Performative Apparatus and Diffractive Practices: An Account of Artificial Life Art

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Abstract Drawing on our own art/science practices and a series of interviews with artificial life practitioners, we explore the entanglement of developments at the artistic edges of artificial life. We start by defining key terms from Karen Barad's agential realism. We then diffractively read artificial life together with agential realism to discuss the potential for interventions in the field. Through a discussion of artificial life computer simulations, ideas of agency are problematized, and artificial life's single purposeful actor, the *agent*, is replaced by *agential*, an adjective denoting a relationship rather than a subject-object duality. We then seek to reinterpret the difficult-to-define term "emergence." Agency in artificial life emerges through what Barad calls *entanglement*, in this case between observers and their apparatus, a perpetual engagement between observations of a system and their interpretations. The article explores the differences that this diffractive perspective makes to artificial life and accounts of its materialization.

1 Introduction

In this article we reframe artificial life (ALife) and explore ideas connected to computational life forms, drawing on a series of interviews with biologists and computer scientists. Referring to the philosophies of Karen Barad [2], we argue that there is a need for a new ontology—one that positions ALife as a "lively process." Continuing Helen Pritchard's research on the overlapping or fusing of computational and nonhuman animal bodies [28], we explore the entanglement of developments at the artistic edges of ALife. Our correspondents include the computer scientist and roboticist Steve Grand. His *Grandroids* [14, 15] (virtual creatures [16]) are constructed from models of complex networks of virtual brain cells, biochemical reactions, and genes. We also interviewed the stem cell researcher and liver pathologist Neil Theise. Lastly, we interviewed the simulation expert and member of the *TechnoSphere* [30] team, Mark Hurry. *TechnoSphere*, originally made with Gordon Selley in the 1990s, was a simple ALife environment populated by *creatures*, many of which were designed via a Web interface by online users, with others created automatically by the system to increase the initial population. *TechnoSphere* is now being

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redeveloped as a mobile ALife application making use of GPS, augmented reality, and 3D printing, in response to contemporary debates and technologies that suggest and enable new ways of working with material and embodiment. In the new *TechnoSphere*, simulated creatures enter the physical world in 3D form, and the environment the human inhabits affects the ALife system and the creatures, with users and creatures becoming blended.

We discuss the use of ALife computer simulation as apparatus by artists working with scientists in projects like *TechnoSphere*, to suggest that artists using existing scientific apparatus produce and participate in intra-actions through which understanding or knowledge emerges. Both *TechnoSphere* and *Grandroids* might be described as profound material-discursive reconfigurations of bodies and processes.

2 Material Practices of ALife Art: A Timeless Story?

Much discussion surrounding ALife in the 1980s and 1990s focused on ways in which technical artifice can produce life or "lifelike behaviour" [37]. This emphasis led to an understanding of ALife as a human-designed process that described the autonomous animation of inanimate material through formal models inspired by natural phenomena. The *weak* conception of ALife as "computationally based models of natural biological systems" [24] is built around a human protagonist (programmer) breathing life into technical artifice, writing a lifelike program that potentially exceeds the programmer's rules by displaying emergent behavior, which is discussed later. The key to this definition of weak ALife is the use of the term "model." Claims for *strong* ALife suggest it is possible not only to model but to *create* life, using other media such as mechanical automata, chemical life, or the computational medium of a computer. The associated idea that life is a medium-independent phenomenon [24, 7] has been challenged [27] by comparisons with one cybernetic concept of the mind that views cognition as embodied and embedded, both ecologically and socially [5]. This debate has led to a revision of the definition of strong ALife that focuses on the usefulness of seeing life as dynamic processes intra-acting with their environment, rather than seeing a specific material that constitutes "aliveness." While noting these weak and strong positions with regard to ALife, we are not subscribing to the belief that ALife is computationally based, nor that computation lies at its core. By contrast, central to our thesis is the argument that at no point can any tool (computer or otherwise) be considered neutral in the production of ALife, which we consider to be an embodied and situated practice. As we have learnt from ALife studies of emergent behavior [7], there is more to ALife than what is breathed into it by a human designer. Emergent behavior accounts for the agency of ALife systems, and emphasizes that ALife is more than the enactment of a textual instruction, such as source code, on matter. It has long been understood in ALife practices that the activity of reading source code representations of ALife will not necessarily result in a clear understanding of the behavior of an ALife system [23].

ALife has repeatedly reconfigured our practices and caused us to reconsider the boundaries of the living and the artificial [34, 31]. However, despite their openness to engaging with the systems we design [1], ALife theories have remained bound to ontologies that privilege the opposition of life and artifice, inanimate and animate material, nature and culture. In this article we go beyond the idea of ALife as a solely human pursuit to argue that ALife *materializes* through the properties of nonhuman elements such as the hardware and software employed, through the discourse that surround these and the practices of their application. We suggest that ALife is not the practice of "breathing life" into inanimate matter, but an entangled and co-constituted process emerging from the material discourse of ALife itself.

We now define key terms from Barad's framework relevant to this article, specifically "agential realism," "intra-action," "entanglement," and "diffraction." We later relate them to ALife.

3 Summarized Definitions of Key Terms

Agential realism is a theory proposed by Barad using analogies from quantum physics to re-conceptualize the practices and processes through which scientific objects and knowledge are created. Agential realism rethinks agency within scientific practices [2], demanding that we understand how the apparatus of science (for instance, ALife models or simulations) are formed through practices, for example, looking through a microscope to observe the chemical process through which a cell is formed. “According to agential realism, knowing, thinking, measuring, theorizing, and observing are subjective material practices of intra-acting within and as part of the world” [2, p. 90]. Barad uses the term “agential” or “agentially enacted” in place of “agency,” to connote the complexity and contingency of an agency that emerges from the interplay of relations between loosely bounded entities. The new sense of causality suggested by Barad is not the simple combination of classical options often presented in the humanities-and-science debate, that “on the one hand there is absolute freedom in our choices of apparatus, and, on the other strict deterministic causal relationships” [2, p. 130]. Instead, agential realism proposes a positive conversation between the disciplines and is a useful framework for considering ALife agents that at once seem to have boundaries and yet are acknowledged to be an intrinsic part of a wider environment.

Interaction and intra-action. The term “interaction” is common in discussions of multi-agent systems (MASs), agent-based systems (ABSs) [39], and ALife. In those contexts, interaction assumes that there are separate individual agencies, or agents, and that such separation between entities precedes their interaction. Intra-action works as a counterpoint to the model of interaction, signifying the materialization of agencies conventionally called “subjects” and “objects,” “bodies” and “environment,” through relationships. Intra-action assumes that distinct bounded agencies do not precede this relating but that they emerge *through* it.

Entanglement is a key part of Barad’s agential realism that works on a number of levels. Barad suggests that different entities interweave and entangle, in an ongoing process of intra-action, resulting in the production of new entities that, in turn, entangle with others. Entanglements are distinct from a blended mass. “Entanglement does not mean that what are entangled cannot be differentiated, discussed or remedied, only that the different entangled strands cannot be adequately dealt with in isolation, as if they were unrelated to the others” [18, p. 43]. An intra-active understanding of entanglement also demands that individual strands are not to be understood as self-subsistent entities, but as continuously and co-constitutionally refigured in, and through, their mutual interdependence [18]. Barad uses entanglement to discuss all scales of relationality from the entanglements of ontology and epistemology to those of observed and observer.

Diffraction. We conduct a *diffractive reading* of ALife practice and Barad’s agential realism [2] in order to move beyond thinking of the disciplinary domains of science, theory, and art as separate, and rather to see them as entangled, that is, retaining difference, variation, and heterogeneity. Donna Haraway [19] suggests that the metaphor of diffractions can be a useful counterpoint to reflection. Both are optical phenomena, but whereas reflection creates a mirror image, or a copy, diffraction attends to patterns of difference. As Lynne Keevers and Lesley Treleaven explain, “diffraction produces the spectacular colours and rings sometimes seen around the moon. These rings cannot be attributed to the moon or the clouds but are produced through the intra-action of the moon and the clouds” [21, p. 509]. We find the optical metaphor of diffraction is productive for re-thinking the entities, agencies and events that emerge from ALife art practice. It is noteworthy that diffractive methodologies build on feminist theories of situated perspectives [20, 19, 35]. In diffractive approaches “the point is not simply to put the observer or knower back in the world (as if the world were a container and we merely needed to acknowledge our situatedness in it)” [2, p. 91], but to see no separation between subject and object, which are instead entangled in *phenomena*. Diffractive methodologies are not objective, and do not offer an undistorted mirror image of the world; rather they are methods of accountability and responsibility to the entanglements of which we are a part [2].

4 The Observer and the Observational Cut

In 1973 the Chilean biologist Humberto Maturana, working with his student Francisco Varela, brought together the concepts of homeostasis and systems thinking to describe what they termed “autopoiesis” [38]. They defined such living systems as self-producing mechanisms that maintain their particular form, despite material inflow and outflow, through self-regulation and self-reference [25]. Importantly for Maturana and Varela, the observer was "a living system and any understanding of cognition as a biological phenomenon must account for the observer and his role in it" [25, p. 48]. The observer, they explained, "can only subdivide a system in parts that he defines through his interactions, and which, necessarily, lie exclusively in his cognition domain and are operationally determined by his mode of analysis. Furthermore, the relations through which the observer claims that these parts constitute a unitary system are relations that arise only through him by his simultaneous interactions with the parts and the intact system, and, hence, belong exclusively to his cognitive domain" [25, p. 48]. The human observer is therefore inextricably entangled with the system she observes. The authors go further, highlighting the importance of the observer's use of instruments in the descriptions of any system being observed, and we address this in detail later.

ALifers have been forced to "confront the difficulties posed by having multiple observers embedded within this world whose measurements are necessarily local and relative to each other and whose interactions can potentially alter its dynamic course" ([10, 25, 33], as cited in [6, p. 16]). In ABSs it has been ascertained that it is not simply that the observer will cause what is observed, measured, and described to emerge differently, but that these observations, measurements, and descriptions are also defined by the order of the events that define the reality of what is measured: "the history (or order of events) measured by each observer creates the reality that this observer perceives as the evolution of the system" [6, p. 17]. This is what Barad might describe as a process of space-time-mattering ("existence is not simply a manifold of being that evolves in space and time"); rather, agencies materialize through iterative intra-action [2, p. 234]. It might be said that in ALife software that exhibits behaviors characteristic of natural living systems, nothing is inherently separate from anything else. Barad introduces the term *agential cut* [3] to draw attention to temporary separations. Her term attempts to capture the understanding that any act of observation makes a cut between what is included and what is excluded from observation or consideration. Barad's agential cut includes what we describe as an *observational cut*. We have found Barad's agential realism highly relevant to ALife as discussed by Maturana and Varela. In the following quotation, taken from their list of the epistemological and ontological implications of the observer, they use italics to highlight the difference between reality and descriptions of it, drawing attention to the importance of the use of instruments in the act of observing, measuring, and describing: "[t]he observer generates a spoken *description* of his cognitive domain (which includes his interactions with and through instruments). Whatever *description* he makes, however, that *description* corresponds to a set of permitted states of relative activity in his nervous system embodying the relations given in his interactions" [26, p. 39].

Using our experience of developing CELL, an agent-based simulation [29], we now look closely at the relationship between processes and practices that constitute the ALife simulation of stem cells in light of the ideas of Barad, Maturana, and Varela. This development of ALife software based on natural biological systems, like many objects of science, results from numerous observational cuts.

Prophet visited the stem cell researcher Neil Theise to better understand the laboratory practices used to test his hypothesis that stem cells in the adult body were more plastic than had previously been thought [9]. Looking back at that experience, and associated conversations with the CELL team member and mathematician Mark d'Inverno, about their various methods and practices, we suggest that this collaborative interdisciplinary work included a series of observational cuts, each of which affected the resulting ALife simulation. Those practices included cell biology's experimental protocols and material arrangements, which can appear to be reductionist. As Maturana and Varela might say, Theise's cognition domain was operationally determined by his mode of analysis. For example, Theise tested the plasticity of stem cell behavior by looking at cross-gendered therapeutic transplants, specifically, tissue from women who had received male bone marrow transplants and tissue from men who had received female donor organs. Theise also took stem cells from living 3D dynamic organisms such as mice with transgene expression of GFP in all their cells. The mice were sacrificed at various stages of maturity to look for changes in cell plasticity as the cell lines in the mouse reproduced. Prophet found the necessary act of sacrificing the mice surprising in that it immediately stopped the dynamic activity of cell behavior that was changing over time, the very process that was under scrutiny; but for Theise, studying nonliving tissue to understand the behavior of living cells was accepted as a necessity, as there was no method for observing the cells in situ in a living mouse body. The process of observation was via human interactions with instruments that enabled the stem cells to be observed and *described* (we use Maturana and Varela's italics here). The first observational cut, the moment the organism died, was somewhat arbitrary, the result being as much about all the moments in time that were not chosen as about the moment chosen. The dead organism, temporarily and temporally "frozen," was nevertheless three-dimensional and whole. The second observational cut was the selection of areas of the mouse body to biopsy and the discarding of the rest. The third observational cut, also a physical cutting, reduced the tissue sample to two dimensions. Very thin tissue slices, necessary for close observation on slides under the microscope, were produced from these biopsies, another observational cut that left out more tissue than it retained. The final cut was the material interference of staining, which transformed the tissue slices, introducing artificial color to highlight some areas and obfuscate others. Theise became acutely aware of these acts of translation:

> The possibility for making a minute change [to a biological system] through the processes of observation and interaction are always present, and potentially change the nature of the system's self-organisation. (Neil Theise, pers. comm.)

To describe Theise and Prophet's differing methods is not meant to perpetuate the idea that "[i]f molecular biology is mainly reductionist in approach, one of the suggested promises of Alife research is, that by allowing for emergence of lifelike processes in the computer and ultimately for 'synthesising life', Alife is a way to overcome the gap between holism and reductionism in theoretical biology" [11, p. 96]. The problem with any simple polarizing of molecular biology and ALife is exemplified in CELL, where the ALife is built upon data from the research of molecular biologists. Instead of polarization, we suggest that the reflexive, situated, and embodied use of vision instruments like tissue slicing machines, stains, slides, and microscopes enlarges the cognitive domain of the observer. Indeed, Theise's reflection on the collaboration includes:

> I have not adopted a new methodology in terms of what is on my lab bench [...] but the way I conceptualise stuff set intellectual processes in motion that have not been played out. I do not ask the same questions that I used to ask. I create hypotheses that are different than I would have. I see things that other people in my position don't. (Neil Theise, pers. comm.)

Observational cuts are part of developing ALife software, especially that which is based on natural biological systems. Such software is both a description, based on observations, and a system. To write the CELL software we gathered together numerous descriptions in the form of medical and biological data, represented in research articles that were written after researchers had gone through the sorts of processes described above. Key discourses are part of all these practices, and we cannot ignore the discourse of scientific publishing that led to the broader collection of articles available to us. The next series of observational cuts occurred in relation to which articles we studied (only those written in English) and what parts were taken from those articles. From this collection of data we wrote a *plain English* model, a *description* of what we knew about how cells behave, which lead to a 'Formal' model, or set of rules. Even if the English model (description) were able to gather together all known medical and biological research data about how stem cells behave in the adult human body, the resulting formal model would remain full of gaps, lacking fine detail. This is because while more and more is known about natural biological systems, such as stem cells in the adult human body, there remains a huge amount that we do not understand. These models led to the rules embedded in subsequent computer code and algorithms that formed the ALife engine for CELL. In summary, all these practices and processes in laboratories and computing departments were necessary to develop the apparatus of CELL's ALife software. As we produced the apparatus, we were aware that we could not define the way that stem cell systems work in plain

English, let alone in computer code, and our model (like most models) was much simpler than the process it represented. The complexity of the natural biological system we were simulating had been immeasurably reconfigured by the observational cuts of human, nonhuman animal, and computational agencies.

5 Intra-action, Emergence, and Observer

Emergent behavior is the phenomenon whereby a system of interacting agents, each behaving according to a simple set of rules, seems to exhibit behavior that has not been programmed in those simple rules. In natural biological systems, ant foraging behavior is often cited as an example of emergent behavior. Each ant is believed to be walking around following some simple rules, but when many ants walk around, each following the same rules, their interactions cause unexpected behaviors to emerge that could not have easily been predicted by studying the behavior of one ant [13].

Scale and observer distance are important in observations of emergent behavior, enabling the observer to see higher-level organization obfuscated when looking at a system close up. Just as looking at the structure and growth patterns of one tree might not reveal it was part of a forest (higher levels of organization are not determined by lower levels of organization), emergent behavior is often said to be "greater than the sum of the parts." Langton, writing about ALife in 1987, claimed that "The 'key' concept in AL is emergent behavior. Natural life emerges from out of the organized interactions of a great number of non-living molecules, with no global controller responsible for the behavior of every part. Rather, every part is a behavior itself, and life is the behavior that emerges from out of all of the local interactions among individual behaviors." It is important to note, however, that "[t]he field of artificial life (Alife) is replete with documented instances of emergence" [32, p. 13], though Ronald notes that there has been debate as to the meaning of this term.

Our agential realist approach to understanding configurations of ALife sees them as emerging through material-discursive relations. Emergence is performative and occurs through intra-actions that include the discourses surrounding instruments used in the act of observation and of configuring. Examples are discourses about the specificities and limitations of the microscope [8] and discourses relating to the fields of science in which these instruments are used, such as strong versus weak ALife. Using an agent-based analogy, we might say that discourse is part of the "environment," influencing the behavior/state of an agent/thing. In many ALife works, intra-actions occur between matter, most commonly natural biological systems, which are subjected to observations and measurements via instruments such as microscopes and sensors, and to modeling using computer programs. ALife as a field has been, in part, a study of the interplay of human bodies, human and animal bodies, humans, animals, and instruments; at the very least, ALife has made connections between these its focus. Moreover, ALife and its often related discipline, ABSs, has developed *observer agents* as a response to the *observer effect*—the awareness that the act of observation has an impact on any phenomenon being observed. Observer agents are an acknowledgement of the "contamination" of systems by observers, or, we might say, the intra-action of the observer in the natural system. Such agents are designed to address the perception that "human observers have limited observation capabilities: some relevant aspects of interaction may escape their attention; moreover they can be biased in collecting use data" [4, p. 43]. Intra-action disrupts theories that presume that there is clear separation between the observer and the observed, that we can draw a distinction between bodies, between, for example, human and machine.

We propose that the ABS, as it relates to ALife, might be usefully reconsidered, by adopting Barad's intra-active premise that all agents emerge from the assemblage that they are an inherent part of, and that they are not individual and rarely separate from one another or their environment (our discussion of observational cuts addressed the rare instances where separation occurs). According to Bateson [5] and Varela [38], entities do not exist singularly but rather emerge through cognitive sensory perception with the world and, for Bateson, through circular causal loops. This is similar to how Barad conceptualizes knowing as a form of intra-activity; however, for Barad there is no clear differentiation between agent and environment—in fact, her agential realist framework assumes that the material world (including, in our argument, combinations of matter, software, humans, and animals) is a constant *process* of becoming or being, and therefore agents are always emerging. Barad argues that our notions of linear causality should be replaced by entanglement, the emergence of processes through intra-action between entities, for example, the human researcher and nonhuman material processes. As Barad explains, "It is important to note that the 'distinct' agencies are only distinct in a relational, not an absolute, sense, that is, agencies are only distinct in relation to their mutual entanglement, they do not exist as individual elements" [3, p. 33].

"Intra-action," key to Barad's agential realist framework, is a neologism describing the process of materialization, connection and emergence, and resonates with some characteristics of MASs. MASs are commonly held to be software, composed of agents and their environment [39, 21]. However, a broader definition of MAS allows for the agents in a MAS to be other than software. Agents might be robots, humans, animals, or less apparently animate matter, or combinations of these. This definition of MAS shares some characteristics with agential realism. In MASs and agent-based systems, individual agents are usually characterized as bounded and rational. They perceive and act according to the computational rules that define them, to further their own interests. MASs are useful for gaining insight into the collective behavior of agents obeying local rules, such as cells in the body. The environment in which an agent is situated is central to the MAS and to theories of the associated field (ABSs). In an ABS, the environment (or model of it) is as important to the overall system being modeled as the individual agents are. However, while MASs and ABSs assert the equal importance of agent(s) and environment, these are commonly held to be separate, with the environment having one set of rules by which it is determined and the agents having other rules. While the agent(s) and the environment may constantly interact and influence one another, they are, at the same time conceptually separate.

ABS experts may dispute our interpretation of their use of the term interaction. It is certainly Prophet's experience of developing the ABS of stem cells [9] that the team she worked in believed there was no clear isolation of the cell from the environment of the human body—moreover, that the so-called *boundaried environment* of the human body was only nominally separate from the larger environment, with porous borders between human and nonhuman (e.g., orifices, skin, membranes), resulting in blurred boundaries [12] and an ever more complex, constantly emerging and changing, entangled system. However, it was common practice for the CELL team to temporarily think of agents as isolated from their larger environments and/or from one another in order to develop a clearer sense of how, for example, a particular type of cell behaved, as described in our discussion of observational cuts. To develop their ABS, CELL referred to material discourses of then-current research in stem cell behavior, visiting labs, attending stem cell conferences and reading peers' articles to define the characteristics and behavior of individual cell types [36].

6 ABS, the Observer, and the (Meta-)observer

While it is common to many ABSs that the observations of each agent (in this case, each cell) are modeled as part of the system, we wanted to extend this modeling of observers to take account of those that we might term (meta-)observers—specifically, CELL's human scientist and programmers who designed, wrote, and ran the program. These (meta-)observers might be described as observing the ABS and explaining, discussing, and writing articles about it for scientific peers who are similar (meta-)observers. This account of our practices as (meta-)observers, evident in our recorded discussions, recognized that *what* we observed (the ABS, the formal model, the mice in the wet lab, the slices of human and nonhuman tissue) was affected by *how* we made our observations. We reminded ourselves that even though our synthesis remained scientifically useful, our practices would always lead to a partial and flawed synthesis (because we would be writing a formal model that did not take full account of our impact as (meta-)observers). The belief that we cannot isolate observers from the things that they observe, from "the real world out there," is prevalent across a wide range of disciplines, from social science, where scientists "must consider multiple observers in a continual co-evolving interaction with each other and with their environment" [6, p. 2], to quantum physics, where distinctions between observer and observed are replaced by “a symmetric notion of mutual observers interacting with each other” [6, p. 16].

The observation of emergent behavior becomes contentious given our discussion about the impact of the observer on a system; the temporary and disruptive act of the observational cut, the expansion of the human observer’s cognitive domain via instruments, and the way instruments that have been designed to show particular things may leave out more than they reveal. It would seem that “seeing” emergence is contingent on all the interferences and entanglements listed above. Therefore, we agree with Ronald et al. that we should be wary of proposing that emergent behavior is occurring “whenever the unexpected intrudes into the visual field of the experimenter” [32, p. 13]. In summary, that emergence, relative to any ALife model, is “the deviation of the behavior of a physical system from an observer’s model of it” [7].

7 The Apparatus of ALife

The agential realist discussion of representation is premised on an understanding that the act of making representations is performative and that representations and the objects they propose to represent are not independent of each other [2]. Barad uses the term “apparatus” to elaborate on the performativity from which the representations of an experiment emerge. For Barad, apparatus includes both processes that get labeled as “scientific” and processes that get labeled as “social.” An apparatus is not just the set of instruments or mediating devices needed to perform an experiment, instead, it is the arrangement of nonhuman and human material-discursive forces (such as formal models, algorithms, microchips, computational textures, floats, objects, single-cell creatures, GPS technologies, minerals) through which particular concepts are given definition and through which particular physical properties are produced [2]. The microscope is a useful example of an arrangement of nonhuman and human material-discursive forces: “Before cell doctrine emerged, other possibilities were explored. The ancient Greeks debated whether the body’s substance was an endlessly divisible fluid or a sum of ultimately indivisible subunits. But when the microscopes of Theodor Schwann and Matthias Schleiden revealed cell membranes, the debate was settled. The body’s substance is not a fluid, but an indivisible box-like cell: the magnificently successful cell doctrine was born” [36].

What is key in understanding the apparatuses of ALife is to recognize that they are boundary-making practices, through which particular simulations of ALife with particular meanings emerge, and that these simulations of ALife are themselves also part of the apparatus they emerge from. The recognition that representations are performative demands that we heighten our awareness of what is “in process” when representational techniques are used, when time-based events are represented via still images, when three-dimensional objects are represented in two dimensions, or, in the case of ALife, when algorithms are represented via 2D or 3D graphics or audio. In this section we discuss with practitioners of ALife the performances of representation through intra-actions within ALife practice. It is important to flag here that our engagement with ALife representation is not an attempt to redraw the distinction of “life made by man and life made by nature” [22], nor do we wish to imply that the representation of dynamic entities is merely an illusion or snapshot of life. Instead we are proposing that ALife emerges from a “condensation of multiple practices of engagement” [2, p. 53] distributed across humans and nonhumans, across nature and culture. We seek to understand the effects of ALife practices as an engagement that creates real consequences, creative possibilities, and responsibilities.

In developing ALife or multi-agent systems, the representation of entities that were dynamic as entities that are static is a performative process that includes observational cuts such as those necessary to develop the CELL simulation. Similar performative processes are at the heart of the creation of most simulations of complex natural systems—multiple representational events (multiple observational cuts) take place to create simulations, each of which abstracts, simplifies, and distorts the subject. The resulting simulations often affect previous understandings of the entity being simulated; for example, the ALife simulation of stem cells in the adult human body changes our understanding of the natural biological system it represents. In ALife "subject and object do not preexist as such, but emerge through intra-actions" [2, p. 214]. We can see this emergence through intra-action in projects such as *Grandroids* [14], the development of an ALife system based on many years of work across neuroscience, robotics, AI programming, and games design. In an interview for this article, Grand gave an example of how working with matter intra-acted with his simulations of the brain by discussing the influence of his robotics work [17] and building physical mechanisms:

> One thing [building physical mechanisms] gave me, was what it took away from me, namely, the opportunity to cheat. Once you deal with "real" matter as opposed to "simulated" matter, when faced with real problems you can't get around them. [...] The constraints of the medium drive you forward. [...] By building the physical thing I could see and understand patterns and relationships that helped me to solve the problems that I did not know how to solve. [...] There were things I saw, patterns I understood from working with electronics that had commonality with things I saw in the brain. (Steve Grand, pers. comm.)

8 Subject and Object (E)merging through Intra-actions

Many ALife projects use code, often derived from plain English and formal models of biological systems, to drive simulation. Both the plain English and formal models are representations [9], as is the subsequent ALife simulation. Therefore, in the case of the simulation of stem cells [9] the ALife simulation of cells is performative. In summary, ALife models of natural biological systems—including the application of ideas and principles from biology and evolution to computer science in the areas of optimization, intelligent agents, and engineering—feed back to, and change our understanding of, the biological sciences. Our understanding of the natural biological systems, and the experience of biological systems themselves, emerge through the intra-active process of making representations and through direct material engagement with the world. Knowing and being aware of the performative nature of these scientific practices has an influence, makes a new scientific practice, and contributes to positive conversations between science and the humanities/arts. Theise expanded on this:

> When we had the simulation running, the stem cells sent off little bursts. That's not in the [biology] literature. It suggested that rather than being a continual flux of stem cells from the bone marrow into the circulation, that they happen in a cyclical, burst-like fashion. That's predicted by our model and we could do experiments that would test to see if that is happening. If we find that they do behave like this, in burst, then we have a new understanding of the biology, if we do *not* find that, then we'd know that something in the model needs tweaking. The first question is not, is the model wrong? [...] The first question is, is there something in the biological system that we have not observed before, because we did not look for it? Our model suggested new things to look for. (Neil Theise, pers. comm.)

Reconsidering our approach to the way we make representations is one of the desires driving the new versions of *TechnoSphere*, currently in development. *TechnoSphere*'s Mark Hurry notes that the 1990s version consisted of an ALife system that was closed to the human user, who had no control over a creature they had created:

> Interaction with the original version was about creating the creature and then receiving email updates when the creature did something interesting, or going online and seeing what the creature stats were, very much a passive observer type experience. The first 3D version added the ability to follow the creature around a virtual world and observe its

interactions with the environment and other creatures, but no interaction or further control by the user. (Mark Hurry, pers. comm.)

By contrast, the contemporary *TechnoSphere* application takes accounts of the entanglements of the real environment, computational system, and human and ALife creatures. The situated act of observing the creature, by activating GPS in the app, has immediate impact on the creature being observed, as GPS-related data becomes part of their behavioral controllers.

> Presenting the 3D creature in its real world environment, [by] incorporating the user's GPS position as way of locating the creature in the real world [...] could lead to creatures interacting with specific places [...] Data collected from other on-board sensors such as light meters, could allow a creature's visual acuity to be affected by differing light levels from day to night, but also from lit to unlit locations. (Mark Hurry, pers. comm.)

9 Conclusion

Throughout the article we have made a diffractive reading of Barad's agential realism, through the practices of ALife and ABSs. Through translations between terms such as ALife's "agent" and "agential realism," ALife's emphasis on the boundaries between agents come to matter [2, p. 210]. In the transformation of ALife concepts of interaction to Baradian theories of intra-action we recognize the ongoing entanglement of the observer and the observed. Diffractively reading Barad's understandings of observational cuts against ALife practices reveals their entangled intra-actions.

The authors now have a new awareness of the formation of ALife apparatuses, including our way of thinking, our conceptual models. In projects like CELL, we accept that ALife code is not separate from cellular systems, but rather our understandings and models themselves emerge, are emergent, when we as humans intra-act with ALife apparatuses. We should be mindful of the performativity of ALife apparatuses, the oscillation between inclusion and exclusion that material-discursive structures offer. However, we should also be open to the potential that apparatuses have to 'reveal'. If we recognize that an apparatus is performative, we can be open to the generative potential of new ALife, or new experiences of known ALife, in a different way. Allowing for our own agency (or, as ALife would suggest, allowing for the influence of our role as observers of the diffraction) caused us to shift from describing our inquiry as diffractive reading to what we term "diffractive practice." "Diffractive *practice*" reminds us that we are not simply observers or readers, but artist practitioners; it prompts us to make close readings of our practices as artists, as well as the practices of the biological and computer scientists that we work alongside. Often we each become so acclimatized to the norms of our own practices and processes that we become blind to them. The perspectives, experiences, contacts, and discourses that have formed the artist's apparatus are qualitatively different from those of an experienced cell biologist or mathematician, each of whom is familiar with their everyday apparatus. We believe it is possible (but not automatic) that the diffractive practices of collaborative teams composed of members from different disciplines can expose blind spots via the questioning of one another's necessarily unfamiliar processes and discourses, in other words, one another's apparatuses. We hypothesize that close readings of diffractive practice-as-it-happens will further highlight the interferences between our patterns of practice.

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