kong that long, but are you interested in developing your research in new directions in China as well?

SD Land reclamation in Hong Kong is enormous. I am still trying to understand a lot of it myself. I was walking in the middle of the city the other day, really, in the middle of Hong Kong, and I happened upon a historical marker that designated the former coastline. And I looked around—I couldn't see water anywhere, not in any direction! There was no water in sight, and I would have had to walk longer than I would be willing to walk to find it. So, in Hong Kong, you have massive land reclamation composed of both marine and terrestrial sediments, where thousands or even millions of years could separate the geological origins of what is under my left foot and under my right foot, and it is all completely paved over. So, it is a tip of the iceberg indication, what I've been looking at, but the diversity is going to prove to be

SOIL / PROFILE TIME / SPACE



* Rate of peat accumulation = 2cm per 100 years
Source: D. J. Charman (2002) Peatlands and environmental change

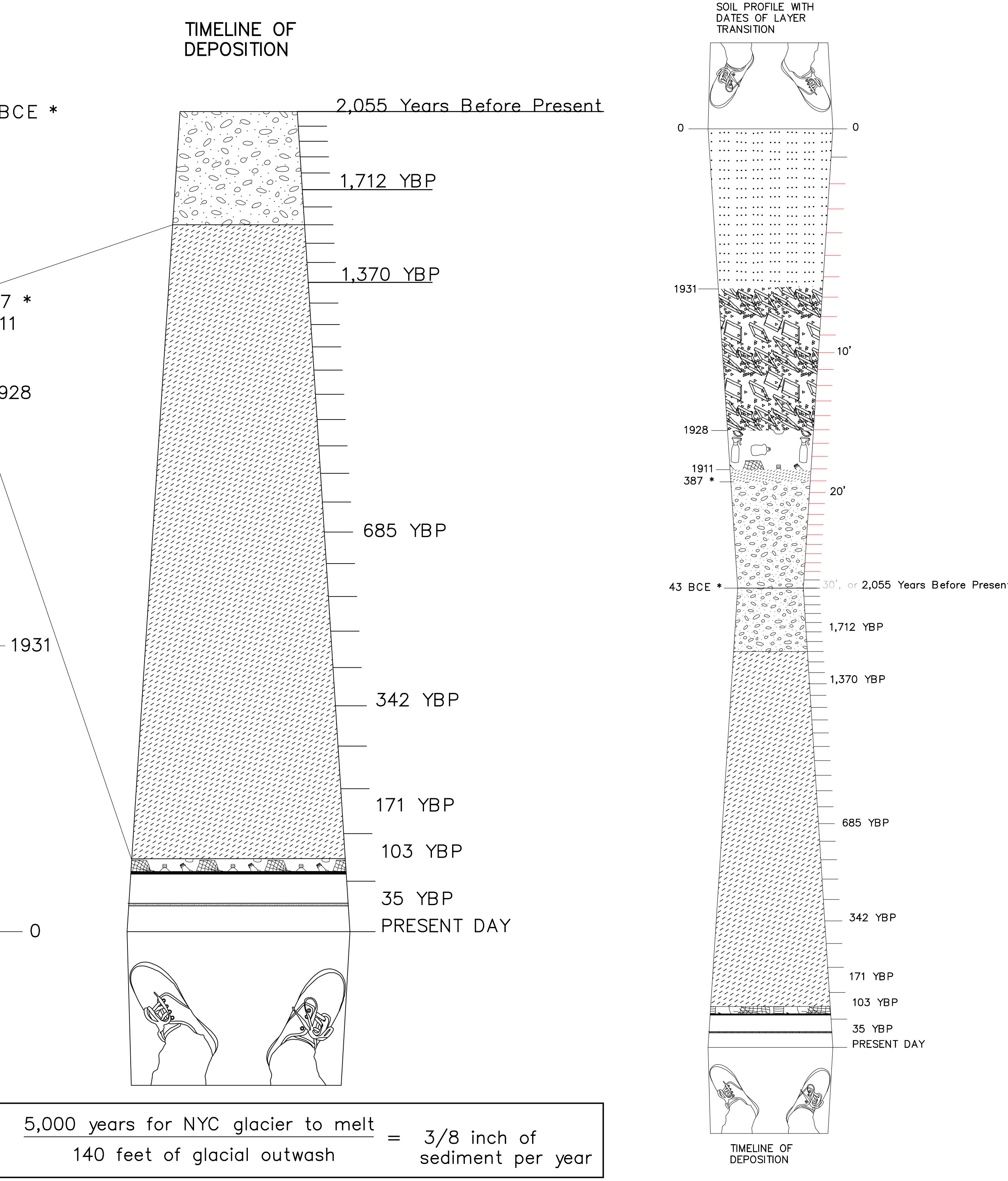


Fig.9 Space and time in a single soil profile from Floyd Bennett Field.

quite astounding because it is all anthropogenic soils that have really disparate material and economic histories.

A New Image of Soil

ET That reminds me, when you mention of the left foot and right foot discrepancy, of the drawings you've developed which always include the human feet, and which are quite important and original, as one type describes the process of deposition spatially, while the other type, its mirror, describes the deposition process temporally.**Fig. 9** Can you explain the motive for your development of these kinds of representational drawings that call attention to both spatial and temporal features of soil?

SD In part, it is a way of emphasizing the breakdown of taxonomic systems that are commonly used to describe these things. Soil formation happens within a particular space and, in the USDA taxonomy, soils are only classified down to six feet below grade. The reason for this is that six feet is the zone where the processes of weathering and soil formation create their most distinctive morphological features, their A, B, C horizons in the soil profile. So, what we start to understand is that embedded in the taxonomy of soils that we are using now is particular spatial imagination of what soil is, and this has to do with the time that it takes for soil to form.

But, in the city, we have the interruption of these processes and the spaces they imply. So, the space of soils is dramatically more than six feet, and the time of soils has nothing to do with that space at all. These are two fundamental violations of the logic of the USDA's *Seventh Approximation* —space and time are really disconnected in the urban soil profile and this is precisely what my work in the *Eighth Approximation* tries to begin to think about.

ET My last question is about the specification of your work in the context of the Anthropocene. I am quite interested in the discourse about the "origin" of the Anthropocene because of the way this speculative conversation brings together questions of paleo-climatology, chemical signatures, oceanography, geochemistry, and all the various means by which the sciences contribute to an understanding of the Anthropocene to suggest diverse and interesting ways of reading, or of learning to read, the impact of aggregate human activity on earth.[11] From a soil science perspective, what is your reading of the Anthropocene?

SD The Anthropocene arrives at the moment we understand that geology is not distinct from human production. It is the same thing that happens when we understand that we are changing the climate of the earth because we are producing a thing called carbon dioxide that has certain effects that create atmospheric conditions that we are going to have to live in. In soil science, it is very clear that we are producing our future conditions. It is at that moment that we can ask questions like, what kind of cities do we want to build? And, what kind of conditions do we want to live in? So, the moment the Anthropocene becomes relevant as a discourse is the moment at which we understand that we are creating fundamental geologic and biological conditions that we will be living with in both the very near and very distant future, and that the decisions we make have to be made in relation to these ethical and political futures of the city.

ET So the real significance of the Anthropocene, for your work, is that before it can ever be read as a geological epoch, it must first pass through its life as soil?

SD There is absolutely nothing of human habitation on the planet that does not, at some point, pass through the soil because, and this is very important to understand, the soil is the filter through which all material production must pass.

Notes:

1. I am currently editing the proceedings of the conference, as well as a number of additional essays, projects, and interviews, for the book *Architecture in the Anthropocene: Encounters Among Design, Deep Time, Science and Philosophy* (MAP Office/MAP Books Publishers, *forthcoming* 2013). The collection argues that the speculative dimension of geological and stratigraphic science implied by the discourse of the Anthropocene offers a productive framework within which design research and practice, theoretical inquiry, and science can collaborate to develop specialized but hybrid practices across disciplinary divisions.

2. See Seth Denizen, "Approximations," in *Architecture in the Anthropocene: Encounters Among Design, Deep Time, Science and Philosophy* (MAP Office/MAP Books Publishers, *forthcoming* 2013). The original lecture is also available online at http://vimeo.com/38107407.

3. http://anthropocenesoil.wordpress.com/.

4. Antonio Stoppani, "A New Force, A New Input, A New Element: Excerpts from the Corso di Geologi," edited by Etienne Turpin and Valeria Federighi, translated by Valeria Federighi, in *Making the Geologic Now*, edited by edited by Jamie Kruse and Liz Ellsworth of Smudge Studio (Punctum Books, *forthcoming* 2013).

5. See Martin Heidegger, "The Question Concerning Technology," in *The Question Concerning Technology and Other Essays*, translated and with an Introduction by William Lovitt (New York and London: Garland Publishing, Inc., 1977), 3-35.

6. John Gerrard and Michael A. Morris, "Corn Bomb: A Short History of Nitrogen 1660-2008," in *Collapse: Philosophical Research and Development*, Issue VII: Culinary Materialism, edited by Reza Negarestani and Robin Mackay (July 2011), 85-118.

7. Ibid.

8. For an analysis of the asymptotic curve of production in the Anthropocene and its aesthetic implications, see Seth Denizen, "Aesthetics of the Anthropocene," in *Scapegoat: Architecture| Landscape | Political Economy*, Vol. 05 – Excess, *forthcoming* July, 2013.

9. Stoppani.

10. Urban Soil of Floyd Bennett Field at 13 orders of magnitude: http://anthropocenesoil.wordpress.com/2012/05/18/film-power-of-ten-eighth-approximation/.

11. See, for example, *Philosophical Transactions of the Royal Society*, A 2011 369, "The Anthropocene: a new epoch of geological time," edited by Jan Zalasiewicz, Mark Williams, Alan Haywood and Michael Ellis.


PLASTIC
(ELECTRO)NOMADIC
HOUSE
SIMONE FERRACINA

We have to foster a desire to live inside which is actually a living with, we have to declare not necessarily emphatically, that 'I want to live inside this monster.' Or to put things a bit strangely, it may be required to 'undomesticate' the house.[1]
Ben Woodard

…humankind should prepare itself for living in a more plastic and nomadic manner….[2]
Slavoj Žižek

The 'home' we inherited from Western culture is a material expression of the clear-cut separation between human beings and non-human life, culture and nature. Its walls bound interior ecologies (objects, memories, climates) predicated on maximum human control—and sheltered from the irrational moods of the biosphere. The very idea of 'homeness' depends on binary oppositional narratives grown out of this division: interior and exterior, private and public, safe and dangerous, clean and dirty, inert and alive, and so on.
But what happens to 'home' when the boundaries of the human subject herself expand and diffuse—continually negotiated with the environment?[3] When our nervous system spans across geographies and time, and traces of nonhuman life are found in our very breath? How are we to 'inhabit' when deep ecological pathologies prove the inadequacy of our current lifestyles and our attitudes toward the environment, non-humans, and fellow human beings?

1.
Ben Woodard, "I Want to Live Inside this Monster: Haunted Houses and Ecological Design," in *Organs Everywhere No.3* - Cyborgs and Monsters, www.organseverywhere.com/pdf/OE_3_Cyborgs-and-Monsters.pdf (accessed February 1st 2012)

2.
Slavoj Žižek, *Living in the End Times* (London: Verso, 2010), 430.

3.
Antoine Picon identifies the formal obsession of digital architects—particularly with skins and continuous surfaces—as an attempt to "overcome the notion of a clear-cut separation between the human subject and the non-human things that surround him/her." But isn't this superficial approach all too easy, all too *superficial*? Doesn't the "conception of a human subject in continuity with his/her environment" necessarily entail a more radical and engaged relationship with reality—one that exceeds form, limits control, and demands sustained collaboration?
See Antoine Picon, "Continuity, Complexity, and Emergence: What is the Real for Digital Designers?" in *The Real Perspecta* 42, ed. Matthew Roman and Tal Schori (Cambridge, MA: MIT Press), 153.

DOLL HOUSES

In our collective imagination, doll houses represent and distill an idea of homeness that coincides with a warm and intimate interior protected from the outside world. Tiny pieces of hand-made furniture are carefully laid out in surgically exposed rooms. The reduced scale further increases a sense of "cuteness," along with one of absolute control. We could even say that the doll house is the ideal prototype of the western home—one that can function based exclusively on the owner's actions and desires: a frozen home with no outdoors, no metabolism, no history outside of our own.
The images in these pages infect the perfect independence of doll houses with water, dirt, nonhuman life, automation and unintended change.

In the propositional space between reality, fairy tales and science fiction, a new kind of domestic space emerges—one open to outside ecologies and porous to material and informational flows: a Plastic (Electro)Nomadic House. Rather than an 'interior' dialectically opposed to an 'exterior', the P(E)N House collaborates with the outside, of which it is nothing but a difference in degree, in concentration. Rooms are not defined in terms of human usage (a kitchen is where you cook, a bedroom is where you sleep, and so on), but of dynamic relationships with wider ecological horizons, of biodiversity and built-in inefficiencies.
Cybernetic loops are absorbed and channeled through the house generating ambiguous encounters and flexible, metamorphic spaces.

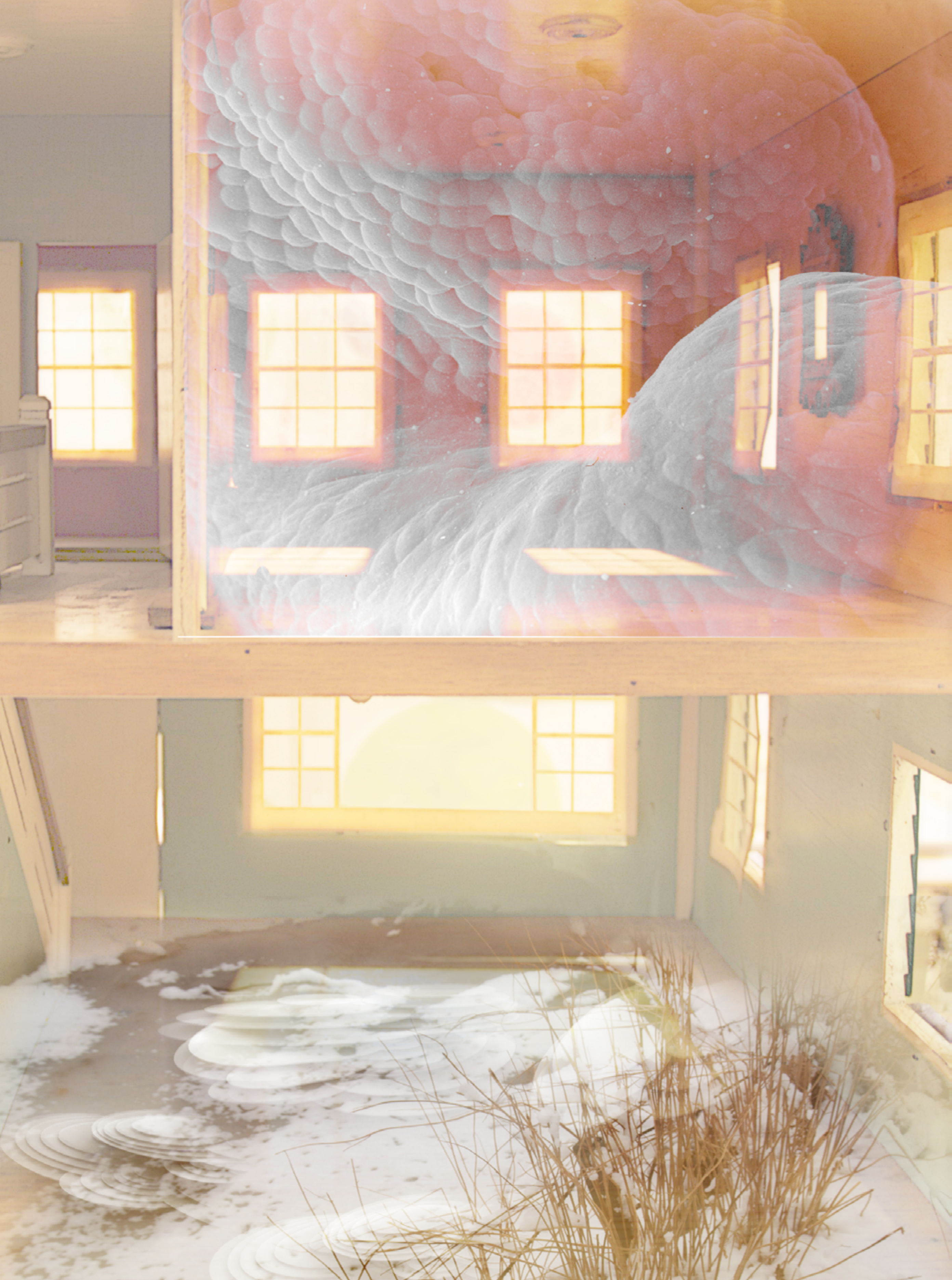
Flood Rooms

When the rainwater harvested in large rooftop cisterns reaches predetermined target levels, control valves open up allowing it to seep through to selected interiors. In some rooms water drips from colorful micro-perforated roses suspended on ceilings—loudly ticking as droplets rhythmically shatter on floors. In others, it fills tanks inside the walls, oozing out of overflows at baseboards and windowsills, and slowly swelling into pools around the furniture. Other rooms absorb it in sponge-like fashion, erupting into wet mountains and valleys. Discrete floods progressively submerge each room, rising until only a few plateaus and bridges surface above the water level. That's when sensors activate pumps that automatically blow air into folded forests: inflatable atolls, rafts, chairs and cocoons. As these objects unfold and puff up, they release nutrients, and column-shaped pots filled with gravel and seeds grow into ephemeral, lush islands. In the meantime, the inhabitant's belongings—words, images, and sounds—float in the virtual space of potentiality, unharmed.
Rainwater also travels inside the partitions of so-called *River Rooms*—flowing pressed between two layers of transparent glazing. Green algae, bacteria and several species of fish populate the thin blades of water, carried by seasonal tides—translating monsoons and droughts into changing levels of privacy.

Living Fridge

The P(E)N House undermines the opposition between dwellings and places of production brought forth by the industrial revolution[4] , and calls itself a farm—one that is

4.
See Walter Benjamin, *The Arcades Project* (Cambridge, MA: Belknap, 1999), 19.

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autonomous, self-sustaining and yet networked to a million others in a super-grid programmed to ensure abundant food and energy for inhabitants and passers-by.

A heap of solar-powered robotic machines overcrowd hydroponic trays, carefully growing lettuce, tomatoes, strawberries and a variety of other fruits and vegetables. Magnetic tracks enable them to weightlessly run by each segment carrying out their precise assignments, attending to plants and monitoring their development. *Pump robots* move water from the various indoor fishponds to the grow beds, supplying a continuous stream of nitrogen-rich fertilizer. *Robotic bumblebees* fly along the trays testing water acidity levels with their proboscis, and wirelessly sending results to *hose-machines*, which compensate by releasing more water. *Robotic scissor-hands* cut off diseased or dying plant parts and collect organic waste to be transformed into gas by anaerobic digestion, and used to generate additional energy. *Iron robots* collect ripe fruits and vegetables in excess and dehydrate them for future consumption. *Thief machines* steal food for ants, birds and other local animals. *Vigilant robots* keep track of air temperature and humidity levels. *Musical interpreters* translate heliotropic changes into sounds, broadcasting wirelessly over loud speakers. And so on.

Meteorological Suits

Hydroponic trays are placed along the perimeter of the House—a microclimate enclosed on two sides by adaptable glazing units capable of modulating insulating and reflectivity performance and of growing bacterial frits and fluorescent spore interlayers on a need basis. Their changing geometry—the narrowing and widening of the horizontal spaces between them, their increasing and decreasing depths—do not speak of interior functions, nor do they frame select vistas. Rather, they are derived from calculations aimed at optimizing growth according to the specific orientation and needs of each plant. And only partially do they correspond with the threshold between the exterior and a thermally conditioned interior.

Rather than being sealed off, many of the rooms in the P(E)N House are in fact open to the outside, and subject to its climatic tempers. The dweller's body upstages the envelope as the threshold of thermal control.

Inhabitants wear breathable electronic suits weaved with smart textiles and programmed to keep the body at a set temperature, or to endow each space with a customized perceptual climate—temperature, relative humidity, even haptic sensations of rain, mild itching, hail.

Closed Loop Printing

The P(E)N House is also a site of manufacturing—each house being fitted with a set amount of high-quality recycled plastic, and a series of robotic appliances designed to print it, melt it down, extrude it, and re-use it to print something new. Algorithm-generated designs are continually selected by users of a public website, and printed when surplus energy is available and an equal amount of plastic has been fed back to the robots. Things metamorphose into one another: tables into chairs, chase lounges into silverware, bookshelves into walls. Matter circulates in a dance of unchoreographed appearances and disappearances. Objects and rooms shape shift. Domesticity is supplemented with the periodic need to adapt. When repetition is required, copies are made by printing molds and letting fungal mycelium grow into them.[5] During the winter, snow and ice are poured into the molds, engendering transitory collections of translucent beds, desks, bowls and armchairs.

5.
"Eban Bayer: Are Mushrooms the New Plastic?" http://www.ted.com/talks/eben_bayer_are_mushrooms_the_new_plastic.html, (accessed August 1st 2012)

Digesting Reality

The private individual, who in the office has to deal with realities, needs the domestic interior to sustain him in his illusions.[6]
Walter Benjamin

When we flush the toilet, we imagine that the U-bend takes the waste away into some ontologically alien realm. Ecology is now beginning to tell us of something very different: a flattened world without ontological U-bends.[7]
Timothy Morton

6.
Benjamin, *Arcades*, 19.

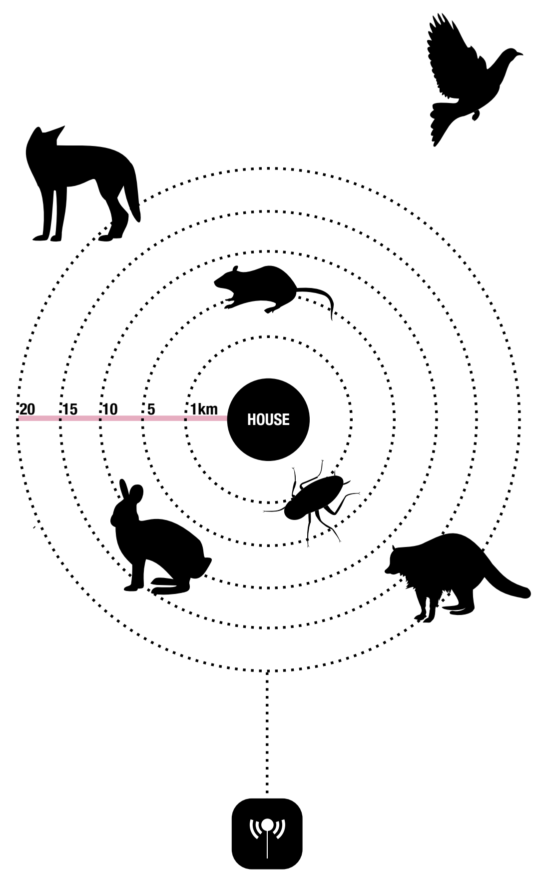
7.
Timothy Morton, "Peak Nature – Capitalism has no soul", in *Adbusters 98 - American Autumn*. http://www.adbusters.org/magazine/98/peak-nature.html (accessed August 1st 2012)

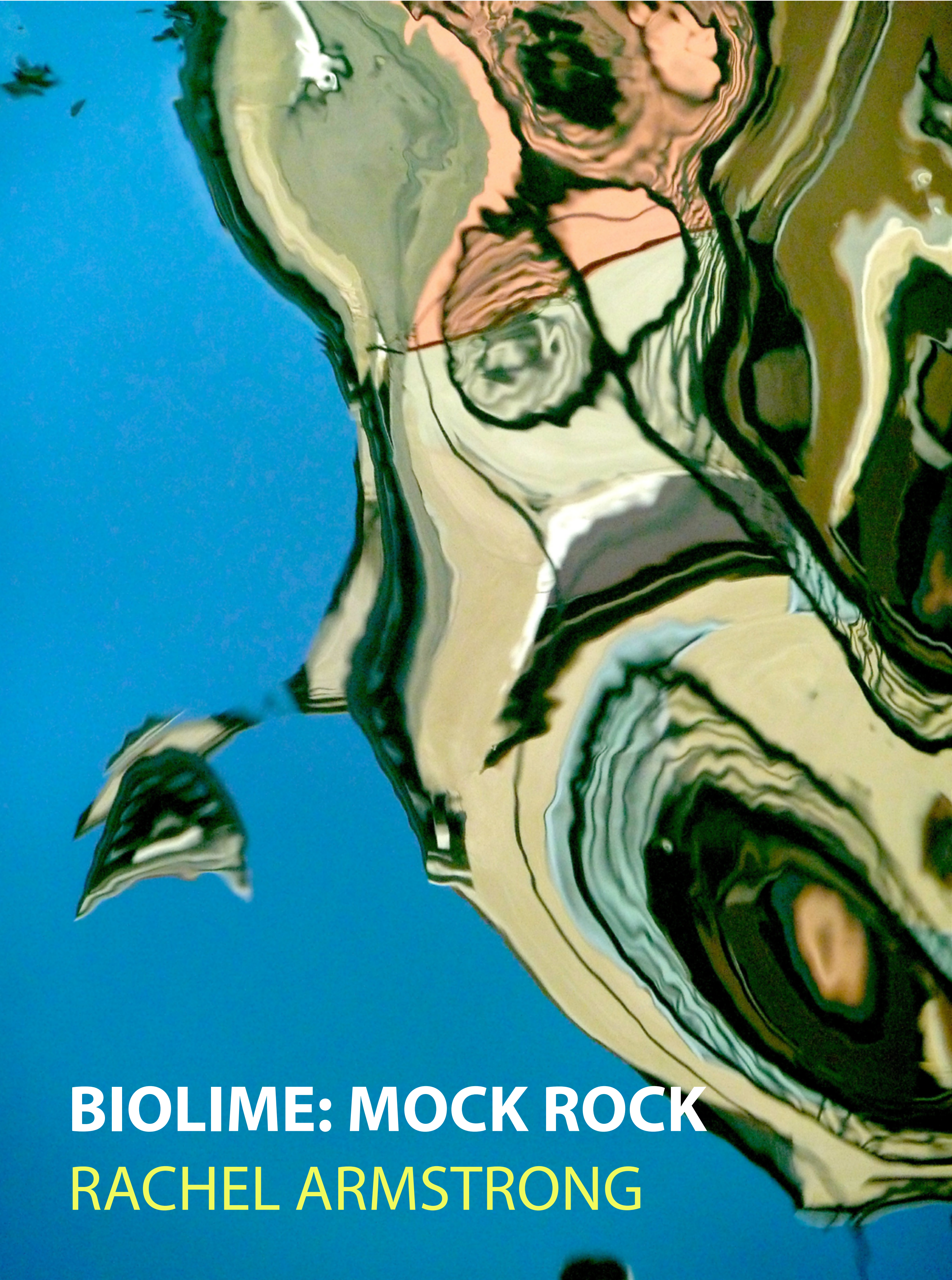
In the P(E)N House, waste that cannot be up-cycled is fed to the *Digester Room*, a "personal landfill" that employs mycelium to slowly decompose refuse. Along the narrow walkway overlooking rubble and fungal growths, in the darkness, real-time video projections document life in sites of resource extraction and industrial manufacturing.
Surgical Rooms are spaces blemished by beautifully designed cuts and tears that expose the interstitial organs concealed between visible surfaces: plumbing and sewage, electrical cables and wooden posts, cockroaches and batt insulation, beams and nails. They remind us of the constructed nature of buildings, and of the extended metabolic networks from which they—we—depend.

Transient Rooms

Environmental sensors trigger shifts powered by geothermal energy sources. *Accordion Rooms* inflate and deflate according to the temperature fluctuations on distant mountaintops. *Chameleon Rooms* progressively change color based on air pollution levels. *Cave Rooms* are slowly chewed by chemicals, or carved by artificial winds. And the floors in *Topographic Rooms* are comprised of soft hydraulic columns that move upwards and downwards following the whereabouts of tagged animal specimens toward and away from the House.

The P(E)N House erodes 'homeness,' challenging its perceived separation—our separation—from the surrounding ecosystem, and proposing a sort of "domestic nomadism."
It refuses architecture's epistemological premises of anthropocentrism, hyper-hygienic comfort, instant gratification and control, and hopes to facilitate a sense of promiscuity and interconnection between individuals and their environment, human perceivers and nonhuman things perceived—an architectural openness.





BIOLIME: MOCK ROCK

RACHEL ARMSTRONG

For those that had never been to the city of Hardwich, it was impossible to tell whether the houses in the Mossville suburb had actually come 'alive' or not, for whenever sunlight stroked the mineral-clad buildings their facades seemed to quiver with an energized, metabolic glow. Early morning joggers took advantage of the freshening air caused by the solar activation of the limestone. Dirt stains faded and curious cellular plant life toyed at the edges of the slowly creeping rock as if they were deciding whether they had encountered a friend or foe.

The Biolime surface coating on the outside of the Mossville houses had been deemed a 'friend,' but the new technology had not been accepted without controversy. Indeed, if it weren't for the irrefutable fact that climate change was happening even faster than all forecasts had predicted, resulting in increasingly turbulent weather patterns, Biolime would have remained a curiosity of chemical behaviour that was only of interest to an elite group of scientists working in the new field of the Origins of Life sciences. Unusually, these researchers had collaborated with a group of architects who were interested in the carbon fixing qualities of living systems as a way of generating sustainable architectural practices. The collaborators had produced a simple oil-in-water droplet emulsion that used carbon dioxide from the atmosphere to drive a chemical process that formed a rock-like salt called 'carbonate', similar to limestone. The resultant work was generally regarded as a fringe research activity, though some years later the renewed interest in finding ways of dealing with the runaway carbon count prompted journalistic investigation into the technology and led to a prime time news feature entitled 'Mock Rock'. In the wake of endless speculation in spin-off magazine articles such as 'Mock Rock around the Block' and 'Mock Rock da House' this sudden and rather unexpected global coverage of the research prompted the researchers to patent their technology as 'Biolime'. Yet, despite the growing interest in the system and the increased recognition that this technology could actually make a real contribution to the health of urban communities, Biolime continued to be regarded with suspicion. A number of outspoken critics conjectured that, even under the current circumstances, the Biolime technology really belonged only in a laboratory setting and that it had no place in the natural world.

Part of the problem was that the technology had been implemented at the national level in the wake of a series of fractious G20 summit meetings. After a series of high profile public protests leading to widespread outbursts of civil unrest and political humiliation regarding the ineffectiveness of the G20, its members were finally forced to take action. The embarrassment caused by media-led popular opinion finally spurred the major economic powers to undertake draconian measures on a scale that had not been previously attempted. Programmes that relied on the good will and environmental responsibility of individuals were simply not making sufficient impact on the soaring greenhouse gases responsible for climate change, and there was unanimous agreement amongst the representatives of the world's nations that it was time to generate an orchestrated and creative response to the problem. Of course, they suspected that a patriarchal approach to planetary welfare would be resisted, but it was time that the public faced the facts. The old methods and various forms of public bribery were just not good enough, and a completely new approach was necessary. Political attention quickly turned to the 'Mock Rock' technology since it had recently become a popular chat show subject. After a number of rather cursory national polls conducted to investigate public attitudes towards the technology, the First World countries endorsed Biolime as the most immediate and effective way to combat climate change.

The government decided to pilot Biolime-based solutions in urban areas to demonstrate the benefits of the new technology in the form of community-based public schemes. The Mossville area of the city of Hardwich, which had already responded to national sustainability initiatives through exemplary practice, seemed a prime location for further government-initiated improvement. Mossville boasted a well-supported permaculture project that had opened up garden spaces for the public cultivation of fruit trees, which allowed people to exchange fruit as seasonal currency, and had adopted a staunch stance against plastic packaging. Shopkeepers either refused goods with wrappers from suppliers, or removed and recycled them at the point of purchase. Mr. Grant Soames, who ran a hypermarket chain in several locations around Hardwich, further capitalized on this practice when he discovered that there was a thriving market in recycled packaging materials. His stores not only became a focal point for community de-packaging activities, but also served as meeting points for the youth who used the worthy excuse of recycling duties to escape their homework responsibilities.

Less than a month before the project began the local councillors received official notification of the Biolime initiative by traditional post, which was a little unusual, but the Mossville councillors prided themselves on being progressive individuals and staunch government supporters, with careers to protect. So, they organized a public meeting to salvage some semblance that a democratic process was taking place and head off any misconceptions about the centrally driven imperatives. The response to the public notices was overwhelming and a swell of banners that read 'Block Mock Rock' or 'Rock Mocking Us', soared above the Mossville crowd that had turned out for the meeting.

Councillor Arthur James, the youngest and most ambitious of the local politicians, brushed down the front of his suit in preparation for conflict with those that had elected him and asked the staff to open the doors. He'd agreed to lead the public meeting partly because the senior committee members admitted they didn't know what a 'metabolism' was and partly because he actually believed in the value of the project. Although Arthur had initially been as sceptical as anyone about the hype surrounding the Biolime technology, he had become increasingly charmed by its simplicity and effectiveness. Councillor James reminded the assembly of stony-faced people that limestone occurred naturally in underground caves and that the scale deposits that it formed resulted from everyday processes, like boiling water in a kettle. He then urged the congregation to consider this as a way to build and maintain buildings naturally, albeit unconventionally. He also asked what it might mean to the community if the Biolime technology enabled their homes to do something more important than provide warmth and shelter. How would they feel if their homes were able to contribute to the health and healing of the planet? After a few moments of stunned contemplation, some audience members raised objection to the technology by drawing analogy with genetic modification, but Councillor James was quick to point out that the cell-like agents used in the Biolime process did not have any genes. Biolime itself was not alive and although it shared some of the characteristics of living systems, it would die without the continued nurturing of the community. Mrs. Angela Darling, who was already considering spending more time outside for health reasons, wondered what the councillor meant by this and was told that the Biolime needed to be continually replenished to keep the carbon-fixing process going, as it did not last forever. The fragility of Biolime and its dependence on the active participation of the community was sobering news and appeared to endear the technology to the congregation, which seemed less anxious and began to ask questions about the necessary cultivation methods.

On account of his youth, Councillor James found it harder to deal with the more philosophical issues that were raised in objection to the new technology. Hearing Arthur's voice strain at Mr. Henry Norton's recurrent interjections that Biolime was 'an act against God', Councillor Andrew Talbot felt the need to step in and assist his colleague.

Mr. Norton was not easy to console as he'd just lost his wife and was angry with everyone about everything. Councillor Talbot though managed to affirm and dismiss Mr. Norton using a rather meaningless but effective platitude, before moving the conversation swiftly onwards. In fact, Councillor Talbot had most difficulty with the permaculturists, who were the most vigorous objectors to the 'unnatural nature' of Biolime and could not accept that artificial processes may coexist with natural ones. They blamed all forms of technology as being responsible for the sorry condition of the planet and Councillor Talbot responded to these objections with a theatrical and ponderous demeanour. He cast the congregation's attention back to the days of planting orchards and using grafting technology to 'enhance' plants as being inherently unnatural pursuits that had ultimately benefited humankind. Councillor Talbot conjectured that those groups who worried about the implications for 'natural' systems were resisting the need for change, rather than making a sound case against the Biolime project itself. He raised the stakes of the meeting by grandiosely urging Mossville to take a lead in making amends to the planet on behalf of the human race by embracing Biolime.

An overwhelmed and exhausted audience found themselves applauding the veteran councillor and were invited to cast their votes on the Biolime project. Despite the handful of vigorous objections that had been voiced during the meeting, 'Mock Rock' was accepted with an overwhelming majority. Even Mr. Norton was overheard muttering to himself on his way out of the town hall that if 'the abomination' meant that he didn't have to spend every Sunday morning sorting rubbish, then he was all for it. Life was too short to sort rubbish.

A public holiday was held in Mossville the day that the Biolime was delivered and became a community event. Large containers of locally prepared Biolime solution were assembled on a cordoned-off section of the road. People helped each other in filling up portable spray containers and coating the outside of their homes, fully clad in overalls, goggles and masks.

Mrs. Kathleen Gately, who looked oddly alien in goggles that were too large for her sunken features, had problems using the hand-pump with her rheumatoid hands. James Chesney, who had just come from next door to complain about the persistent yapping of her toy dog, which was upset by Mrs. Gately's appearance in protective clothing, decided to help out. In the meantime, Kathleen repeatedly asked him why they were spraying a liquid on to the buildings when they'd been promised some rocks? Jimmy mumbled from behind his mask that the rock was grown from the solution and nipped over the fence to finish off his own place. Kathleen took off her overalls, which settled the little dog, and sat on her front wall looking back at her house in disbelief. How could it be true that water would turn into rock? She shook her head. In her view, this was something that would 'beggar Jesus' to figure out, so help her God.

Since everyone was fully occupied with diligently applying Biolime to their homes, the usual neighbourly vigilance had slackened as people were concentrating on the job in hand rather than wondering what their neighbours were up to. The community was later astonished to find that an unpopular modern statue had been drenched in so much Biolime solution that it now resembled a spacecraft. Nor were they able to explain how the local skate boarders had managed to acquire a Biolime 'ramp' that gave them enough air to be clearly visible from Mr. Norton's back yard.

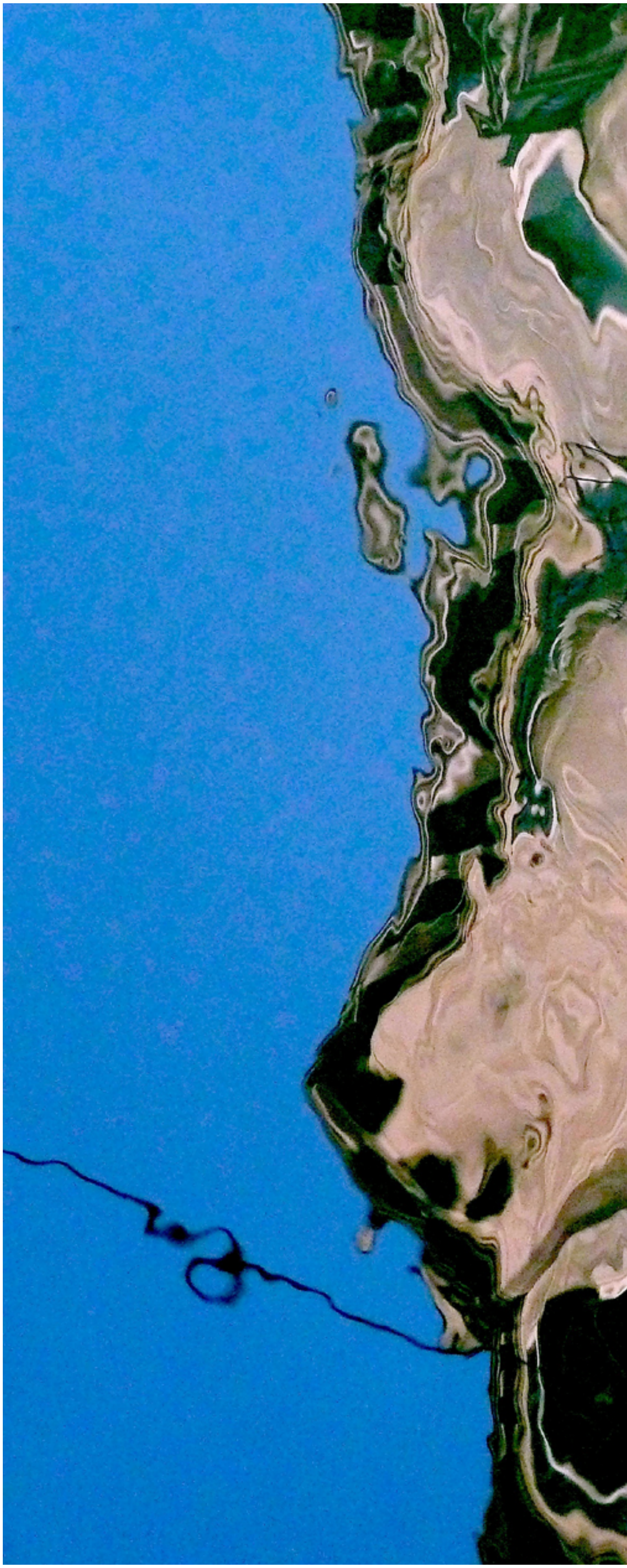
Otherwise, the day came and went uneventfully and after the initial flurry of activity and excitement, Mossville settled down again to its frugal routines.

A few weeks later those areas that had been sprayed with the Biolime solution began to transform and produce a moist, heavily patterned, whitish rock. Delicate crustings of this material appeared in gutterways and grew into stalactite fingers where water had accumulated. Small children picked at oddly shaped protrusions that were sometimes used by wildlife and the Biolime could also be found in places where it had not been deliberately applied. Playground drains became unnaturally frosted and Biolime trails squeezed like toothpaste through gaps in the pavements. Where the Biolime had died it became laced with white ribbons that were prone to fracturing. On a dry day, these brittle splinters of rock could be heard cracking and falling like old plaster from the walls. Rain tasted clearer, fires burned brighter and even algal blooms in the waterways were more vigorous than before Mossville embraced Biolime, and whilst many subtle differences were noted in the environment, the people continued with their usual, well-meaning but peculiar ways.

Gradually, Biolime became part of the everyday community tensions. Jimmy grew tired of Mrs. Gately's moaning that he hadn't done the front of her house properly and refused to stop by any more. As a result Kathleen's façade looked scarred and provoked snide comments when she queued at Mr. Soame's checkout. Kathleen expressed her defiance against her neighbours by allowing her little dog to urinate on the corner of Mr. Norton's house. This act of wilful vandalism was quite a spectacle, as the acidic urine caused the Biolime to fizz like freshly shaken lemonade. A vigilant Mrs. Darling, who had finally found her excuse to spend more time outside by taking up smoking, witnessed the sabotage and swore at Kathleen through her nicotine-stained lips. It was people like her that were responsible for global warming in the first place! Without so much as casting a backwards glance, Kathleen flipped two rheumatoid fingers at her critic and patted the little dog on the head. Affronted, but in greater need of a cigarette fix than of altercation, Mrs. Darling resumed her smoking and cursed through her breath right to the end of the butt.

In his government report about the Biolime pilot scheme Councillor James commended the community for intensifying their permaculture and recycling efforts and commented that the only real difference to Mossville was the remarkable snow-like coating of the buildings. Councillor Talbot on the other hand was more perceptive, remarking that the presence of Biolime helped the community feel that their individual efforts in combating Global Warming were significant. In his opinion, Mossville had realised that if something as small as the chemical fragments of technology that constituted Biolime could make such a difference to the health of the community, then the efforts of each individual, no matter how trivial, would make an even greater difference in their collective quest to tackle the weighty issue of climate change.

Photographs by Rachel Armstrong



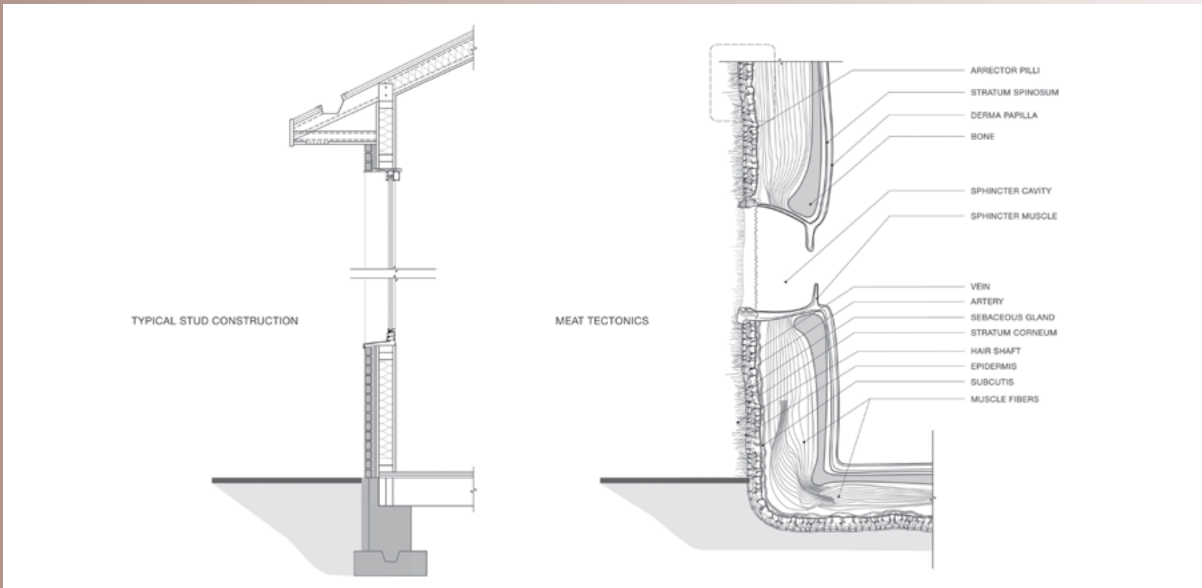
IN VITRO MEAT HABITAT

MITCHELL JOACHIM

TERREFORM ONE

This is an architectural proposal for the fabrication of 3D printed extruded pig cells to form real organic dwellings. It is intended to be a "victimless shelter", because no sentient being was harmed in the laboratory growth of the skin. We used sodium benzoate as a preservative to kill yeasts, bacteria and fungi. Other materials in the model matrix are: collagen powder, xanthan gum, mannitol, cochineal, sodium pyrophosphate, and recycled PET plastic scaffold.

As of now, the concept model consists of essentially very expensive fitted cured pork or articulated swine leather with an extensive shelf life. The actual scale of the non-perishable prototype is 11"x3"x7".



All images by Mitchell Joachim, TERREFORM ONE

COMBINED ADVANCED TECHNOLOGIES & FLEXIBLE URBAN INFRASTRUCTURES: MAPPING THE LANDSCAPE FOR AGILE DESIGN

RACHEL ARMSTRONG

Thinking about new design paradigms to underpin our future cities differently invokes the invention of new technologies that—in keeping with Clarke's dictum—may provide the kind of 'magic' necessary to make them our new reality. But just how can radical solutions magically emerge from 'the familiar'—a pathway that appears to already have a certain destiny?

The 20th century convinced us that the future has a linear trajectory that progresses incrementally—so that tomorrow is exactly like today, only a little bit different. Anything that deviates from this predetermined path is obviously fiction. Sometimes we call it 'science fiction' because, although we rationalize its potential, the outcomes don't seem likely when considered incrementally. But if we pay heed to the predictions of science fiction and the trajectory of evolutionary history itself—as evidenced by biology through the strangeness of the natural world and its archive, the fossil record—we should not be surprised at being surprised by the future.

We already know that the speculative narratives of science fiction authors have the uncanny ability to 'come true.' At the 2011 Virtual Futures II conference, cyberpunk author Pat Cadigan observed that George Orwell's 1984 dystopian reality—the oppression of surveillance on everyday life—had become 'just a ****ing game show.' [1]
Even in the sciences we appreciate that the future is more than just a different kind of today and that it is underpinned by real-world processes—even if we don't fully understand them.

In 1972 Stephen Jay Gould and Niles Eldridge championed the idea of 'punctuated equilibrium,' which predicts that a lot of evolutionary change takes place in short periods of time and is tied to speciation events—the diversification of life. Punctuated equilibrium represents an alternative evolutionary process to Neo-Darwinism, which, by proposing a set of incremental genetic variations selected by the environment, actually embodies our industrial model of technological change. Yet, punctuated equilibrium is just one of the stranger methods in nature's creativity portfolio. It sits alongside equally outrageous design strategies such as symbiogenesis— the radical re-synthesis of living things, championed by Lynn Margulis—and the direct exchange of body parts proposed by Donald Williamson.[2]
Our reality is that the world we inhabit is strange, disobedient and not at all homogenous. So, how do we design with

1.
See Patt Cadigan, "What Happened to Our Future?". Accessed May 2012. http://www2.warwick.ac.uk/knowledge/themes/virtualfutures/patcadigan/.

2.
http://edge.org/response-detail/846/what-do-you-believe-is-true-even-though-you-cannot-prove-it/ (Accessed May 2012).

all this inconsistency?

Surrealists—like Neil Spiller—draw inspiration from the intangible influences that shape our world and enact them through traditional modes, using subversive methods. The "Communicating Vessels," for example, use symbolism (baguettes, baronesses and lobsters), rare materials (gold, holy grease, amber), psychology (dreams, optical illusions) and theatrical delivery methods (chicken computers) to gain traction on the slippery world we inhabit in a manner that is Sur-real—above the (Enlightenment) real.

Today new technologies can provide tactics similar to those employed by surrealists, and engage with real-world revelations that continue to shock and provoke us. For example, electron microscopy exposed the 'forbidden mating' between two completely different kingdoms—a cyanobacteria and a fungus.[3]

It was also once assumed that there were only female Anglerfish—until scientists realized they were looking for males in the wrong place. New pressure-proof bathyscaphes, remote controlled robots and biotechnological analyses revealed the shocking dynamics of the Anglerfish partnership. Young male Anglerfish, once lithe and free swimming, become parasitic on their giant female mates. They literally sacrifice their freedom to live off the female's blood supply and shriveled to little more than a nubbin of sperm-producing flesh.

Advanced technologies have served to remind us that Nature itself speaks not of predetermined functions and propriety, but demonstrates proclivity for abundance and excess.

Underpinning our current design ideas is the assumption that we are instructors of an obedient world. On this premise we have founded the practice of building cities. My aim is to unsettle this claim and consider our terrestrial materiality as a way of opening up new, potentially radical design transformations.

Thinking Differently—Dynamic Materials

Where does this idea of an obedient material world—one in which we can shape and bend matter to our will—come from?

Architectural design practice is trapped within the fram-

3.
A. Schüßler, D. Mollenhauer, E. Schnepf and M. Kluge, "Geosiphone Pyriforme, an Endosymbiotic Association of Fungus and Cyanobacteria: the Spore Structure Resembles that of Arbuscular Mycorrhizal (AM) Fungi," in *Botanica Acta* 107 (1994): 36-45. Accessed May 2012.
http://epub.ub.uni-muenchen.de/3282/1/3282.pdf.

ing of the Enlightenment—of a Cartesian reality situated within a Newtonian universe. The 'natural law' of the Enlightenment is based on geometry and mathematics and persists to rationalise our strange world. We neurotically test our preconceptions of a rational engagement with matter—through incessant measurement, as we no longer trust our senses. This results in the notion that matter is inert, operates at a particular scale, is unaltered by its context, is untouched by time and needs rational instruction. It is typified in the machine worldview, made up from component parts of fundamental particles, called atoms.

As measuring devices got better, science started to observe that at very small scales, notably at the atomic scale, Newtonian rules did not always apply. Quantum mechanics provided a different view of matter through an appreciation of the qualities that made up the atomic substance, rather than its geometry. The consequence of this new perspective enabled the possibility of a new kind of materiality—one that was unpredictable, lively and even entangled with the measuring equipment. Ilya Prigogine, who introduced the notion of time irreversibility into the laws of physics, noted that 'the role of the observer was a necessary concept in the introduction of irreversibility, or the flow of time, into quantum theory. But once it is shown that instability breaks time symmetry, the observer is no longer essential.'[4]
Pioneers of complexity theory such as Gregory Bateson also described their approach to materials differently to the Cartesian/Newtonian paradigm, in terms that looked at the relationships between things that lead to complex phenomena. As Prigogine observed—"We need not only **laws** but also **events** that bring an element of radical novelty to the description of nature."[5] *(My emphasis)*

The scientific re-framing of the material world provides an opportunity for designers to challenge the 'brute' materiality of the machine and to set out a cultural framework that can incorporate the possibility of a **material agility**.

Jane Bennett has coined the phrase 'vibrant matter' drawing inspiration from Bruno Latour's notion of 'actants'—bodies that can exert influence and effects on their surroundings and that may or may not be human or alive.[6] Non-human actants have a relatively weak influence on the human experience, but their effects are amplified through recruitment.

Architect Mark Morris notes[7] that non-human 'intellects' may have persuasive purchase in an entangled reality, sug-

4.
Ilya Prigogine, *The End of Certainty: Time, Chaos and the New Laws of Nature* (New York: The Free Press, 1996), 5.

5.
Ibid., 5.

6.
Jane Bennett, *Vibrant Matter. A Political Ecology of Things* (Durham: Duke University Press, 2010).

7.
These observations were all made during a Future Cities conference held at the University of Greenwich, 19th April 2012 and are documented in this PDF booklet of abstracts at: http://earth2hub.com/uploads/files/FUTURE%20CITIES%20PDF/Future_Cities_PDF_-_full_info.pdf.

gesting that biological 'augury' may inform us about the significance of events on an expanded scale, as a kind of collective human/non-human consciousness. Bacteriologist Simon Park reminds us that we are guests in a bacterial world, and technologist Nathan Morrison notes that in these functional couplings, humans are not necessarily in charge.

Bennett uses Deleuze and Guattari's term 'assemblage' to describe the cumulative pressure that materials or bodies can exert independently from, or participating within, the human realm. Although matter is not autonomous—it depends on other actants to exert its effects—it becomes creative and convincing through bottom-up forms of interaction. The outcomes of these, according to the laws of complexity, can be surprising.

Bennett's proposition enables materials to operate in a lively manner, escaping the Newtonian dictum that materials are dumb and therefore require rational instruction—which is the principle that underpins our current forms of manufacturing. But these traditions can be challenged. Lee Cronin's group at the University of Glasgow, for example, recently published a paper in Nature describing reactive labware—a manufacturing process that fuses the environment and the participating chemistry in a single step, using a low-end printing technology.[8]

8.
Helen Shen, "Homegrown Labware Made with 3D Printer," *Nature*, 16 April, 2012, accessed May 2012. http://www.nature.com/news/homegrown-labware-made-with-3d-printer-1.10453.

Design Principles

But if materials are lively, then specific qualities relevant to heterogeneity, entanglement and vibrancy need to be incorporated into a practical design approach—to underpin the evolution of our cities.

Notable qualities when considering engagement with vibrant materials are:

Scales of interaction—while bottom up forces cater for the environment, human concerns are frequently met through top-down notions of control. The optimum design approach is to select at which scale the participating actants meaningfully intersect.

Context—matter presents various conditions under which its actants participate more than others.

Time—matter works with directionality on different time scales to human experience.

Hubs—are organizing centers for complex entities, yet Barabasi and colleagues observed that, counter intuitively, these active sites of connection are not the regulators of complex systems.[9]
Instead, there appear to be driver nodes that exist beyond the active hubs and are capable of exerting influence on dense, homogenous complex networks. This explains why external influence can be exerted on very robust complex networks, resulting in a system that can't be completely controlled, but is incompletely influenced.

Control—working with dynamic matter engages with an established tradition of design practices in which, like in gardening and cooking, the designer is a co-author of a process.

Infrastructures—Potential for Growth

We can only go so far by appreciating the dynamic capabilities of materials. Something else needs to happen for their liveliness to continue. Infrastructure provides the context in which dynamic systems can keep away from equilibrium and also in which their materiality can become organised or even persistent. For materials to perform according to their complex and quantum potential, they need organised proximate environments that complement or augment their innate abilities.

In recounting the conditions in which matter became lively, William Bryant Logan observes that "the sea was the proto-soil, where Earth, air, water, and the solar fire met for the first time. It was an inverse soil; you might say, with the liquid element providing the matrix for the mineral soils and for dissolved gases, a role that the mineral elements would later come to play. But from a certain point of view, all Earth's later history is a consequence of that first mixing. In that sense, life is the story of bodies that learned to contain the sea."[10]

In a complex system, this primal flow and exchange between actants, driven by the arrow of time, both underpins the organizing forces and gives rise to a dynamic nature. Yet the infrastructure of today's cities follows—rather than anticipates—the needs of its dynamic population. Resource scarcity is the condition in which our megacities are expected to rise. Arne Hendriks notes in his "Incredible

9.
Yang-Yu Liu, Jean-Jacques Slotine, Albert-László Barabási, "Controllability of Complex Networks," accessed May 2012. http://barabasilab.neu.edu/projects/controllability/.

10.
William Bryant Logan, *Dirt: The Ecstatic Skin of the Earth*, (New York and London: W.W. Norton and Company, 1995), 11.

Shrinking Human" project that when the responsiveness of landscapes—their ability to adapt to increasing demand—is damaged by resource constraints, the resulting evolutionary pressures will profoundly impact on their inhabitants.[11]

Indeed, the proliferation of infrastructure is a necessary precondition for evolutionary adaptation, growth and diversity. A recent paper by Taylor S. Feild and colleagues[12] reported fossil evidence to underpin the dramatic explosion in plant evolution during the Cretaceous period. They proposed that the density of veins in the leaves of non flowering plants (gymnosperms) enabled the delivery of water, then the fixing of carbon enabled speciation and gave rise to more complex forms of plants that could bear flowers and fruit (angiosperms). Without the necessary infrastructure in place, the transition from simpler to more complex and diverse forms of organization would not have been possible.

The importance of adequate infrastructures is taken seriously by corporations like Arup, which is now calling for more agile,[13] modular and small-scale infrastructures to deal with processing vital substances such as grey water. Yet, keeping up with existing demand does not equal anticipating its increases. If nature's strangeness and potential for disruption appears associated with a condition of abundance, rather than careful conservation, then how may it be possible to create this kind of excess in resource-constrained environments?

In his recent book *Abundance: The Future is Better than you Think*[14] Peter Diamandis notes that our resource challenge is not about the absolute amount of stuff available for us to make things with, but about discovering new ways to access and engage with resources. While appreciating that there are strong views[15] countering that we have reached our limits for growth, it may still be possible to discover abundance within the built environment in places that have been previously overlooked.

One possible approach is to look for access to resources at different scales. Mark Morris[16] notes that architecture "represent(s) culture and link(s) the small- and full-scaled worlds in a dynamic temporal relationship. The materiality of this architecture is a bit of a mystery." A biological example may help reveal how these mysterious spaces could be made accessible. Modern cells may appear to be continuous blobs of mixed-up stuff, but they are highly organized units riddled with channels called 'endoplasmic reticula.'

11.
http://www.the-incredible-shrinking-man.net/?page_id=286.

12.
Taylor S. Feild, Timothy J. Brodribb, Ari Iglesias, David S. Chatelet, Andres Baresch, Garland R. Upchurch, Jr., Bernard Gomez, Barbara A. R. Mohr, Clement Coiffard, Jiri Kvacek, and Carlos Jaramillo, "Fossil evidence for Cretaceous escalation in angiosperm leaf vein evolution," ***PNAS,*** **accessed May 2012. http://www.pnas.org/content/early/2011/04/27/1014456108.**

13.
Steve Lennon, "We Need Agile Cities," 23 March 2012, accessed May 2012. http://thoughts.arup.com/post/details/177/we-need-agile-cities.

14.
Peter H. Diamandis and Steven Kotler, ***Abundance: The Future Is Better Than You Think*** **(New York: Free Press, 2012).**

15.
Thomas Robert Malthus, ***An Essay on the Principle of Population as It Affects the Future Improvement of Society, with Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers*** **(London: J. Johnson, 1798). Description from the Library of Economics and Liberty, accessed May 2012. http://www.econlib.org/library/Malthus/malPopCover.html.**
See also Donella H. Meadows, Dennis L. Meadows, Jorgen Randers, and William W. Behrens III, ***The Limits to Growth; a Report for the Club of Rome's Project on the Predicament of Mankind*** **(New York: Universe Books, 1972).**

16.
Mark Morris, "Dream a Little Dream," ***Protocell Architecture: Architectural Design*****, Volume 81, Issue 210 (2011): 44-49.**

These interior chemical superhighways produce a maximum surface area within the minimum volume on which biochemical reactions that keep the cell entity away from equilibrium can take place. This incredible folding of linear space into a three-dimensional volume produces channels that span different scales and are separated by time. This microscopic distribution of organized matter through time and space underpins the most vibrant forms of materiality, and is a necessary attribute for life.

William Bryant Logan observes of soil—which might be considered as the 'endoplasmic reticulum' of planet Earth, and redistributes matter in time and space—that, 'The difference between a desert, a fertile field and a swamp is not the presence or absence of water in the subsoil, but its availability. Free loose exchange from depth to surface—is the best recipe for a fertile soil.'[17] Today machines usually manufacture matter as a dense, solid material—a configuration the furthest away from such 'free loose exchange'. However, if the lens of analysis is changed from manipulating brute Cartesian geometry to engaging the heterogeneous actants of complexity, then matter is freed to act. It is free to filter pollutants, or to facilitate chemical reactions that create deposits such as carbonates that might provide the basis for self-healing capabilities. Perhaps these new undiscovered spaces are microenvironments where the conditions of excess in which innovation and disruption flourish can exist.

17.
Logan, *Dirt*, 109.

Yet, the framing of our design realities itself need not be homogenous. There is additional value in understanding where different frameworks and infrastructures can intersect with each other. For example, highly porous, synthetically active materials could be used strategically and synergistically with existing structural building components. The merging of Cartesian geometry and relations of complexity could help produce countless sites of abundance—fertile substrates in which new technologies can be meaningfully sown and woven into the architectural landscape

New Technologies: Convergence to Transformation

Once a nurturing landscape that speaks to abundance has been identified, another layer of organization needs to come into play. Technology—operating at different scales, and through unique portfolios of actants— might persuade hubs of organization to adopt particular configurations. Kevin Kelly proposes technology itself is not just a jumble of wires and metal but a living, evolving organism that has its own unconscious needs and tendencies.[18] Certainly, dynamic infrastructures favour a more lively understanding of technology. Following a generation of 'digital natives', the advent of cheap manufacturing platforms[19], the blossoming of networked knowledge-sharing communities such as TED, and Diamandis' assertion that in the next decades we will see another 3 billion minds online,[20] then technium-facilitated disruptive change within our urban fabric is increasingly likely to occur in the coming decade.

With the appropriate infrastructures supporting them, combined technologies can form new kinds of qualitative engagement between buildings and the megacity environment. New kinds of technology are on the horizon, and even a new kind of scientific thinking.

A NSF (National Science Foundation) sponsored report has been particularly influential in precipitating a new kind of scientific approach, suggesting the unification of the sciences and the converging NBIC (Nano, Bio, Info, Cogno) technologies under a common goal: to greatly benefit humanity and industry. Centrally-supported funding initiatives are encouraging traditional scientific disciplines to adopt this more openly speculative approach to scientific research in ambitious "sand pits" of expert exchange. An example is the 'cyberplasm' project that combines synthetic biology and robotics to produce a programmable device with a metabolism.[21]

Hybrid scientific disciplines, such as Morphological Computation, are emerging from these fertile environments of shared ideas and designing with emergence, where fresh forward-looking perspectives are effectively dealing with an empirically un-testable future: the traditional stronghold of science fiction. This has opened up new avenues for further exploration as research groups from non-scientific disciplines share equal stakes in the outcomes of these new fusions.

For example, the Advanced Virtual And Technological Architectural Research (AVATAR) group has been working in collaboration with scientists such as Martin Hanczyc on protocell technology, and engaging in knowledge exchange with Sustainable Now Technologies. Industry partners such as Autodesk and Arup are also creating the conditions under which new approaches, tools, and materials are likely to be produced as a direct result of these open innovation

18.
Kevin Kelly, *What Technology Wants* (New York: Viking, 2010).

19.
As we saw earlier with the Cronin Group.

20.
"Peter Diamandis: Abundance is Our Future," accessed May 2012. http://www.ted.com/talks/peter_diamandis_abundance_is_our_future.html.

21.
Jeffrey Mervis, "Digging for Fresh Ideas in the Sandpit," accessed May 2012. http://www.sciencemag.org/content/324/5931/1128.2.summary.

platforms and will lead towards more dynamic and responsive cities.[7]

These condensations and fusions of approaches are leading towards the discovery of new ways of underpinning human development through design and the built environment. The challenges are not trivial, and the solutions are not near at hand, but that's the point. Building community and extending the envelope of possibility helps create narratives and visions that will go beyond today and tomorrow, and will be shared by the next generation of architectural designers.

Cities are Evolved—not Made

We live in a world of definable probability in which life and matter evolve continually. When we appreciate the full vitality of matter and its power to shape our proximate environment, then we can begin to practically engage in the design of experiences that are evolved, not made. The grand vision of achieving positive human development in the 21st century will require effective coordination between disciplines, institutions, cultures, and geographical regions. The pressing concerns that affect us all are many and varied—and would require humanity to perform at its very best to secure a long-term partnership with this unstable earth that is our home.

The magic of our reality is not that absolutely anything is possible—but that there is a great deal of untapped potential that already exists. By re-framing our understanding of matter we may be able to get a whole lot more from it, and understand it not as a dead thing to be controlled or consumed by machines, but as a partner in co-evolving our cities and future.

Indeed, our very survival depends on the re-invigoration of matter.

~~Matter is dead.~~

Long live matter!

Images by Rachel Armstrong