4 Method

An encounter that does not explain but produces. (Stengers, not dated)

4.1 Overview

This chapter outlines my research methodology, which is based on the knowledge gaps identified through an extensive literature search that established the architectural and scientific contexts for my practice. My research questions were formulated under the supervision of Neil Spiller, who guided my architectural design investigations, Martin Hancyzc, who oversaw my chemical studies and Philip Beesley, who I collaborated with in the Hylozoic Ground installation, which informed much of my practical architectural design work. Their continued guidance and support have enabled me to navigate the theoretical and practical aspects of my inquiry. These research questions became the building blocks for further speculative proposals about the possibilities of this multidisciplinary architectural design method and helped me reflect on its broader potential for architectural design practice in the 21st century.

In formulating my research questions, I developed a combined methodology that is informed by a number of mutually supporting research methods:

— Multidisciplinary approach: This enabled me to identify synergies between different knowledge fields through shared interests, so that it was possible to broaden knowledge sets and explore previously unknown and unchartered territories.
— Action research: Action research methods enabled me to develop new skills, ideas and approaches by immersing myself in new disciplines or context for example, during field trips, conducting laboratory experiments, or building installations.
— Speculative practice: The limits of possibility may be extended through speculative practices that enable new relationships between otherwise unconnected disciplines or skill sets, to be explored conceptually and practically.
— Morphological computing: This provided a platform for testing new ideas and embodying them without recourse to machines.

4.2 Multidisciplinary Approach

A first principles basis for the acquisition of knowledge was adopted using foundational propositions or assumptions that could not be deduced from other knowledge sets. This approach is consistent with my research questions, which require reimagining the nature of matter through process philosophy and applying these ideas in testable ways to the field of architectural design and chemistry. Since I was attempting to work across Two Cultures (Snow, 1959), it was essential to create partnerships and build new knowledge from the synthesis between these different disciplines. Working across knowledge fields has helped me distil common concepts that could be dealt with through mutual re-synthesis, such as designing the Hylozoic Ground chemistries, which was equally influenced by a working knowledge of chemistry and architectural design. Despite the multidisciplinary nature of my research, it is fundamentally an architectural study concerned with the construction of spatial programs and the development of design tactics. Specifically, the questions I was asking regarding the nature of materiality in architectural design is situated within the realms of experimental architectural inquiry pioneered by cyberneticist Gordon Pask, who built a chemical ear that responded to street sounds (Bird and Di Paolo, 2008, pp.185–212), and Stafford Beer's use of daphnia and pond ecologies (Beer, 1994), who was investigating alternative substrates for the production of architecture.

Teams of multidisciplinary practitioners were curated to inform my practice in many ways – ranging from expanding my subject matter reading to developing new experimental techniques such as Unconventional Computing and Architecture (Building Centre, 2010), Artificial Life and Architecture (Artificial Life XII, 2009) and WETFab (Adams, 2012). From the outset, I have aimed to keep my objectives clear, communicate frequently and be very specific about authorship and how work is credited, such as developing drawings for the Vibrant Venice project with Christian Kerrigan and GMJ. Collaborative practice is not simply a meeting of minds but a much more extensive system of how relationships are built and actively managed (Driver, Peralta and Moultrie, 2011). This has been key to completing my work, which has required me to work in different countries and organize research time in studios outside my own university such as, arranging laboratory time in a busy scientific laboratory at the University of Southern Denmark, working with the European Centre for Living Technology in Venice, or constructing an installation for the 2010 Venice Architecture Biennale.

Adopting a multidisciplinary approach has enabled me to identify synergies and enable fusions to take place across subject boundaries. These can be explored as a research conversation, or practical engagement, between subject fields and collaborators. My approach is consistent with Isabelle Stengers' constructivist, multidisciplinary method, which operates through building 'an ecology of practices' (Stengers, 2000) where different knowledge sets, or participants, create their own new understanding of a subject by working alongside each other. Stengers looks to the outcomes of synthetic practices to produce ideas that can reinform us about reality rather than proposing endless critiques of the various methods used by the contributing disciplines. This constructivist method enables researchers to work in a non-hierarchical way (Stengers, 2000, p.87) so they can find commonalities between disciplines and change assumptions by coming into contact with new views. These, in turn, feed back into the method to further refine practices (Resnick, 1989). Roy Ascott uses the term 'syncretic' to describe a particular kind of synthesis that does not provoke homogenized practice but enables collaborating disciplines to retain characteristics of their discipline of origin (Ascott, 2005). The convergent approaches that I have applied in my research may not only give rise to synthesis, in which disparate things meld into a homogenous whole and lose their individual distinction, but may also produce syncretic or entirely novel events. My research does not value one kind of outcome over another, but rather aims to utilize the various events appropriately, in a design context.

The value of convergence through multidisciplinary collaborations in producing novelty has been recognized in an NSF report (Roco and Bainbridge, 2003, p.9), which proposed that these approaches have the potential to bring significant economic and human benefits, particularly through the emergence of new, combined technologies.[27] This so-called NBIC (Nano Bio Info Cogno) convergence has led to funded 'sandpits' both by the NSF and EU, where multidisciplinary practitioners, predominantly scientists, collaboratively addressed 'grand' challenges such as artificial photosynthesis, and has resulted in projects such as the cyberplasm robot.[28] Convergence between the Two Cultures is also gathering support as a method of innovation from central funding sources, and currently the UK government is supporting STEAM (science, technology, engineering, arts and mathematics) in which the contributory role of arts is supported and recognized (Else, 2012).

4.3 Action Research

My studies are consistent with action research where an investigator is immersed in their subject matter – specifically, architectural design and chemistry, as well as their associated practices (Whitelaw et al, 2003; Creswell, 2009). This approach is frequently used in clinical practice and anthropology, where researchers explore theoretical issues by working within the research environment (Diamond, 2012; Latour and Woolgar, 1979; Hird, 2009; Goodall, 1969). Action research enables researchers to learn from their collaborators and environment to acquire new

27 The non-deterministic, forward-looking, speculative nature of these constructivist scientific approaches does not amount to 'science fiction' (Bassett, Steinmueller and Voss, 2013). Steve Fuller proposes that the literary genre has relevance to understanding the impacts of new technological developments on society. Fuller notes that the 'exclusion of science fiction from sociology pertains less to its content than its institutionalization. In other words, à la Karl Popper (Popper, 1959), if we were to treat science-fictional propositions as revisable hypotheses rather than stand-alone fantasy worlds, then they could quite quickly form a kind of sociology' (Fuller, 2011, p.45), so its character is primarily sociological rather than scientific or technological. Yet science fiction does not provide testable hypotheses but deals with a technological 'fait accompli', with little attention paid to the detailed procedural aspects of its existence.

28 The 'cyberplasm' robot is an example of the kind of projects that have arisen from the NBIC 'sandpits', which is a melange of biological and mechanical systems (Cyberplasm Team, 2010).

knowledge and make repeated, informal evaluations and judgements. In achieving my research aims my abilities were broadened specifically in tasks, such as careful planning, practical skills, sharpened observation and listening, evaluation, and critical reflection. In an architectural design context, by working with Philip Beesley and with Martin Hanczyc, action research helped me develop the Hylozoic Ground chemistries. These experiences enabled the cross-referencing of different ideas and practices to synthesize new ideas and approaches, such as developing 'Carbon Eater Flasks', which removed dissolved carbon dioxide and fixed it into mineral form. I also participated directly in the scientific research community by joining in conversations on advanced materials and technologies such as synthetic biology and morphological computing.

The new skills I acquired have been applicable to other related activities such as building an installation at the Synth-ethic group show at the Natural History Museum in Vienna in April 2012 (Synth-ethic, 2011) and for the 'En Vie/ALIVE' group show at the Espace Foundation EDF in Paris, in April–August 2013 (Textile Futures Research Centre, not dated; Meyer, 2000). By engaging myself in field research in the city of Venice, I was able to imagine how the city might find a means of surviving the relentless assaults on its fabric by responding differently to them and found direct evidence to support my hypothesis through field work. Photographic surveys of the waterways and lagoon-side experiments were particularly useful in informing how programmable droplets could become a city-scale morphological computer that would meaningfully produce a form of vibrant architecture within Venice's waterways. By visiting the site during different seasons, I was able to appreciate the different synthetic cycles of the marine wildlife (which were more vigorous in the spring and summer seasons) as well as observe how the accretions grew and even changed colour in niche-specific ways.

Action research methods have enabled me to practically engage with my subject matter through creating new work and reflecting on the outcomes to produce new knowledge, which was transferable to other areas of research. For example, I have provided students in Canada, England, Italy and New York with recipes to make Hylozoic Ground chemistries and have also been able to reach new target audiences, like using a modified 'hygroscopic' form of the chemistry in public demonstrations such as for the UK ArtScience Prize (Ignite, 2013) and also for the Glenfiddich Pioneers event (Future Laboratory, 2010). The downside of action research is the risk of introducing bias into the research and requires steps to be taken to minimize this. However, I did not use action research approaches for scientific experiments and my influence within the systems under study was anticipated and even desired. For example, in documenting the lifelike behaviour of Bütschli droplets, I created the conditions in which it was possible to influence Beesley's decision to use Bütschli droplets as an integral system within the Hylozoic Ground installation.

4.4 Speculative Practice

Speculative approaches are consistent with the theme of probability that underpins my experimental work. As such, to explore the 'adjacent possible' available to vibrant matter in architectural design practice I make frequent use of propositions that are conceptually plausible, yet experimentally unproven. Taking a propositional approach to working with emergent systems has helped me to resist over-directing the outcomes, which carries the risk of skewing, constraining or biasing the research. Instead, speculative proposals help keep solution spaces open for exploration and therefore preserve access to a broad range of possible applications, rather than seeking to advance any particular formal solutions at such an early stage of its characterization. Throughout my research I used a range of speculative approaches including, Design Fiction (Sterling, 2011; Bosch, 2012; Koch, 2013; Sterling, 2013), Science Fiction (Fuller, 2011), 'fictionalism'[29] and 'post-normal' scientific research (Hulme, 2007; Funtowicz and Ravetz, 1992). Additionally, I produced speculative fiction narratives to imaginatively explore issues that were raised during the research period, so that the implications of the emerging materials, methods and technologies could be considered in much broader contexts beyond the laboratory and field (see Fig. 4.1).

Figure 4.1: The use of reflections in my photographic documentation helped me make a transition between objective material study and propositional designs. Photograph, Rachel Armstrong, August 2012.

29 Fictionalism is the philosophical view that a serious intellectual inquiry need not aim at truth (Kalderon, 2005).

Yet these speculative propositions did not stand alone as imaginary constructs but were reflected back on my research findings and design explorations to inform new possibilities; for example, possibilities raised in Chapter 9 informed the production of 'protopearls'. Indeed, speculation is widely used as an architectural research method and includes: the European Commission-funded VISIONS project (Funtowicz and Ravetz, 1992), architectural prototyping (Davies and Vercruysse, 2012) and also Bio Design (Myers and Antonelli, 2013). Indeed, the National Endowment for Science, Technology and the Arts (NESTA) proposes that there is a link between science fiction and innovation (Turney, 2013; Bassett, Steinmueller and Voss, 2013), where speculative approaches build mutual relationships between scientific and design practices – not to predict the future, but to increase the probability that desired outcomes will come true, since storytelling prepares societies for change. Even with no ready means of testing the proposals, speculative explorations can be used as models to represent and compare ideas or to explore incomplete knowledge sets. This allows increasingly more reasoned trajectories to be developed, which may eventually be experimentally testable and gain the status of scientific hypotheses.

4.5 Morphological Computing

> *I long for the day when we can see objects forming, like pools of mud, flowers on a wall or clouds in the sky, as pure products in a context of pure productivity, without any intermediaries. These will be no desires, no opinions, no critics, no designers, just pure flourishing.* (Spuybroek, 2011, p.333)

Architect Lars Spuybroek's vision of a new technological platform that 'is not simply the means to the made, it is the construction of a vast horizontal plane of making' (Spuybroek, 2011, p.332) sounds like a form of Nature. While Spuybroek imagines this design utopia being located in digital computing, my research proposes that it is possible to work with matter directly using a different kind of technological platform to produce lifelike systems that are consistent with the characteristics of Millennial Nature. This is forged by vibrant matter whose fundamental agents form assemblages and can be shaped by internal and external influences. Coordination of these events is called morphological computing, which provides a very different technological platform to machines. Some key differences are summarized in Table 4.1.

Morphological computing is a form of natural computing that originates from a branch of robotics where the physical composition of the system directly contributes to its performance. Where digital computing employs the actions of subatomic particles, called electrons, to embody its binary outputs, the decision-making abilities of morphological computing take place upwards from the atomic to molecular to macroscale events, which are capable of parallel processing. In the context of

Table 4.1: A comparison between mechanical system and natural computer

	Mechanical system	Natural computer
Component	Object	Agent
Order	Series	Parallel
Power structure	Hierarchical system	Non-hierarchical
Functional system	Machine	Assemblage
Energy	Extrinsic	Intrinsic and extrinsic – spontaneous operations may be prolonged with resource supply
Control	Hard	Soft
Transformation	Binary – on/off	Variable states. Generally conservative but may behave unpredictably and collapse or transform at tipping points
Influence	Internal	Internal and external (environmentally sensitive)

vibrant matter, morphological computing enables chemistry to exceed the traditional expectations of materials by tapping into its environmental responsiveness and ability to autonomously produce effects. The aim of morphological computation is to work with, rather than dampen out, the unpredictability of the material realm.[30]

The fundamental design units of morphological computing – atoms, molecules, complex chemical assemblages – couple information flow (droplets, proteins, DNA) and energy transfer with matter during the computational process. Morphological computing is therefore a leaky material system, which is capable of adaptation and change. It does not use top-down instructive programming such as genetic modification, but orchestrates the intrinsic power of matter by promoting the horizontal coupling between heterogeneous agents and working with the passage of time as a creative agency (Prigogine, 1997). In other words, morphological computing establishes the conditions in which the material world – and by implication, architecture – can begin to perceive the world, not merely be acted upon by other agencies. Morphological computing also uses the properties of matter as effectors at many scales, and can read and respond to physical changes by virtue of its parallel processing abilities. It reveals and provides a way of working with the strangeness and dynamic potential of a material world that we thought we already knew by

30 Ilya Prigogine observes that his insights into the irreversible effect of time on a system provided a means to extend the theory of classical dynamics, not invalidate it, noting, 'that we now need to extend classical mechanics … is quite unanticipated. Even more unexpected is the realisation that this revision of classical mechanics can guide us in extending quantum theory' (Prigogine, 1997, p.109).

opening up new design possibilities.[31] A table comparing and contrasting between a process-led view of matter that underpins assemblage technology and the atomistic worldview that informs machines is presented in Table 4.2.

Harnessing the key qualities of vibrant matter in new ways is essential in establishing a platform for a new kind of material synthesis. Key to my research inquiry is that the agency inferred in vibrant matter is not ephemeral, or vitalistic, but is real and takes the form of non-classical behaviour of matter at far from equilibrium states. This is essential for the operationalization of the 'assemblage' platform as a technology, which produces its effects by 'horizontally' coupling complex phenomena together to produce its effects and even generate novelty. Similar processes are observed in natural systems, where, for example, the protein myelin exploits phase changes in its structural system to produce self-assembly (Hewitt, 2013). Rather than viewing myelin as a self-assembling machine, which does not operationalize non-linear phenomena but dissipates them, the protein may be usefully considered as an assemblage whose work is a function of phase transitions that can be provoked by the collective agency of actants. Using different concepts, such as assemblage, to consider Nature-like solutions may open up new strategies for working with materials in architectural design contexts. Importantly, non-classical phenomena may require different infrastructures and initial conditions to machines to harness complexity in their systems. For example, morphological computing operations require appropriate infrastructure such as water or soils, which keep the flow of matter and their chemical processes open, spatialized, multidimensional and temporalized. These tactics enable the system to couple and build on the non-classical dynamics of these systems so they evade the decay towards equilibrium (Schrödinger, 1944) and may even become evolvable.[32]

31 Timothy Morton calls this the 'beautiful soul syndrome', which is based on Wilhelm Friedrich Hegel's formulation of an aspiration to attain moral sensitivity and purity of vision that severs humans from the world of nature and disempowers people from taking action during ecological crisis (Morton, 2007, pp.182–183).

32 Ilya Prigogine notes that entropy is the price for structure, the idea that life might evade the production of entropy by distributing its structures temporally and spatially to resist the production of architectures, but once they occur in themselves they provide the means to continue to resist equilibrium states by increasing the time and space between sets of interacting molecules. For example, biological cells have a long 'endoplasmic reticulum,' which is an internal system of tubes that can maximize flow through the cells and delay the sudden consumption of nutrients. This speculative proposition may be investigated through the technologies of morphological computing. 'Smart' droplets systems demonstrate this possibility by being able to distribute matter in time and space and appear to resist equilibrium, which can be observed as a set of 'living' characteristics (Armstrong and Hanczyc, 2014). Ultimately of course, the system reaches thermodynamic equilibrium but the structures produced by these dynamic acts of resistance may tell us something about the spatial nature of living processes and what kinds of architecture may be desirable to provoke 'living' qualities in technological or synthetic systems.

Table 4.2: Vibrant matter compared with atomism

Characteristic	Vibrant matter	Atomism
Model of reality	Probabilistic	Deterministic
Entropy	Exists at relative non-equilibrium	Operates according to the principles of relative equilibrium.
Physics	Quantum, 'spooky action at a distance' (*Science Daily*, 2013), paradoxical behaviours, not linearly scalable but follows continuity principle (Bohm, 1980)	Underpins classical Enlightenment perspectives, or Galilean 'spell' (Kauffman, 2008, pp.129–149)
Properties	Dynamic. Operates within fields of definable probability that possess limits. Exhibits lifelike characteristics, such as unpredictability, robustness, flexibility, adaptability, growth, movement, sensitivity and evolvability	Fixed, geometric, hierarchical, object-oriented
Boundaries	Permeable	Discrete, fixed
Geometry	Non-Euclidean, chaos, dissipative, organic, manifolds, 'abhors' straight lines (Hundertwasser, not dated)	Euclidean, straight lines
Qualities	Potency, fertility, transformation at tipping points	Brute, inert, requires instruction
Principles	Operates through networks, relationships and flows	Exists as objects, hierarchies with 'essential' qualities
System	Open. Evades decay towards equilibrium. Requires nutrients, energy and removal of waste products	Closed, operates at equilibrium states
Relationship with environment	Contextualized. Continual negotiation with environmental conditions to inform, sustain and augment performance	Belligerent to context
Behaviour	Stochastic	Predictable
Interactions	Cooperative. Constantly negotiated. Formation of assemblages extends fields of operation, which are contextualized according to environmental changes	Insular
Agency	Autonomous force	Requires instruction
Technological system	Assemblage	Machine
Nature	Couples with and transforms natural systems (which also exist at relative non-equilibrium) into subversive, relentlessly material bodies and combines with them as synthetic ecology and post-natural fabrics	Works in binary opposition to Nature

Morphological computing is not exclusively concerned with 'empirical' outcomes and may also include aesthetic (Bateson, 1979) or poetic effects such as Spuybroek's 'entangled knots of mutual feeling and action' (Spuybroek, 2011, p.322). These outputs are created through the collaboration and codesignership between a population of design agents and human designer, or 'programmer', and may produce effects by:

— Modifying an environment (such as changing its acidity to induce movement (Hanczyc et al, 2007))
— Acting as a carrier system to move matter through time and space (Toyota et al, 2009)
— Integrating with other systems to produce highly contingent, synthetic outputs (Armstrong and Beesley, 2011)

Although morphological computing proposes a terrain in which 'life' is a possible event, it does not aim to be a form of artificial life per se. Yet, the emergence of fully 'alive' systems from a morphological computing platform is a possibility, since the solution space in which autocatalytic sets of interacting agents (Kauffman, 2008, p.55) could conceivably become fully autopoietic. Indeed, there are many types of evolution (Gould, 1994) and morphological computing could be considered as a way of conducting experiments in replaying 'the tape of life' (Morris and Gould, 1998), which may ultimately result in artificial biological systems, or new kinds of Nature.[33] Indeed, morphological computing could be considered as a hylozoic system of quintessentially ecological acts, which possess the capacity to produce lifelike events and even artificial 'life' itself.

4.6 Summary

My research develops a practical approach to exploring the principles of vibrant matter and establishes the conditions for its realization within architectural design practice. By working across disciplines, immersing myself within a field of discovery, applying the judicious use of speculation and facilitating convergent approaches, it may be possible to discover how vibrant matter, ELT and morphological computing can be practically applied to influence design outcomes.

33 Timothy Morton proposes that we need to challenge contemporary notions of 'green' practice and how our ideas about 'Nature' influence both cultural and scientific outcomes. Instead, he suggests working with the material conditions that exist in the present, rather than trying to recapitulate ideas from other locations and ambient spaces that are not dominated by humans, such as 'the wilderness'. Morton remarks that 'Nature is always eluding being conceptualized – not because it transcends the material realm – but because it is relentlessly material' (Morton, 2007, p.70).