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Many-Headed: Co-creating with the Collective

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In this essay, I critically reflect on my artistic encounters with the slime mould, *Physarum polycephalum*. Since 2008, this non-neuronally intelligent organism has provided stimulus for diverse creative enquiries and speculative actions, including time-lapse studies (testing and revealing behaviours), objects and installations (for public exhibition), and embodied encounters (inviting groups of people to enact slime mould rules). Focussing discussion on selected projects and processes developed over the past decade, connecting public audiences with slime mould behaviours, I will address the organism as a working material to be manipulated, coerced, or encouraged to 'perform' and as a conceptual model, to explore notions of embodied intelligence between human and nonhuman entities.

Whilst looking directly at the collective behaviour of the organism, the narrative also addresses wider processes of human enquiry, the slime mould as a vehicle for curiosity and discovery. The concept of *polycephalism* – many-headedness – here relates not only to the internal cellular mechanisms of the slime mould, but to the methods developed to connect diverse ways of thinking and working in a process of co-enquiry. My artistic practice is a literal and symbolic investigation of information distribution mechanisms, diverse knowledge systems, and collective intelligence – an invitation for interdisciplinary and interspecies encounters. This essay is as much about the emergent properties of the creative process and the interactions between disciplinary approaches, as it is a study of the properties of slime mould itself.

3.1 Introduction

As an artist I have long enjoyed working with biological materials, having previously cultured my own skin bacteria, built growing installations employing the tropisms of seeds, and experimented with the camouflage capabilities of cuttlefish[1]. Working with living matter is a balance between artistic intent (my ideal impositions) and biological behaviour (the characteristics inherent in the organism). To a great extent, this logic can be applied to any process of making, a negotiation between artistic aspiration and material property – form cannot be imposed upon a piece of marble but must be carved out with consideration to its inherent structures and imperfections. This need to understand material properties is, however, more prevalent when working with a living system, where the material in question possesses agency and exists within its own 'ümwelt'[2]; and where motivations, perceptions, and intentions relate to vastly different needs. Here, the subjective reality of the organism operates through unfamiliar sensory and communication mechanisms and notions of artistic control and authorship are called into question.

My first encounter with slime mould took place in July 2008 when I was gifted a live culture after a visit to the laboratory of Dr Simon Park at the University of Surrey[3]. It was a speculative meeting to share common interests in microorganisms and exchange creative activity across art and science. As I prepared to leave, aware that I had worked with living organisms before, he handed me a petri dish containing a small yellow blob. The only care instructions given were that it liked to be kept dark and damp and its favourite food was porridge oats. Simon had a hunch I would be intrigued by the structure and behaviour of slime mould. He wasn't wrong.

The organism in the petri dish was *Physarum polycephalum* – literally meaning the 'many headed' slime mould – one of over 700 known species of slime mould, a single-celled organism that lives a relatively quiet existence digesting rotting vegetation in temperate woodland. A slime mould cell may contain thousands, often millions, of individual nuclei, fused together and operating as one collective entity. Within the organism, a channel of protoplasmic streaming[4] distributes nutrients across the cell mass,

[1] A portfolio of previous works can be found on my website at: www.heatherbarnett.co.uk

[2] Literally translates as 'surrounding world' – a term coined by German biologist Jakob von Uexküll relating to how an organism perceives its environment uniquely and subjectively.

[3] Simon Park has worked for many years at the intersection of microbiology and art. Many of his experimental practices can be viewed on his blog *Exploring the Invisible.*

[4] A regular rhythmic oscillation within a vein-like structure. It is within this pulsing mechanism that many of slime mould's achievements are believed to lie.

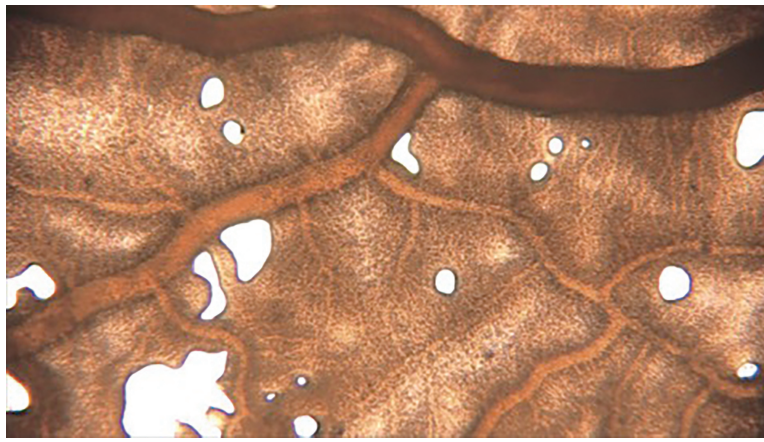

Figure 3.1 Protoplasmic streaming within *Physarum polycephalum*.

as well as communicating valuable chemical information about environmental conditions (Figure 3.1). It has built-in mechanisms enabling it to compute a range of cost/benefit trade efficiencies and allowing it to make variable decisions without a brain. The slime mould has demonstrated that it can recognise pattern by anticipating events and is entirely self-organising, with no centralised control system – purely a mass of cellular cytoplasm operating at a capacity far greater than the sum of its parts.

3.2 The *Physarum* Experiments

Safely housed in a shoebox and growing on a moist substrate, I began the rather ad hoc process of empirical enquiry and discovery. My new studio pet was fed on an eclectic diet of foodstuffs, including decaying plant matter and desiccated insects (Figure 3.2). Its material environment contained a range of materials with different 'moisture holding' properties and its housing ranged in size and material form, from laboratory glassware to Tupperware. My initial thoughts were that I could get the organism to draw for me, that I would lay down a trail of food and that the slime mould would dutifully follow, creating intricate growth patterns along the way. It soon transpired, however, that this was a naïve assumption.

I ground down oats and boiled them into a paste, which was then piped into shapes and lines. I placed food on pieces of felt and moved them around, following the growth trajectories through a combination of time-lapse photography and stop frame animation. This was an intuitive process of

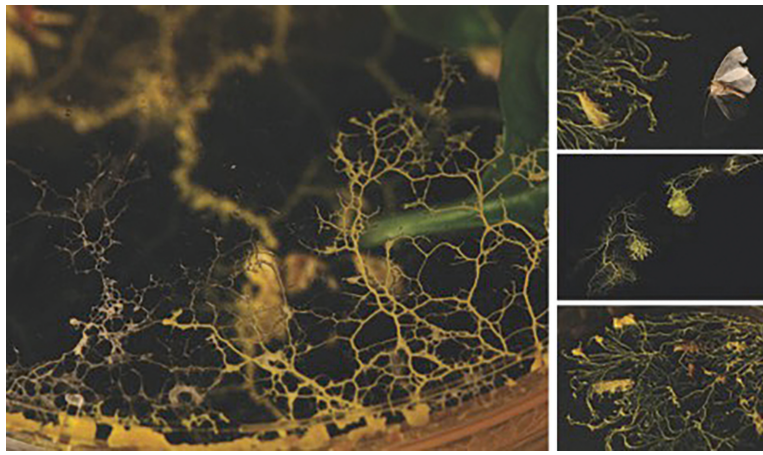

Figure 3.2 Early culinary experiments with *P. polycephalum*.

trial and error in intervention and observation, learning from the organism's response to given stimuli. Through this process, it became apparent that any ideas I had of imposing my own aesthetic sensibilities on the organism were not necessarily compatible with the organism's own desires. Rather than trying to coerce the slime mould into doing what I wanted, it was clear that I needed to work with its inherent properties instead, to understand its fundamental needs and behaviours and use them as a starting point for experimentation. If this 'collaboration' was going to go anywhere, I needed to work with the slime mould on its own terms.

Hence, a process of enquiry followed with a meandering trajectory, exploring to what extent I could affect the organism's behaviour. By understanding its motivations, intentions or reactions, I could learn how far I could control or influence its growth and pattern formation. My early time-lapse studies lacked consistency. Without an automated set up to capture the pace of growth – I simply took a photograph manually when I could – the results were haphazard, with time frames shifting at irregular intervals (Barnett, 2008). Whilst these early studies had low production values and lacked aesthetic 'flow', they provided enough visual feedback to indicate that something interesting was going on, that the organism would respond to given cues and exhibit novel behaviours (Figure 3.3).

As my time-lapse techniques improved, the organisms' behaviours began to reveal themselves more clearly through my interventions. For example, in *Study No. 011: observation of growth until resources are depleted*

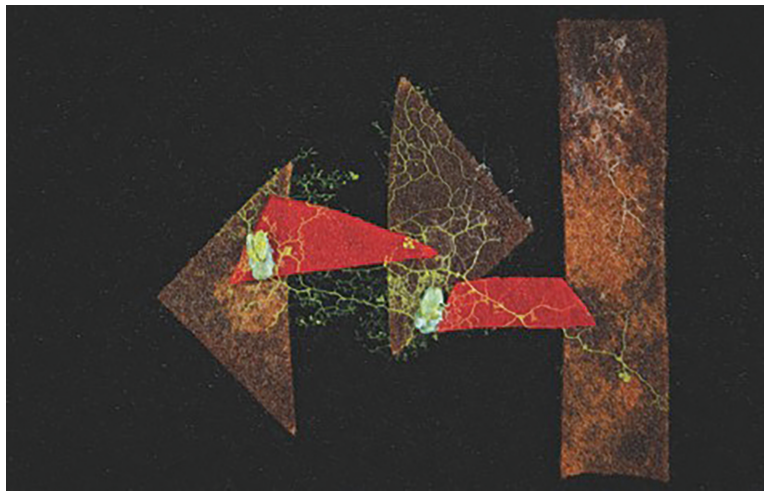

Figure 3.3 Film still from *The Physarum Experiments, Study No: 008* (2009).

(Barnett, 2009), having fed on a pile of porridge oats, the slime mould went off exploring in two directions simultaneously. At one point, the two branches grew towards one another, but before they collided, the growth slowed, paused and then reversed direction. Somehow the slime mould knew it was already there and should divert energies into exploring new territory elsewhere – a point of recognition, decision and action (Figure 3.4). I was impressed that an organism with no brain or sensory organs could map its environment in such an efficient manner and operate with seeming intention.

What then developed was a process of influence and observation; I would encourage growth with attractants, or discourage with repellents, and note the responding behaviours and structures. The artistic process became one of 'creating the conditions for something interesting to happen' and then observing the outcomes, choosing to intervene (or not) depending on what I was exploring. Over time, I have created a number of time-lapse studies exploring navigational abilities, interspecies encounters, problem-solving strategies and pattern generation (Barnett, 2018). Within these studies, my role became that of instigator rather than sole author. Whilst I could predict certain behaviours, I could not control the outcomes. What ensued became an on-going 'collaboration', a process of negotiation between an artist and a single-celled organism.

As I continued to create scenarios and environments to test the slime mould's abilities, I began reading up on other studies and a vast world of

Figure 3.4 Growth Studies (digital prints) - from *The Physarum Experiments, Study No: 011* (2009).

research began to unfold. I discovered that slime moulds could find the shortest route through a maze (demonstrating a primitive form of intelligence) (Nakagaki), could form efficient networks between food sources (replicating all manner of networks whilst doing it), and that they possessed the capacity for memory (Saigusa). The transport network experiment (Tero), whereby the slime mould replicated the Japanese railway system surrounding Tokyo, spawned a whole host of further navigational enterprises for the slime mould, including mapping myriad other transport systems, migration routes, drug-trafficking routes, and evacuation pathways. These notable experiments had translated from academic journals to editorial features and online blogs. Other modes of enquiry were less widely available, residing within highly specialised academic journals. On a recent search, Google Scholar cited 59,000 published academic papers on slime mould[5], a great many heads from diverse disciplines asking different questions of this simple yet complex organism.

In addition to the many feats of computational navigation and memory cited in scientific research, slime mould has inspired those working in sectors as diverse as arts, humanities, industrial design, and philosophy. For example, its network formation has informed new structural designs for

[5]On entering the search terms "slime mold OR slime mould" to capture both American and British spellings (note that this is English language texts only).

partition walls in Airbus' planes (Rhodes); used as a speculative model for resource distribution networks within urban design speculations (ecoLogic-Studio); and employed in philosophical discussion on the nature of cognition and decision-making in nonhuman forms of life (Shaviro). It was not only *Physarum polycephalum* that featured as a model organism. Other species of slime mould also provided a rich territory for enquiry, most notably the cellular slime mould *Dictyostelium,* with research ranging from studies on aggregation, motility and altruism by renowned biologists such as John Bonner (2010) (Durston), to experimental research using the organism in the context of human healthcare (Huber and O'Day) and agricultural ecology (Amaroli, 2015).

As I developed my own image-making techniques, I also turned to the early films of Percy Smith for inspiration. A naturalist, inventor and pioneering filmmaker working in the early 20th century, Smith's vision and innovative cinematographic techniques captured the character of a broad range of natural systems, including slime mould as seen in his 1931 classic *Secrets Of Nature – Magic Myxies* (Smith). Some of my experiments also took inspiration directly from the scientific literature. As homage to Nakagaki's maze experiment, which demonstrated primitive intelligence, I built a three-dimensional model of the maze for the slime mould to explore (Barnett, 2013). In the scientific experiment researchers filled a maze with pieces of plasmodium, which spread and conjoined into a single mass cell. Food was then added at two points and the organism was observed as it contracted to form a thick tubular network connecting the two nutrient sources. The organism retreated from empty areas of the maze and adapted its morphology to form a single pathway, choosing from four possible solutions. The experiment was repeated several times, a significant number resulting in the slime mould selecting the shortest and most efficient route. Rather than replicate the scientific experiment to rationalise networks I was interested to observe the slime mould making arbitrary decisions at each turn to find its own path through the maze (Figure 3.5).

A range of exhibition outputs stemmed from these early *Physarum Experiments* including digital prints of growth studies, time-lapse films and sculptural objects (such as the maze), which could house a living sculpture – though at a top speed of 1-cm growth per hour observing living slime mould requires extreme patience. However, the amplified pace of time-lapse films in accompaniment in exhibition can help connect viewers with the mechanisms of the organism and reveal its potential, albeit imperceptible, growth trajectories.

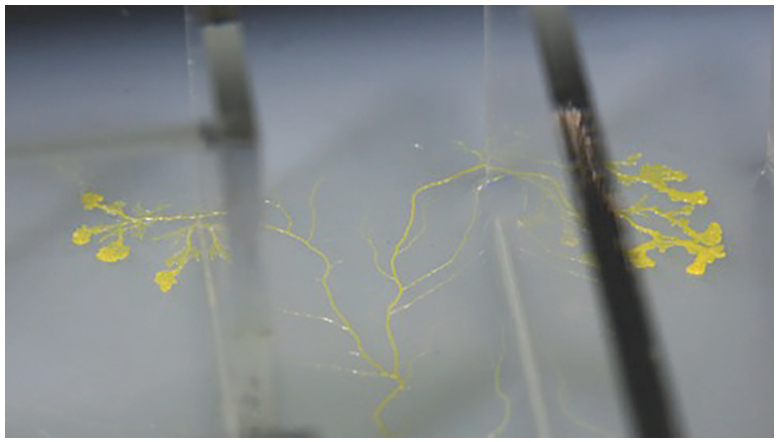

Figure 3.5 Film still from *The Physarum Experiments, Study No: 019 The Maze* (2013).

As I worked in the studio, getting to know my new 'collaborator' and discovering a world of enquiry through the research papers and articles, I posted every time-lapse study I made online, irrespective of its seeming success. I wanted the process of experimentation to be transparent and open, and I also wanted to connect with others curious about the behaviours of this organism, so one month after being given my first slime mould, I set up an online network, The Slime Mould Collective (slimoco), as a way to pool interest, share research and connect experimental practices. It was important that the network operated across disciplinary boundaries and beyond academic walls – a democratic knowledge space where professors and students, designers and scientists, enthusiasts and the simply curious, could engage on a level footing. There was also a subtext to the network, which was to see who would find it and how knowledge of it would spread through the existing online networks and search engines. After all the World Wide Web operates on similar principles of emergence as does the slime mould: namely, local interactions, pattern recognition and feedback loops, with no overriding control mechanism (Johnson, p. 22) – a self-organising platform for knowledge exchange, with all participants equal agents in the system. To date, the network has facilitated international exchanges, distributed collective knowledge and experience, helped experimental problems be solved, fostered collaborations and instigated many slime mould swaps.

Over the past ten years, through working in the studio, undertaking desk research and interacting with other slime mould researchers, practitioners and enthusiasts, I have developed a range of experimental practices, which explore slime mould behaviour and engage audiences with the questions that this organism raises. Through a range of techniques including film making, photography, print-making, sculpture, installation, interactive media, workshop design and participatory experiments I have tried to draw attention to the intriguing mechanisms of this natural phenomenon through creative and collective action.

3.3 Encounters and Interactions

The intention with *The Physarum Experiments* has never been to 'represent nature' – though that is a perfectly valid pursuit and inevitably forms a part of what I do – but to 'work with' a natural system that is little known to the general public, often overlooked and not fully understood (even by the scientists who have spent years studying it). This process of working with a living system can be incredibly time consuming (most time-lapse studies take several days to shoot and several more to edit) and involves a certain amount of uncertainty (until the hundreds, sometimes thousands, of individual still images are composited as a video I never really know if I have captured anything interesting). Similar to the latent image of an analogue photograph emerging in the developer bath, the time-lapse reveals what has been imperceptible in real time observation at the point of rendering.

A primary motivation to make artworks, or create experiences for audiences, is to encourage people to look at and to think about things I find interesting or important. This may seem a selfish pursuit, but in very simplistic terms it is at the core of any artist's agenda, to draw attention to things that others may not notice. In presenting works from *The Physarum Experiments* in public exhibition, wherever possible I aim to translate some aspects of the essence of slime mould, a gradual reveal of the organism's behaviour, and bring an element of individual discovery. Every exhibition aims to present an opportunity for interspecies encounters.

One example of bringing different strategies together is the exhibition *BioDesign* (2013), curated by William Myers and held at the Neu Museum in Rotterdam. For this presentation a trio of works was developed to engage viewers with the slime mould through observation, simulation and enactment.

Exhibited under the name of slimoco, as a collaborative endeavour[6], I brought together various elements intended to encourage close observation and interaction.

The first element comprised a selection of time-lapse studies from *The Physarum Experiments*. This showreel presented a range of slime mould behaviours included moments of open exploration, rationalisation, decision-making, retreat and self-recognition. Behaviour was not made explicit, but could be deciphered by the viewer. The second element encouraged viewers to interact directly with a computational simulation of slime mould networking behaviour[7]. As people entered the gallery, a motion sensor located their presence and mapped them onto a screen – each visitor becoming a virtual food node for the digital slime mould to 'consume'. As it explored its screen domain, the simulated slime mould located the food nodes, joined the dots and formed a network between the visitors in the gallery. As viewers moved, their positions were tracked in real time on screen. Albeit slowly, viewers became connected by the virtual organism and could test the dynamic network formed between human and digital agents (Figure 3.6).

Whilst the simulation went some way to engage viewers with the underlying mechanisms of slime mould behaviour, the computational simulation took reference away from its biological source. I wanted to find a way to directly address the biological effects of the behavioural rules. A third element was therefore developed to push the viewer further in trying to understand slime mould existence through a process of 'enactment', a way to directly experience something of 'slimemouldness' and explore how an organism can self-organise and cooperate from very simple elements. Devised initially in collaboration with Daniel Grushkin[8], some rules of behaviour were extracted from *Physarum polycephalum* and applied to a participatory exploratory experiment. Much discussion was had about how to form a dynamic supercell network where individuals could be held within an adaptive membrane[9],

[6]slimoco (The Slime Mould Collective) has also been used as an umbrella name for public exhibitions where several members of the network and/or external collaborators have co-produced outputs.

[7]The interactive piece was developed from a model of slime mould provided by computational scientist, Jeff Jones, and reprogrammed as an interactive installation by digital artist, Alex May.

[8]Daniel Grushkin is a science journalist and co-founder of Genspace, the first community laboratory, in Brooklyn, New York.

[9]A system of yellow ropes was used in this first iteration of Being Slime Mould, which could connect and disconnect to form an adaptive network, but never used since as they were far too distracting.

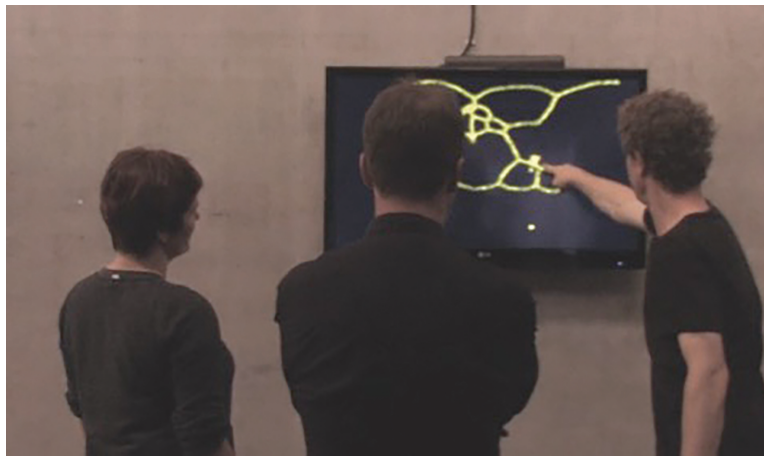

Figure 3.6 Gallery installation view of slime mould simulation, *Biodesign*, New Museum (2013).

how people would be permitted to communicate, and to establish what level of instructions should be given for them to understand the task at hand.

The experiment took place twice: once on the opening night within the museum and again the following day outside the museum in a tree-lined park. Both experiments were followed by filmmakers Jasper Sharp and Tim Grabham, who were shooting for the feature length slime mould documentary, *The Creeping Garden* (2014). The task for the group (a random collection of strangers on each occasion) was to navigate their environment as a single collective body, to locate food sources (giant oats) and form an efficient network (a competition against slime mould network optimisation). The experiment that took place within the building experienced some issues with bottlenecks forming, and enforcing the rules of behaviour proved quite challenging – perhaps exacerbated by a few drinks consumed on the opening night – but there was some attempt made by the group to collectively organise, communicate and cooperate, with partial success (Figure 3.7).

The next day passers-by were bribed with a specially commissioned slime mould T-shirt and the promise of beer[10] and, once a group was formed, the strangers were set the task of navigating a park populated with multiple obstacles (trees). The rules of *Being Slime Mould* on this occasion maintained the need for a *constant physical connection between 'cells'*, though this should

[10]We replaced oats with beer as an attractant for the effective recruitment of members of the public on a busy Saturday afternoon.

Figure 3.7 Daniel Grushkin explaining the rules of Being Slime Mould on the opening night of *Biodesign*, New Museum (2013).

Figure 3.8 Being Slime Mould enactment, public experiment, *Biodesign*, New Museum (2013).

be dynamic and not fixed, and *no speaking*, the slime mould communicating through some form of improvised oscillation. The task here was to *locate a food source* (beer) and *distribute resources* across the network to nourish all parts of the cell (Figure 3.8). The experiment lasted around 15 minutes and there was clearly some evidence of problem-solving in navigating around obstacles and reaching attractants whilst maintaining a collective and cohesive body, and in the end, everybody got a beer.

Clearly, *Being Slime Mould* is not a scientific experiment. It is not intended to prove a hypothesis or demonstrate anything measurable. In many ways the experiment is set up to fail, in that humans cannot 'be' slime mould. It is a knowingly impossible task. The point of the exercise, therefore, is in the trying – the attempt to let go of deeply held human traits for a short period of time – by following some fundamental rules of an 'other' life form. By setting a few simple rules, directing the mode of connecting, communicating and decision-making, complex behaviours can emerge.

In many ways, the most interesting outcome of *Being Slime Mould* is the discussion that follows the experiment. On this run, as people drank the beer they had collectively located and distributed, they reflected on what they had just experienced and shared their observations. Depending on their background they tuned in to different interpretations: a biologist compared the chemical signalling of slime mould to the quorum sensing of bacteria; a psychologist observed the range of human responses to the task, that some people lead and others followed; and an urban design student enquired whether we were trying to engender social agency in the group by thinking about how we relate to our environment as a collective entity.

Since this first attempt at *Being Slime Mould,* the exploratory experiment has evolved, adapting to different groups and situations. The slime mould has proved to be a malleable metaphor for exploring ideas ranging from communication strategies and organisational systems, to social agency and distributed intelligence. Through each iteration the framework remains the same – applying some simple 'logic' of nonhuman collective behaviour to a group of humans – but the specifics change depending on context. Notable examples include: entreating a group of digitally orientated corporates to navigate a conference room of a Mayfair hotel[11]; testing the self-organisational capacity of a largely Swedish audience interested in biomimicry[12]; sensory explorations with a small but committed group in the Arizona desert[13]; challenging a group of collective behaviour scientists to embody the same mechanisms that they observe and measure in their own research[14]; and looking at slime mould through an educational lens (learning being a biological and phenomenological endeavour)[15] (Figure 3.9).

[11] After lunch slot on Day 1 of the Financial Times Innovate Conference 2014.

[12] At The Conference in Malmö with approximately 300 people, the largest group yet, 2015.

[13] Programmed off site on the first evening of the Open Embodiments Conference, Tuscon, 2015.

[14] At the Collective Motion Conference 2016 in Uppsala, Sweden.

[15] ELIA conference keynote presentation, University of the Arts London, 2017.

Figure 3.9 Being Slime Mould experiments (various).

By embodying some fundamental rules of slime mould the experiment invites people to act first and think second, to enact and then reflect on the experience of attempting to shift ontological perspective. In many ways, this organism is utterly alien to us, yet by possessing traits that we can relate to (such as learning, memory, and problem-solving), it somehow resonates. Beyond observation or measurable analysis, to embody an experiment is to learn through direct experience. Much of my participatory work encourages tacit, rather than purely explicit, learning to recognise diverse forms of knowledge. Including material thinking and embodied cognition, I aim to create opportunities for people to explore through doing, whether in the studio, the gallery or the park.

3.4 Playful Pedagogies

My own material experiments in the studio are very much 'with' the organism, learning from direct experience, and sharing the process of intervention and observation with others. My practice as an artist has co-evolved over the years with my practice as a teacher[16], each informing the other. Hence,

[16]I have been involved in community arts and formal education since 1992. I am currently Pathway Leader on the MA Art and Science at Central Saint Martins (University of the Arts

workshops and educational activities have always played an important role in what I do as an artist. From science museums to floating cinemas, and from arts festivals to community laboratories, I have facilitated numerous workshops and participatory experiments bringing different groups of people into creative contact with the slime mould[17]. The aim of these activities is threefold: for people to engage with the organism as a living subject to observe (an interesting specimen of non-neuronal intelligence – 'isn't it fascinating?'), an object of enquiry (a system of knowledge for research – 'what questions are being asked of it?') and, thirdly, a model for examining larger questions of communication and cooperation (a comparative model – 'how do we relate to it?').

In workshops, the intention is not to present a prescribed view of the organism or to 'instruct' a lesson, but to use the slime mould as a vehicle for creative and critical exploration. Whilst people need to have a certain amount of information at their disposal in order to be able to engage meaningfully with the organism conceptually or experimentally, I am not in the business of science communication. The workshops aim to be associative rather than didactic.

An introductory preamble should equip a group with some fundamental knowledge about the organisms' behaviour – for example, its morphology, function, communication mechanism and motivation – so that they can then design their own practical experiment. Questions embedded within the experimental design may relate to navigational abilities, foraging behaviour, pattern formation, or problem-solving; or people may simply wish to provide an interesting habitat for it to explore. The format of one workshop invites participants to create an experimental environment for the slime mould to explore within a small petri dish. They build into the circular arena with coloured felt, pipe cleaners, filter papers and other absorbent materials (to create ideal levels of humidity within which the slime mould can flourish). Water is added and a selection of attractants and/or repellents[18], and then finally slime mould is introduced, transferred from a parent culture via a miniature cookie cutter. The tools people are given are purposely simple and require tactile manipulation, an invitation to explore haptically and, most importantly, playfully. As anyone who makes anything knows, the physical activity of

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London), a Higher Education Academy National Teaching Fellow, and led the Broad Vision art/science research and learning project at University of Westminster from 2010–2015.

[17] I estimate that, in the past ten years, over 3000 people have participated in some form of slime mould related workshop, encounter or participatory experiment that I have facilitated.

[18] Attractants include oats, pasta, rice and flour; repellents include salt, chilli and lemon.

manipulating materials engages just enough of the brain to free up associative cognition[19]. It is important for creative thinking that participants don't overly predetermine the outcomes, but allow ideas to coalesce and emerge. From the same base materials diverse experimental environments are designed, from elaborately intricate networks to functionally experimental platforms, some intended for open exploration, others attempting to test a particular hypothesis about how the slime mould will respond to the conditions set. At the end of a workshop participants are invited to take their new pet home, given care instructions[20] and encouraged to share any results on slimoco (The Slime Mould Collective).

The social aspect is also important in any workshop situation, the bringing together of people from different disciplines, ages, and backgrounds and providing a context in which they can exchange ideas, converse as they make, and share moments of individual discovery (Figure 3.10). This combination of knowledge exchange and interdisciplinary interaction has gone on to form

Figure 3.10 Observing protoplasmic streaming, BLAST workshop (2015).

[19]Think about how many writers are regular walkers or how many ideas you've had in the shower.

[20]Care instructions include acknowledging the nomadic nature of slime mould and its need to move house regularly, its preference for dark and damp conditions, and ideal diet of porridge oats; as well as instructions on safe disposal of slime mould if it is neglected and doesn't survive.

the basis for extended workshops and situated collective experiments, which cross borders of knowledge, discipline, and practice.

3.5 Collective Experiments

In recent years I have been developing a series of expanded workshops which use the slime mould as a starting point to explore other networked systems across species and scales – a form of bio/social collective experiment. Each situation responds to a specific set of conditions: a conference, an urban environment, a specific context, and/or a core question. Here, I reference a few examples which demonstrate the iterative and adaptive process of co-enquiry and share some of the methods and practices developed.

3.5.1 Nodes and Networks

In 2015 I was invited to contribute to a scientific conference, a three-day workshop on *Physarum* Transport Networks to be held at Columbia University in New York City. The invitation came from Professor Hans-Günther Döbereiner[21], a biophysicist working with slime mould, based at the University of Bremen. Whilst the scientific field of slime mould research already operates across the domains of biology, physics, mathematics and computer science, the event organisers were also keen to include educational and art practices in the proceedings. I was more than happy to contribute to the conference and engage with the scientific research, but also wanted to connect the academic delegation with the city's art and science community[22]. Thinking about slime mould transport networks in the context of New York City, a framework was established for exploring the city as a superorganism, a collective interconnected body of networks and information channels. Organisms such as slime mould offer intriguing models to test how ideas spread, how group decisions are made and how communities evolve.

Taking the behaviours of *Physarum polycephalum* as stimulus, a multi-disciplinary team was recruited, comprised of artists, writers, architects and designers working with biological systems, and scientists from the fields of biophysics, ecology, genetics, and neuroscience. Together we devised a

[21]The Döbereiner group are interested in the biological physics of cellular systems and soft matter. In vivo studies of animal cells and slime molds are combined with in vitro investigations of model membrane systems.

[22]Having previously delivered talks and workshops at Genspace community laboratory and contributed to exhibitions such as Cut/Paste/Grow at The Observatory in Brooklyn.

series of experiments to explore the interconnections between biological, cultural, and social collective systems and invited public participation for a marathon day of activities which took place at the BioArt Lab (School of Visual Art), in Central Park, and in The Metropolitan Museum of Art (in collaboration with MET Media Lab). The nature of the experiments varied. Material exploration in the laboratory used attractants and repellents as a means to create social maps of the New York boroughs, exploring subjects of pollution, crime or gentrification (Figure 3.11). Modelling experiments played out in Central Park, adapting the rules of *Being Slime Mould* to affect motivation, communication, and collective coordination. Finally, The Metropolitan Museum of Art provided a human petri dish for us to conduct a series of cultural foraging experiments tracking human behaviour in the galleries (whilst back in the lab the slime mould was exploring a scaled down 3D model of the same territory).

Nodes and Networks (Barnett et al., 2016) provided an opportunity to combine different methods of research with participatory art practices, situated in a specific location and context. Through a partially self–organising process, everyone involved could explore different ways of thinking about

Figure 3.11 Social mapping with *Physarum polycephalum*, *Nodes and Networks*, New York City (2015).

networked intelligences and collectively contribute knowledge and experience. The project brought many heads together to create novel ideas through a creative emergent process.

3.5.2 Swarm/Cell/City

Other collective experiments have addressed specific traits and mechanisms of the slime mould. In September 2017, working in collaboration with performance art duo *plan b*[23], I ran an extended workshop at Art Laboratory Berlin (ALB) as complement to the exhibition *Nonhuman Networks*[24]. A participatory collective experiment in art, performance and biology, *Swarm | Cell | City* invited participants to view the local urban area through the nonhuman perspective of *Physarum polycephalum*. Using the local topography around ALB as inspiration, we ran a series of experiments exploring mapping mechanisms, spatial awareness and stigmergic[25] marking of territory. In practice this involved creating maps for the slime mould to navigate, mapping our own trails using GPS trackers (Figure 3.12), devising cooperative nonverbal navigation techniques, and developing a biosemiotic system of communicative chalk markings. All activities were documented and the subsequent film formed part of the exhibition (Barnett and plan b).

Within the group I recall a biochemist, an anthropologist, a choreographer, several artists, and a writer – typical of most slime mould workshops, where disparate disciplinary backgrounds centre around the organism from individual points of interest. Questions raised during the two days were plentiful and cannot be fully recorded here, but to give a flavour discussion ranged from curiosity about pigmentation and colour indicators, through questions of epigenetics and learned behaviours passing through generations of cell lines, to philosophical musings on a duty of care towards nonhuman organisms and recognition of the slime mould's performance (sacrifice)

[23]plan b are Sophia New & Daniel Belasco Rogers. See more of their work at: http://planbperformance.net/

[24]Nonhuman Networks featured work by Saša Spačal, Mirjan Švagelj & Anil Podgornik, and various works from *The Physarum Experiments.* The exhibition, the last in the Nonhuman Subjectivities series spanning two years, ended with a three day international conference exploring themes of *Nonhuman Agents in Art, Culture and Theory*, November 2017.

[25]Stigmergy is a process by which an organism leaves a trace in its environment which affects the behaviour of other organisms, such as ant pheromone, termite mudballs or slime mould membrane.

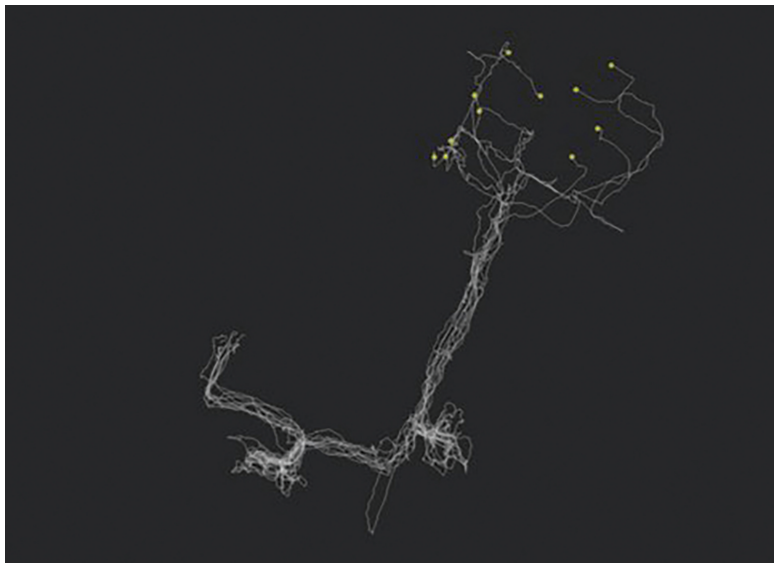

Figure 3.12 Trail making in *Swarm | Cell | City* workshop (2017).

for our intellectual curiosity[26]. Throughout the workshop, the slime mould operated as a springboard for sympoetic working[27] – collectively exploring, experiencing and discovering.

This model of co-enquiry has been developed and applied to a number of different situated experiments, many relating to urban contexts. For example, *Crowd Control* (Barnett et al., 2017), a month-long interdisciplinary residency with Arebyte Gallery in Hackney Wick, an area of East London which has undergone a great environmental and economic change in recent years. Connecting visual, digital and performance art practices with contemporary scientific research, law and urban design, the project explored the mechanisms of collective behaviour across biological, urban and social scales. Other examples include *Spatial Negotiations,* an on-going collaboration with choreographer Emma Ribbing[28], using the slime mould

[26] At the end of the workshop one participant dedicated a poem by Emily Dickenson to the slime mould in recognition of its contribution to our enquiry.

[27] 'Sympoesis' meaning creating together, coined by scholar and community activist Beth Dempster in relation to self-organising human systems.

[28] Emma and I met at the Collective Motion conference in Uppsala, Sweden, whilst facilitating embodied experiments with a group of collective behaviour scientists. She was the most dynamic cell in the Being Slime Mould experiment and inspired the idea of working with dancers.

as a stimulus for movement research. And at the time of writing, a number of bio/urban exploratory experiments are planned to take place in Munich[29] and Amsterdam[30], each a platform for shifting perspective from a human-centric position to embrace the multitude of interspecies interconnections.

3.6 Polycephalism

Like the slime mould I move with seeming intention, yet very little of what has been described here has been in any way predefined. Most of the practices – the time-lapse studies, the workshops, the gallery installations, the absurd experiments (Bates) – stem from a creative process which has unfolded over time… each encounter or experience leading to new learning, novel insights and hybrid forms of enquiry. Not to exhaust the metaphor (too much), but my own creative process has operated much in the same way as slime mould behaves. I forage until I find a resource (a piece of research which acts as a stimulus or tells me something new; a collaborator who shares a common interest but who brings a different perspective; or an observation of a novel behaviour in the organism itself), and then form connections between these nodes. New projects and ideas coalesce and the exploration continues, finding other bodies of knowledge or points of connection along the way. In the ten years I have been 'working with' slime mould, my practice has evolved in new directions and with unpredictable results – the creative process operating as its own many-headed emergent system.

The notion that we 'can learn from semi-intelligent slime' (Barnett, 2014) should not be taken too literally, but there is much to be gained from taking note of its capabilities. As an artist, the slime mould offers me a set of aesthetic properties to work with (it is beautiful), a fascinating subject (it is biologically and behaviourally peculiar) and a muse (it raises many interesting ontological and epistemological questions). The slime mould is, for me, a story telling device – a vehicle through which we can appreciate the complexity of natural systems. As a model organism, it offers myriad curiosities to investigate questions of decision-making, distributed intelligence, and computation. In pragmatic terms, it provides an amenable body for experimentation, without the need for ethical approval or high-level

[29]Part of {un][split}Micro Performance and Macro Matters Science & Art Festival in Munich, September 2018.

[30]Part of Open Set's Summer School and Labs Programme, Fluid Rhythms: Urban Networks and Living Patterns, August 2018–February 2019.

laboratory controls. Yet the achievements of this single-celled organism do raise some important philosophical questions about how we recognise and engage with other forms of intelligent life. As for assessing a duty of care to my living co-worker, I have come to realise that the relationship here, between artist and organism, is far from 'collaborative', but more akin to a form of benevolent slavery (though consensus on who is a slave to who is yet to be reached).

In his manifesto, intended for artists working with living systems, Mark Dion (2000) sets out a series of guiding principles addressing questions of responsibility, anthropomorphism, nostalgia, representation, and language. He proposes that "The objective of the best art and science is not to strip nature of wonder but to embrace it. Knowledge and poetry are not in conflict." (ibid, p. 240). Like Dion, my work seeks to explore how we understand and interrelate with nature through different forms of knowledge. My creative explorations with slime mould are less directly 'about' the organism, but far more about 'ideas of' the organism: how we view and interpret and make sense of its way of being in the world we share with it. The intention is to hold up this organism as a subject, a model and a metaphor, to capture curiosity and to offer up discussion around different ways of knowing and different ways of being, "as humanity cannot be separated from nature, so our conception of nature cannot be said to stand outside of culture and society. We construct and are constructed by nature" (ibid, p. 239).

The argument for 'polycephalism' is, therefore, not that we should become more like slime mould, but that we should become more acutely aware of other living systems around us (and within us for that matter)– a reminder that 'we are always inside an environment with a group of other interdependent living organisms' (Manacorda, p. 15). It is an encouragement to be open to different ontological perspectives, be they from diverse humans speaking different disciplinary languages or from diverse populations of nonhuman cohabitants.

Whilst methods and intentions vary and have evolved as my understanding of the organism has grown, what lies at the core of all my practices and processes is a fundamental curiosity about what drives the behaviour of this fascinating organism; a desire to share that curiosity and discovery with others; and a will to bring others into the process of enquiry, not as passive participants, but as active agents. I may amplify inherent behaviours which reveal traits and abilities; I may set the frame through which I invite people to ponder, and I may create the stimulus by which I ask people to engage. However, creating the conditions is far from controlling the results.

I have spent considerable time, energy and effort over the years getting to know this curious organism, to understand how it works, and to develop methods for working with its inherent mechanisms. I have fostered collaborative relationships with scientists, designers, choreographers, programmers, and musicians, travelled the world talking about what a wondrous organism it is and persuaded groups of unsuspecting individuals to let go of their humanness and attempt to 'be' slime mould for a short while. And in all this time, I realise all too well that the subject of my close attention remains utterly ambivalent to the human curiosity it has unknowingly inspired.

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