A Framework for Action and Reflection: Using Play to Understand the Relationships between Art Practice and Life Science.

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A thesis submitted in partial fulfilment of the requirements of Birmingham City University for the degree of Doctor of Philosophy.

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30 October 2021

Table of contents

Figure list

Abstract

My hypothesis asserts that integrating play into art–science research creates an innovative collaborative framework that promotes reflection and multidisciplinary interaction. This thesis investigates play as a research tool to enhance advanced imaging and microscopy in life and natural sciences, cultivating an aesthetic sensibility that enriches both artistic and scientific exploration. I argue that play can elicit technological, ethnographic, dialogic, practice-based and process-led data, by engaging with interpretative and critical aspects of art as research. By focusing on play as a vehicle to explore the intersection of art and science, I aim to enhance creativity and encourage unorthodox problem-solving by subverting scientific protocol. A flexible play-based art practice demonstrates how play can extend traditional scientific methods and facilitate new learning in technology, visualisation and communication through working constructively with scientists. Core themes informing my three imaging-lab art projects include play, digital drawing, pixel granularity, dissemination and the reimagining of scientific image conventions. Each lab was selected for its novel imaging technologies, and the life- and natural-science source data were unique to each facility. Findings emerged from the analysis of distinct data and imaging technologies, and from applying art-practice research methods to three projects, which resulted in digital drawing, data montage and film. The result is the creation of an adaptable framework for art–science collaborations. This framework is designed to foster collaboration through play, leading to a system to create artwork that can be used for dissemination, to encourage critical feedback that deepens understanding of interdisciplinary practices, and fosters ongoing dialogue between art and science.

- **Art Project One:** From 2015 to 2019 I collaborated with scientists at the University of Nottingham's Centre for Membrane Proteins and Receptors (COMPARE),

adopting a play-based approach to challenge conventional Confocal, Light and Super Resolution Microscopy techniques, revealing aesthetic imaging not previously explored. This led to customised experiments, speculative testing of cell signalling protocols and enhanced data processing to capture material modifications observed in the lab. Artistic outcomes were shared at COMPARE 2017 and 2018, with a framework for action and reflection, enabling artists and scientists to compare responses from pharmacology experiments. I developed an adaptive software experimental model which reframed interdisciplinary understanding and extended imaging protocols.

- **Art Project Two:** At the Natural History Museum's Science Infrastructure Platforms Imaging and Analysis Centre (2015, 2024), I used scanning electron microscopy (SEM) to push its optical limits, redefining protocols and documenting interdisciplinary interactions. Through two-way collaboration and independent exploration, I produced previously unseen visuals, breaking scientific norms and introducing new techniques. I reimagined versatile imaging as a three-dimensional sketch in Adobe Illustrator, advancing discourse on drawing and technology. Training in SEM fostered innovation and interdisciplinary learning.
- **Art Project Three:** From 2016 to 2019, I collaborated with the Biofilms Research Centre at Malmö University, and the Centre for Cellular Imaging at Gothenburg University, Sweden, using multi-photon microscopy to explore skin as raw data. Immersing myself in experimental preparations, I mirrored scientists' practices while fostering trust in order to exchange creative ideas. Through two-way collaboration with the Core Imaging Manager, we generated unique datasets, which were presented at the Biofilms Research Centre (2018) and SCANDEM (2019). The images were

then presented as part of a performance, *Skin/KIN* live, at The Lab, Royal Birmingham (2019).

This research uses participatory action-research methodology, integrating cycles of action and reflection to gather primary data and encourage scientists to reassess their technologies, fostering creative autonomy (Dickens and Watkins, 1999). Disrupting empirical protocols constructively provided key insights for me and my collaborators, demonstrating how interdisciplinary communication can lead to novel outcomes. By countering computational data analysis with digital drawing, the research highlights drawing's potential for discovery, innovation and authorship. My contribution lies in integrating play-based art practices with scientific research, creating a replicable framework that bridges art and science, promotes creative exploration and drives the evolution of interdisciplinary practices. New collaborations, exhibitions, conference presentations and publications will further enrich academic discourse, driving innovation and enhancing the understanding of scientific concepts through artistic methodologies.

Acknowledgements

My thanks go to my supervisory team, Dr Ann-Marie Carey and Dr John Hillman, for their support.

I would also like to thank Dr Lisa Kirkham, Dr Deborah Harty and Professor Clare Warden.

Thank you to my husband John and children Noah, Delilah and Job.

Introduction

In 1998, my fascination with collaboration between artists and scientists was ignited upon encountering the SciArt scheme (1996–2006). This initiative, established by the Wellcome Trust, revolutionised collaborative efforts, uniting disparate institutions, artists and scientists in constructive co-operation (Glinkowski and Bamford, 2009: 76). At its inception, SciArt represented a real-world embodiment of what was then a developing area of policy, distinguished by its willingness to take risks and invest in research and development, leaving an enduring legacy. Its interdisciplinary model fostered mutual understanding, educating artists about science, scientists about art, and the public about both fields, creating a significant intersection between art and science (Glinkowski and Bamford, 2009).

In their report, Glinkowski and Bamford (2009: 86) referred to SciArt art projects (made by artists and scientists), drawing on reflections of those involved. One (anonymised) scientist remarked:

> "It was a highly experimental thing to put an artist and a scientist together. The first two and a half of the four years I spent working on [the project] I was just trying to develop the language to understand what the artist was saying. It's a really, really difficult thing to do…C P Snow was right: there are 'two cultures'. SciArt was right to try to bring them together, but it does reflect that this was a significant challenge. Another participant commented: that for 'truly meaningful collaboration to occur between artists and scientist, a lengthy period of familiarisation and exchange was needed'".
>
> (Glinkowski and Bamford, 2009: 86).

These emergent insights fuelled this doctorate project and steered my research. Before this, in 2002, inspired by the ethos of the SciArt scheme, I could already see the potential of disregarding subject boundaries as an artist and looking at distinct disciplinary practices. I saw opportunities to foster interdisciplinary innovation through learning from another disciplinary perspective about imaging technologies, processes and techniques, via direct engagement with scientists. At this point, my interest in scientific lab research was caught by scientific methods of visualising and processing images using optical-imaging technologies; I wondered how I could use this information and data as an artist–researcher for a purpose that was different from my collaborators. The methods used in these labs connected with my creative approach to imaging, since the scientists I met used technological processes including light, industrial processes and computer visualisation technologies in ways that differed from how I used them. For instance, while I created laser-cut light-box artworks for exhibition, lasers in life-science labs were used to visualise cell signalling – the process by which a cell responds to external stimuli through signalling molecules. Though both applications used lasers, their purposes were distinct. This distinction led me to view life-science labs as ideal spaces for creative discovery and collaboration. The connection between art and science became even clearer when I observed that scientists in these labs prioritise visual techniques that integrate cutting-edge technological advancements. This approach aligns with the work of Scrivener and Chapman (2013: 2), who assert that the goal of visual-arts research is to produce a unique creation that fosters a fresh understanding. Furthermore, my doctoral research explores my ability to imagine potential realities from investing in advanced imaging and microscopy, scientific software, scientific data, and our (artist and scientist) connections and distinct positions in the world. While other artists were also prompted to work across these disciplines (see Chapter One), my own interest was specifically in working with scientific data and the process of visualisation.

'Hijacking natural systems' pilot study (2009–2011)

My interest in the field of advanced imaging and microscopy (see key terms of reference and concepts) developed as a direct result of 'Hijacking Natural Systems' – a study that ran from 2009 to 2011, funded by the Wellcome Trust, Arts Council England (ACE), and Derby Museum and Art Gallery. I was the joint Principal Investigator (PI) responsible for the leadership and conduct of this research study on a project directed by Dr. Nicholas Holliday (Associate Professor of Pharmacology, Faculty of Medicine and Health Sciences) and Tim Self (Head of SLIM – School of Life Sciences Imaging Facility, Chief Experimental Officer of Imaging). Holliday's work focuses on understanding the events that happen inside cells in response to a hunger hormone called Ghrelin (Holst, et al., 2004) and using this knowledge to formulate pharmacological interventions that modulate appetite as therapeutic strategies for obesity and diabetes. During the testing phase of this enquiry, I gained proficiency in laboratory practices through hands-on training and participation in activities typically undertaken by post-doctoral research scientists. Despite lacking formal scientific training beyond O-level biology and studying natural history illustration at the Royal College of Art (1988–1990), this experience enabled me to bridge my prior knowledge gaps and engage with the research environment, albeit from the perspective of an outsider of the scientific discipline. Conducting cell signalling experiments advanced my knowledge of basic pharmacology (see Glossary). This was key for my later research as I understood the workings of a laboratory and the scientific process more acutely. In addition, my collaborators Holliday and Self acknowledged that the professional and academic status of the team (Joanne Berry-Frith, Tim Self and Nicholas Holliday) was elevated through disseminating the research via exhibitions and publications. The approach adopted demonstrated the potential of working collaboratively at this interdisciplinary intersection and integrating artistic perspectives into pharmacological research. 'Hijacking Natural Systems' (a pre-PhD project) provided the impetus for my progression into the PhD. Working as a scientist gave me a sense of creativity and enthusiasm during laboratory activities; I found the scientific method and the environment exhilarating. The setting felt rarefied to me; it was technologically advanced and followed strict norms that combined practical, technical and intellectual activity. I observed the everyday routines of scientists, which were unexpectedly creative and fascinating, yet strikingly different from my own approaches to thinking, working and conducting research as an artist. I wanted to find a way to interrogate the connections between artists and scientists who use advanced imaging and microscopy, to demonstrate interconnections and the knowledge gained through sharing ideas regarding our common interest in technology and digital image-making. This way of thinking challenges existing disciplinary silos, as it encourages integration so that artists are embedded as part of the team – working on the same research themes, gaining direct training and use of technology in the process.

Importantly, while working with scientists in this lab, I identified a knowledge gap. My observation of art–science collaborations during 'Hijacking Natural Systems' revealed a persistent lack of mutual understanding between practitioners in the fields of art and science, particularly regarding their approaches to imaging and its potential. Holliday (2009) had to "work hard to find different reference points" and communicate more efficiently in lay terms. My PhD provided an opportunity to conduct in-depth research into advanced imaging and microscopy labs and to contribute to a deeper understanding of how these diverse fields can inform and inspire one another. It illuminated our distinct disciplinary approaches in the laboratory, including use of technologies and data acquisition, image and communication strategies. Feeding back these findings to scientists working in the field revealed new insights into complex concepts and systems, which built knowledge about creativity and innovation from artistic and scientific perspectives. From our interactions during the 'Hijacking Natural Systems' project, Holliday (2009) recognised that "too often the jargon of science comes naturally to us but is meaningless to most non-scientists". To increase my understanding of his field, Holliday went to great lengths to teach me the working methods of the lab, including using a lab book as an essential recording tool. He wrote notes in my lab book about aspects of science I had not encountered, such as molecular weights and experimental protocol. Holliday (2009) stated that working with a person from a different specialism provided him with a "refreshing perspective" on his research, as I "continually challenged [his] explanations of the science in unexpected ways". One key insight I gained was that both scientific understanding and creativity are essential tools for objectively comprehending the world. While Western science has been a remarkable force for advancing humanity, my creative approach – driven by playfulness and curiosity – contrasted with the hesitation of Holliday and others in the scientific community, who were reluctant to embrace these qualities as valid contributors to scientific outcomes. In scientific reasoning, validity ensures the logical soundness of a working hypothesis – an explanation designed to guide further investigation. This highlights the iterative nature of scientific inquiry, where the goal is not to establish absolute truth immediately, but to refine or disprove hypotheses through ongoing experimentation and evidence gathering.

Scientists' reluctance to embrace play as a concept, as well as their lack of conviction in engaging non-empirical, adaptive methods of visualisation, underscored the need for a deeper exploration of the role of play in scientific imaging technologies. This formed the central focus of my PhD research. I wanted to see if play as an insightful concept could provide a new vehicle for investigating the convergence of art and science, increasing creativity for both disciplines and encouraging unorthodox problem-solving in scientific imaging labs. Through play, I aimed to determine whether scientists and artists could push the boundaries of advanced imaging and microscopy technologies, software, data acquisition, and visual representation and communication, thereby fostering innovative concepts for both disciplines. I was particularly interested in how play, through activities such as role-playing, role-switching, mimicking, and play-centred dialogue, could bridge the gap between our diverse perspectives. This exploration aimed to identify aspects of science that extend beyond logic, enhance intuitive knowledge and facilitate the effective interpretation and communication of complex material. To guide my enquiry, I developed several research questions based on this focus.

Research questions

Based on my intuitive use of play in my art practice, my research questions were formed as follows:

1. How can I use the philosophy of play to understand the value and role of play-based art practices while working alongside scientists in the lab?

2. How can gathering diverse qualitative and quantitative data from scientific research in the lab enhance and extend my knowledge and skills as an artist?

3. How could art practice disrupt scientific image conventions in a mutually beneficial way, to advance art and science practice?

4. How could an artist navigate and communicate alternative approaches to science's use of advanced imaging and microscopy, and what insights could scientists gain from this informed by philosophical theories of play and technology?

Research aims and objectives:

To contribute to art–science interdisciplinary collaboration by offering a play-based framework for exploring and reflecting on art practice (see Chapter Two).

To validate the use of structured play for art–science collaboration.

To identify the significance of the artist embedded with the scientific lab for navigating and communicating alternative approaches to science.

To conduct a reflective engagement in the use of advanced imaging and microscopy within the life and natural sciences, based on the philosophical theories of play and technology.

Theoretical position and research design

The philosophical position of this research is multifaceted. It draws from various philosophical traditions and theories of play to test my starting hypothesis and explore the research questions.

I began by considering classical theories of play to explain why play exists and its purpose. In this exploration, I delved into Ancient Greek philosophy, particularly focusing on Plato's notion of *paidia*. This concept provides foundational insights into the purpose of play from both children's and adults' perspectives. Plato acknowledges the moral complexity of play, suggesting that while it can enrich serious cultural practices, it also embodies a quality of being unserious and childlike (D'Angour, 2013: 299). This duality invites reflection on how play balances joy and learning, shaping our understanding of its role in both personal development and cultural expression. I also reviewed early twentieth-century theories that delve into the role of play, exploring not only its existence but its broader functions (Groos, 1901; Vygotsky, 2016). Next, I investigated contemporary theories that enhance our understanding of play, both through their explanatory power and the research they have stimulated (Mellou, 1994: 99–100; Takhvar, 1988: 221–244). I considered why play has been successful in fields like psychology and evolutionary studies, where it is viewed as essential to our adaptability as a species (Bateson, 2014; Ellis, 1973; Grayson and Fraser, 2021; LaFreniere, 2011; Piaget, 2001; Pellegrini, 2009; Rothenberg, 2013). The mechanisms underlying these correlations suggest that play contributes to the development of language and other representational skills, as well as supporting metacognitive and self-regulation attributes (Goldman, 2020; Suryadin, 2021; Whitebread, 2012: 5).

To understand the value and role of play-based art practices I have drawn from both philosophies of play (Caillois, [1958] 2001; Huizinga, [1938] 2016; Winnicott, [1971] 2005 and Gadamer, [1960]1994, [1986] 1998) and – to a degree – technological philosophy (Latour, 1998, 2007, 2010; Verbeek 2005, 2011) to inform my approach (see Chapter One). I have taken a hermeneutic approach – underscoring the importance of interpretation in understanding the meaning of all actions fundamental to collaboration in the lab, as well as activities in the art studio and interaction via dissemination. I examined the ways in which particular meanings can be woven into a rich description of the phenomena as a whole.

The research design was similarly multifaceted. My approach is framed by Bruno Latour's (1993) theory on the interconnectedness of human and non-human phenomena to find out the significance of maintaining both domains, as cited by Verbeek (2011: 13). Enriched by Actor-Network Theory (ANT), a social theory that views the social and natural worlds as dynamic networks, ANT was developed by Michel Callon, Madeleine Akrich, Bruno Latour and John Law. It asserts that nothing exists outside of these connections. All components in a social scenario, including objects, ideas and processes, are on the same level, with no external social pressures other than how network participants interact. Thus, both humans and non-humans are equally important in shaping social contexts. According to Latour, the notion of a network is a powerful way of rephrasing basic issues of social theory, epistemology and philosophy. ANT contends that social forces do not exist and so cannot be utilised to explain social occurrences. Instead, rigorously empirical analysis should be used to "describe" rather than "explain" social behaviour. It presumes that many relationships are both material and semiotic – namely a "material–semiotic" technique. ANT influenced my approach by encouraging me to explore a network of invisible connections among various “actants” – including humans, technologies and image data – emphasising the interplay between human and non-human mediation. This perspective aligns with Latour’s preference for “actants” over “actors” as it avoids the human-centred implications of the latter term (Verbeek, 2005: 102). This approach shaped my outcomes by enabling me to gather diverse data through collaboration with scientists in the lab, applying that knowledge within my art practice to challenge conventional creative outputs. ANT’s iterative nature supported my exploration of play-based practices, framing the research process as dynamic and evolving, where each engagement informs the next. It also encouraged me to consider the socio-technical networks that arise from these collaborations, enhancing my understanding of how play and technology intersect to advance artistic and scientific practices. These are brought to the surface through taking on board ANT (Latour, 2010: 2; Verbeek, 2005: 103).

The play-based art-practice approach produced a supple space within which art and science could function resourcefully, leading to new learning in three distinct core-imaging labs where the field-study research took place. This served as the foundation for developing three distinct art projects.

Art Project One. I collaborated with the Cell Signalling and Pharmacology Department at Nottingham University, from 2015 to 2019. I engaged directly with scientists specialising in cell signalling, pharmacology (Currie, 2018), and advanced imaging techniques. I focused on data from Light Microscopy (LM), Super Resolution Microscopy (SRM) and Confocal Microscopy (CM), and utilised the scientific computer lab’s software (see Glossary). Art practice research was showcased at two scientific conferences at Nottingham University in 2017 and 2018, building on the ‘Hijacking Natural Systems’ project (see Chapter Three).

Art Project Two. This was a collaboration with the Science Infrastructure Platforms Imaging and Analysis Centre (IAC) at the Natural History Museum, London (2015 and 2024). I dedicated several days to understanding how scientists use scanning electron microscopy (SEM) to generate visual data at 100,000x magnification (see Glossary). My focus was on challenging SEM image conventions, exploring versatile imaging as a three-dimensional sketch and examining the structural complexity of organic artifacts (see Chapter Four).

Art Project Three. This involved a multidisciplinary research collaboration with SkinResQU (part of the biomedical photonics group at the University of Gothenburg), the Biofilms Research Centre for Bio-interfaces (BRCB) at Malmö University, and industry partners from 2016 to 2019. In 2016, I spent a week at the Centre for Cellular Imaging (CCI) at Sahlgrenska Academy, Gothenburg University, where I focused on skin research and operated a Multi-Photon Microscope (MPM; see Glossary). The resulting artwork was presented at two temporary exhibitions: the first at the 14th Annual Workshop of Biofilms, Research Centre for Bio-interfaces and Biomarkers in Malmö in 2018, followed by the 70th Annual Meeting of SCANDEM, Nordic Microscopic Society, in 2019 (see Chapter Five).

I planned to draw on my direct experience of working with scientists in these labs, gathering information from scientists about their thoughts and feelings on life as a scientist in order to expand my data beyond computer-generated imaging. Combining different forms of data (documentary footage taken as photography, film and audio, sketching, written notes in a lab book, raw data) was the backbone of my process. I focused on the minutiae of the raw data, such as pixel granularity, subtle characteristics of image data at various scales, and unexpected formations and structural details. Simultaneously, I embraced the creative, playful interactions I experienced while collaborating with scientists in the labs to uncover potential meanings. This process was both systematic and intensive, yet intuitive, enabling me to explore the deeper implications hidden within these details as part of an investigative artistic practice. The intention here was to capture the phenomena (visual, performative, process-oriented, implicit, tactile, haptic, and auditory forms of perception and expression) rather than to just conceptualise it. I sought to transform analysis into engaging learning opportunities to open up a way of describing and evoking the phenomena of play and art practice in all its subtlety and rich layers. Overall, this approach suggests that a holistic exploration of interdisciplinary collaboration between art and science can lead to innovative outcomes.

Latour (Jones and Galison, 1998: 425) claims that to perceive science beyond the usual or practical level and to change knowledge, it must be separated from its material form and re-made, which is a necessary process of development. In line with Latour's thinking, the scientific data and observational subject material I chose to depict went through material modifications in all locations. Taking these theoretical positions suggests that art practice, creativity and collaboration can be promoted, thereby breaking barriers between these two disciplines. My research into art practice revealed the profound intellectual nature of this creative process. It opened up interpretative possibilities that challenged me to reconsider the role of art in knowledge production. I focused specifically on how art can shape my understanding of various concepts (Macleod and Holdridge, 2005: 18–19). The art-practice process was essential for developing my research, which is detailed in Chapters Three, Four and Five.

As part of the PhD process, I questioned whether play's relationship to intuitive knowledge could lead to greater fulfilment, impact, learning and innovation as an artist–researcher working in the laboratory, studio and public space (Alÿs, 2024; Dumitriu and Farsides, 2015; Johnson, 2016; Schrofer, 2019; Lucas, 2020; Rothschild, 2012; Ward, 2022; Zimna, 2010). This approach helped me cultivate a more open and exploratory mindset, allowing me to embrace new challenges and share that mindset with my collaborators. Ultimately, the relationship between play and intuitive knowledge enriched my artistic practice and enhanced my collaborative experiences. Furthermore, I saw an opportunity to determine if playful exploration within the lab and later in the studio via art practice could lead to surprising discoveries and promote an atmosphere conducive to creativity. My hypothesis asserts that integrating play into art–science research could generate an innovative collaborative framework that fosters action and reflection, which promotes multidisciplinary interaction and new, informative perspectives. I believed this would foster multidisciplinary interaction and generate new perspectives. By "platforms", I refer to spaces where artists and scientists can share ideas, experiment and engage in interdisciplinary projects, facilitating interaction and innovation.

Methods

I chose action-research (AR) (Bradbury-Huang, 2010; Dick, 2009; Dick et al.,1999) as a methodology because it allowed for a variety of methods for gathering observable, factual and verifiable data, including Participatory Action Research (PAR) (Gray and Malins, 2004), semi-structured and unstructured interviewing, art practice-based research and reflective practices. This approach was well-suited to my research, enabling the integration of cycles of action and reflection (Dickens and Watkins 1999: 127–140). In this practice-based PhD submission, the written text serves to position my practice concerns (Macleod, 2000: 1–5), providing context within which my work exists. Unlike traditional research that is often bounded by written text, my research is driven by the need to understand what emerges through the artistic process. As an art practice researcher, I sought to emphasise the importance of the experiential and reflective aspects of my practice and communicate this to the scientific community.

Contribution to knowledge

I brought intuitive, play-based art practices into my collaborations with scientists in the laboratory, using PAR to build knowledge through participant observation, practice and semi-structured interviews. This approach goes beyond traditional methods of art practice, for example painting, by incorporating technologies such as advanced imaging, microscopy, scientific software and computer-generated techniques for drawing, data montage, and film. In doing so, it fosters interdisciplinary collaboration between art and science, expanding their synergistic potential through creative exploration and innovative thinking in art practice research**.**

My contributions to knowledge through **Art Project One** lie in the integration of empirical scientific techniques with artistic practice, demonstrating how art can offer novel reinterpretations of scientific data. By employing a play-based approach, I challenged conventional methods in CM, LM, and SRM, revealing aesthetic imaging processes that scientists had not previously explored and likely would not have developed independently. This disruption led to the development of customised experiments and speculative testing in cell signalling protocols, and enhanced data processing techniques, enabling the capture of material transformations observed in the laboratory that constructively impacted both their practice and mine. Through collaboration, scientists were able to engage with the visual dimensions of their raw image data, fostering a shared aesthetic understanding. Artistic methods, including software experimentation, digital remapping of pixel granularity, data montages and multi-layered moving images, enabled me to produce material modifications of scientific data. These techniques not only advanced my creative practice but also prompted critical discussions on image representation and intent at scientific conferences. This cross-disciplinary exchange enriched both art and science, contributing to innovations in pharmacology and cell signalling research.

Art Project Two generated significant opportunities for the development of both my aesthetic and scientific sensibilities, as well as those of my collaborators. I fostered a two-way, instructive collaboration that encouraged both guided and independent exploration, pushing the SEM to its optical limits. This approach actively disrupted standard protocols, enabling the documentation of interdisciplinary interactions and revealing novel perspectives on the imaging process. By purposefully challenging established scientific imaging conventions, I successfully integrated creative strategies into the lab environment, breaking down disciplinary barriers and generating unique SEM images that experienced scientists had not previously encountered. The monochromatic SEM images, created both collaboratively and independently, significantly expanded the outcomes of my practice. Through a labour-intensive drawing investigation, I reimagined the scientific concept of versatile imaging as a three-dimensional sketch, offering an innovative method for communicating complex scientific ideas. Additionally, the project established a flexible dissemination model, facilitating critical feedback through alternative exhibitions, presentations and publications. This model not only deepened the understanding of interdisciplinary practices between art and science, but also fostered an ongoing dialogue that continues to advance both fields. The insights gained from this work are set to inform my future projects, further bridging the gap between artistic and scientific enquiry.

In **Art Project Three**, I generated new knowledge by immersing myself in the cutting-edge developments of multiphoton microscopy (MPM) while enhancing my cognitive and visualisation skills through direct collaboration with scientists. Role-play activities allowed me to break down traditional barriers and foster trust within the team, creating a space for the mutual exchange of ideas. By actively participating in experimental preparations, I was able to mirror scientists' processes and immerse myself fully in a different creative environment. Through two-way instructional play with the Core Imaging Manager, we generated unique datasets and, by recognising the distinct ways artists and scientists approach creativity, I fostered a dynamic exchange that enriched our collective understanding. My artistic approach led to novel ways of conveying skin research, especially through the exploration of pixelation, colour and composition, which resulted in large-scale digital drawings and data montages. I also created experimental videos that combined diverse datasets, blending documentary and scientific data. Collaborating with composer Edmund Hunt further enriched the project, as he highlighted the peculiar and discordant elements of the research through sound. Exhibiting my artwork and presenting my findings at two international conferences reinforced the importance of incorporating diverse perspectives in research. These experiences not only sparked dialogues on bio-interfaces, they also expanded industry views, ultimately contributing to a more comprehensive understanding of the intersection between art and science.

The research contributes to knowledge by providing artists with a systematic framework for integrating art practice into the field of science. The framework I developed is structured around four cycles of cyclical reflection: the first cycle is investigative, the second focuses on explorative creative practice, the third emphasises dissemination, and the fourth consolidates findings and reflections, as outlined in Chapter Two. Both artists and scientists are now familiar with this framework, which has been shared through conference presentations and publications. This dissemination has not only increased awareness but has also led to additional international collaborative opportunities (see Appendix One).

This cyclical approach fosters a continuous dialogue between artistic and scientific practices, enriching both fields and driving continuous innovation. The framework formulates the conditions and principles necessary for intuitive play-based art practice to be successful. It draws on the cycle of practice I developed through several "magic circles" (Huizinga, 2016: 20) during the three art projects that form the basis of this research, as discussed in Chapters Three, Four and Five. Each art project challenged and interrogated scientific methods and intentions, extending beyond the confines of the laboratory. This approach offers a replicable model for other art–science collaborations, allowing for the continued exploration and expansion of these interdisciplinary practices.

Key terms of reference and concepts

The following provides a brief outline of the core concepts used throughout this thesis (as explained in depth in Chapter One).

Advanced Imaging and Microscopy: This encompasses the processing, analysis and presentation of image data obtained from a microscope using digital-image techniques. This cutting-edge technology is typically housed in core-imaging facilities.

Conduit: Bourriaud (2002: 113) sees the artists' role as conduit; artists invent trajectories which connect signs. A conduit here refers to the dynamic role of an independent artist working in conjunction with individuals and/or small groups of scientists.

Game: Gadamer (1998: 124; 1994: 108) characterises the game as an activity that is initiated, devised, or acquired through learning. When engaging in a game, whether it is played individually or with others, we are aware of the rules and the circumstances that define how it is played. The playfulness of human games arises from the establishment of rules and regulations that are only considered as such inside the confined realm of play. Game, in this study, is a framing device where play occurred, as it allowed for the exploration of unknown possibilities.

Magic circle: This refers to the special enclosed environments in which play occurs (Huizinga, 2016: 20).

Play: Play is inherent in humans but often goes unrecognised in contemporary research labs. My goal was to cultivate a conditioned response to established training by introducing a creative approach that challenges conventional scientific norms, exploring how researchers react to this playful disruption – whether it inspires fresh perspectives or provokes resistance. To address the complexities of scientific silos, I investigated play as a phenomenon and developed a philosophical paradigm inspired by Caillois (2001), Huizinga (2016), Winnicott (2005) and Gadamer (1998, 1994). This framework sought to integrate play into scientific inquiry, highlighting how creativity can enhance problem-solving and innovation, while maintaining the rigour of scientific methods. By fostering an environment where play and research coexist, I aimed to encourage a more dynamic and flexible approach to scientific exploration.

Relational Aesthetics: This is centred on the idea that humans have a relationship with subjects, and objects and each other (Bourriaud, 2002). Bourriaud (2002: 113) claims inter-human relational aesthetics is more powerful if bound to the cultural context in which it is situated. As an artist, my interest is in the visual relations between subjects, objects and people.

Thesis structure

The thesis structure is designed to articulate each stage of the research process as follows.

In this introduction, I have outlined my professional experience and the personal interest that led to this PhD research. I have set out my initial hypothesis and research questions, emphasising the importance of collaborating with scientists and how I drew on theories of play as a means to foster relationships to gather many forms of data. I have introduced the contribution to knowledge that my research has added.

In Chapter One I provide the context for the research. I review and summarise the core theories of play and detail how they have informed my process, as well as covering aspects of collaborative practice as theorised by Bourriaud (2002) and Kester (2013). I also pinpoint other artists that have informed my own art practice as well as those who are similarly invested in working across the boundaries of art and science (Aldworth cited in Casey and Davies, 2020; Anderson 2017, Anderson-Tempini, 2023; Carnie, 2024; Dumitriu, 2015; Lyons, 2009; Kesseler, 2024). This situates my art practice within contemporary art–science collaboration. I introduce the cultural producers and brokers (see Glossary) who work within this field, who also influenced my thinking and direction (Arnold, 2018; Stanbury, 2018; Glaser, 2018; see Appendix Two).

Chapter Two covers research traditions and describes AR as my chosen methodological approach. I discuss the methods that I consequently adopted for gathering data; I also outline the stages of engagement and how I recorded all data generated by the different methods. A key part of the research was the reflective stages, which led to the practice-based outputs: producing artworks and disseminating the results.

The field-study research was undertaken in three distinct core-imaging labs which were the basis of the three art projects detailed in Chapters Three, Four and Five. Each built knowledge of methods and approaches for exploring and reflecting upon art practice. In this way, my methods were modified at each stage, based on my own learning. As I was working with sensitive material (such as human tissue), I gave great attention to the ethical issues, which I cover within this chapter.

Chapters Three, Four and Five cover the actual art projects undertaken in each of the laboratories I was invited into. In Chapter Three I describe the art practice developed from research undertaken at the Cell Signalling Imaging (CSI) facility, The Centre for Membrane Proteins and Receptors (COMPARE) and The School of Life Sciences, Queen's Medical School, the University of Nottingham. Chapter Four examines the cycles of art practice from research undertaken at the Science Infrastructure Platforms Imaging and Analysis Centre (IAC) at the Natural History Museum (NHM), London. Chapter Five focuses on research undertaken at The Centre for Cellular Imaging (CCI) Sahlgrenska Academy, Gothenburg University, and The Biofilms Research Centre for Bio-interfaces, Malmö University, Sweden. These three chapters are the focal point of the practice research.

The thesis concludes with a summary of the research outcomes and a clarification of the findings. In this section, I establish my contribution to knowledge, highlighting its relevance to my own art practice as well as to other artists and scientists.

Chapter One: Context and theoretical overview

Contribution to the historical context of art and science

Over the course of many decades, within Western Europe, there have been differing viewpoints on the connection between art and science, and their relative significance. These differences can be dynamic with many potential benefits, but also characterised by tensions (Ruddock, 2018). This contextual review provides an overview of the crossovers and distinctions between art and science in relation to image generation, technology and knowledge creation. As my research contributes to, and emerges from, this Western worldview, particularly the European and North American historical framework, it recognises the philosophical and historical foundations of the tradition of collaboration between art and science.

During the Renaissance, the difference between art and science was less distinct: multidisciplinary, polymathic activity thrived throughout this period, and we can identify people who excelled in numerous subjects, spanning what we now refer to as the fields of art, architecture, engineering and science (Jones and Galison, 1998: 2). Examples include the Italian painter, draughtsman, engineer, scientist, theorist, sculptor and architect, Leonardo da Vinci (1452–1521); German painter, printmaker and theorist, Albercht Durer (1471–1528); Italian physicist, engineer and astronomer, Galileo Galilei (1564–1642); and English mathematician, physicist, astronomer, alchemist, theologian and author, Isaac Newton (1643–1727). The division between science and art in the Western tradition is rooted in the Enlightenment and the rise of empiricism in the 17th and 18th centuries. This phase of enlightenment saw a dramatic movement in knowledge and led to specialisation and classification. As a result, science and art were divided into separate fields, each of which established its own identities and methods.

The link between art and medical research is examined in Daston and Galison's (1992: 81–128) work, which traces its development from the Renaissance to the moralisation of objectivity in the late 19th and early 20th centuries. One key aspect of Enlightenment thinking was the belief in the power of reason and empirical observation to unlock the mysteries of the natural world. This emphasis on empiricism laid the foundation for the scientific method, which relies on systematic observation, experimentation and evidence-based reasoning. As science became increasingly associated with rigorous methods and measurable results, it began to be viewed as a more reliable source of knowledge than art, which was often seen as subjective and lacking in empirical evidence (Daston and Galison, 1992: 113). The late 19th-century industrial revolution created a divide between art (creativity, tradition) and science (technology, progress). Movements like Realism and the Arts and Crafts sought to bridge this gap, with Realism portraying contemporary life and Arts and Crafts advocating for ethical, human-centred industrial production. However, a marked divide between the two fields remained.

The modern age (1850–1960) is distinguished by innovation in politics, science, the arts and culture. There has been a heightened separation between art and science, prioritising precise representation in science, as argued by Kemp (2016: 209). Henry Gray's *Anatomy: Descriptive and Surgical* (1858), illustrated by H.V. [Vandyke] Carter, exemplifies this shift, emphasising technical precision over aesthetic expression. Pivotal moments, such as the development of ground-breaking medical imaging techniques in the early 19th century, revolutionised visualisation methods such as microscopy and X-ray. These developments transformed visualisation techniques, providing a new type of observer, as stated by Crary (1992), leading to changes in knowledge and social practices. This revolution had a significant impact on human cognition, productivity and ambition. In the late 1920s, there was widespread concern about the limitations of human judgement. Erwin Christeller, a research scientist, advised against the practice of scientists generating their own images. In *Atlas der Histopographie gesunder* *underkrankter Organe*, Christeller advocated for outsourcing the procedure to technologists, who could focus on producing mechanical pictures (Daston and Galison, 1992: 113). Christeller's actions removed the possibility that a scientist's ingrained convictions or views might impede the transfer of knowledge from eye to hand. Furthermore, Christeller recommended that his anatomy colleagues submit their work to the publisher using authentic anatomical preparations so that the specimens might be recreated "purely mechanically" (Daston and Galison, 1992: 113). Photographic authority was inevitably associated with the eradication of subjective opinion. Christeller stated that there was always subjectivity in drawings since no method was ideal in terms of colour. Photograms, on the other hand, were not impacted by subjectivity; instead, they were degraded by the coarseness imposed by their limited colour palette and, when offered an option, Christeller favoured the mechanical photographic approach. According to Daston and Galison (1992: 114), at this juncture accuracy was sacrificed at the altar of objectivity. This shift was prompted by the wish to stay close to a factual account, removing the individual as much as possible. However, as an artist, despite my rational comprehension of this result, I saw it as restrictive.

Recognition of the rise of scientific objectivity while conducting a historical overview offered me a historical framework and provided a vital context for my study, particularly because the Modernist period (1900–1940) was marked by challenges to traditional art forms and the incorporation of scientific ideas. C.P. Snow's 1959 (2012) debate on the "two cultures" underscored the perceived gap between art and science, prompting further examination of their similarities and differences. In the subsequent mid-20th century, arguments arose for parallels between creativity in art and science, alongside efforts to bridge this perceived gap. As this thesis explores the differences in perspectives between artists and scientists – particularly the seemingly unique perception of artist and scientist in terms of our differing understanding of image-making, representation and technology – being aware of this historical trajectory was helpful. I would argue that this gap is still vast. My objective was to narrow this apparent divide by offering a valuable frame of reference gained via collaboration with contemporary scientists that specialise in generating images using advanced technology, based on empirical data.

The French philosopher, sociologist and anthropologist Bruno Latour's exploration of scientific practice in action (1998) exemplifies such efforts to bridge the perceived gap. Latour highlights a paradigm shift in scientific thought. He claims that scientific practice includes aspects other than hypothetical ideas – what he calls the theoretical "mind" or the physical world. Latour calls attention to the significance of the practice models that scientists employ – i.e., that it is important to recognise the practical aspects of scientific-knowledge generation and to stress the importance of tools, equipment, writing procedures and visualisation techniques. Latour states that what humans do is co-shaped by the things they use. Latour offers a concept for gaining a closer understanding of the mediating role of technology through praxis and how artifacts or objects mediate action (Verbeek, 2011: 10). Actions are a result of intentions, social structures and material environment. His emphasis and acknowledgement of the practicalities involved in science was important in relation to my research. My objective was to investigate how an artist may effectively negotiate and use different approaches to advanced imaging and microscopy in the field of microscopy to open up other perspectives and avenues to gather findings. This exploration was founded on the insights of philosophy of play and technology. My participation in three cutting-edge core-imaging laboratories, as recounted in Chapters Three, Four and Five, clarified the rationale for my substantial time and investment. Understanding that technologies shape our experiences, I considered how both the human and non-human entities involved in art and science are significant (Verbeek, 2011). For example, human social interaction, in this case between artists and scientists, was mediated by the material environment we were working in and the cutting-edge technology we were using. Later, this influenced how I approached my experiences as I mediated human, technological and scientific subject matter.

Contemporary philosophers of technology, such as Borgmann (Verbeek, 2005: 173–199), Heidegger (Verbeek, 2005: 47–95), Ihde (Verbeek, 2005: 121–145), Latour (2010) and Verbeek (2005, 2011), argue that the interwoven character of technology is critical to understanding our technological culture. In contrast to the postmodern enlightened idea of the independent moral individual, they state that human judgements and actions are increasingly impacted by technological interaction. Here, I summarise the key lessons I learned from each to contextualise my practice within a particular philosophical oeuvre and determine the way my work reworks and shifts these ideas. Heidegger's (1889–1976) philosophy of technology examines the function of technology in human experiences with reality and its influence on our understanding of the wider world (Verbeek, 2005: 49). Heidegger argues that technology is a technique of "revealing" reality – translating the Greek word *aletheuein*, meaning to draw out of concealment and reveal what is hidden (Verbeek, 2005: 50–53). Heidegger's concept emphasised the importance of understanding what technology can reveal to me as an artist investing in new and unfamiliar technologies, software and data in a variety of settings during training and use. Borgmann's view of technology as liberating and simplifying challenging tasks resonated with me while working in core-imaging labs with rapidly evolving technology. He illustrates this through the paradigm of warmth, contrasting the effortless use of modern central heating with the labour-intensive process of heating homes by a hearth in the past. Ihde's perspective on technology's role in shaping our perception and actions, along with his analysis of artifacts and user interactions, offered valuable frames of reference. My intention was to understand the meaning of every action I and my collaborators took, and this spanned contact, experience and cognition. Latour's Actor-Network Theory (ANT) improved my grasp of the fundamental linkages between art, science and technology that could potentially be mapped. How human (scientists) and non-human objects (such as microscopes, scientific gear and devices, subject matter, the computer and lab notebooks) shaped my perception of events and the mapping process. Gaining practical knowledge allowed me to see how working with scientists and observing their conduct could broaden our outlook. It was a way to test my hypotheses that integrating play into art–science research could generate innovative collaborative platforms that promote multidisciplinary interaction. I believed that Verbeek's focus on post-phenomenological terminology in comprehending the mediating function of artifacts made it possible to thoroughly examine particular technologies and provide more complex descriptions.

Verbeek states technological artifacts not only close off but also open new ways of mediating experiences by explicitly addressing the role of objects in their environments. He argues that mediation is a byproduct of an artifact's functionality, shaping the relationship between humans and their world. His study explores the role of mediation in products, focusing on their function as objects rather than as signs. Verbeek highlights how sensorial interaction with material artifacts shapes perception, where their handiness is co-shaped by use. He states that aesthetics, tied to sensory experience, is both visual and sensual (2005: 211). This connection between aesthetics and the practical use of objects reveals how technology influences perception and action. The relationship between people and machines, not just their design, is central to this process. For example, shifting my focus altered my perception of technology's impact (Verbeek 2011: 16). Using computers and microscopes in labs deepened my understanding of "technological intentionality" (Verbeek 2011: 16).

Mihalyi Csikszentmihalyi and Eugene Rochberg-Halton (1995 cited in Verbeek: 223–225) conducted research on the meaning of things and developed a conceptual framework to understand how objects acquire meaning for people. They posited that meaning is generated by the active interaction between people and things, which they interpreted as a transactional process. They argued that meaning is not just physical behaviours but also psychological activities. Artifacts can mediate the bonds between people, involving human functioning and being present in a functional way. Verbeek emphasised the relationship between humans and their world, with things playing a crucial role in this relationship. Technology, in our current culture, mediates how humans are present in their world and how the world is present to them, and this shapes subjective and objective knowledge (Verbeek, 2005: 203–236). In relation to Verbeek's theoretical discourse on the mediating role of technology, I considered how my presence in the scientific laboratory when navigating and communicating alternative approaches to science and gathering diverse types of data was influenced by my use of, and interaction with, various cutting-edge technologies.

In my research on digital image-making, I referenced literature on digital cultures, including Charlie Gere's (2002) exploration of how digital technology influences media, telecommunications, science, technology and money. This literature examines the impact of digital technology on industrial capitalism, warfare, avant-garde creativity, counter-cultural experimentation, radical philosophy and subcultures, tracing the history of digital culture back to the late 18th century. Professor Madeleine Sorapure (2003) states that Lev Manovich's (2001) book, *The Language of New Media,* identifies five key principles of new media as cultural trends: numerical representation, modularity, automation, variability and transcoding. These concepts have a significant impact on the creation, distribution and reception of new media. This study prompted me to consider which aspects of the language of new media are pertinent to my research as a digital artist while working with scientific data. Art historian, curator and photographer Julian Stallabrass (2003) illuminated the implications of net art on authorship and the definition of art, exploring its challenges to the art industry and traditional critical analysis, which prompted me to reconsider how and where to situate my practice. I chose to situate myself in the field of drawing, which I discuss later. In *The Wretched of the Screen,* filmmaker, visual artist, writer and pioneer of the essay documentary genre, Hito Steyerl (2012), examined the politics of the image, which are related to Capitalism's immaterial and abstract flow. She highlights a clear support system, asserting that the digital image is situated inside a cyclical framework of desire and commerce that operates within a certain economic structure. This led me to contemplate which cyclical system I wanted to embrace. Research on the connections between humans and technology, particularly in the *International Journal of Performance Arts and Digital Media* and the *Leonardo Journal*, shifted my thinking on how artists and scientists interpret image data. For example, Gingrich et al. (2024) explore participatory art's impact on social connectivity, while Prasad et al. (2017) examine the role of computer-generated images in contemporary art from psychological, philosophical and scientific perspectives.

Play theories

Figure 1. Timeline of key scholars on play theories and links to other studies of play.

As my research was based on the notion that play could be used strategically to facilitate collaborative relationships with scientists, my starting position was to review existing literature on theories of play, as previously introduced and further explored in Chapters Three, Four and Five. The following 20th-century scholars were the most useful: Huizinga (1895–1945), Winnicott (1895–1971), Gadamer (1900–2002) and Caillois (1913–1978). Following this, I reviewed the literature on collaborative art practice, from the art historians and critics Kester (born 1959), Bourriaud (born 1965) and Stallabrass (born 1960), whose contemporary-focused theoretical approaches guided my understanding of relational aesthetics (Bourriaud, 2002), collaboration and situating practice.

Beginning with the Dutch historian and cultural theorist Huizinga and his definitive philosophical treatise on play, *Homo Ludens* [1938] (2016), my thoughts on the role of play in art and scientific cultures was influenced by the focus on the play element in culture. This made me reconsider how play functions within, and permeates, both domains. Huizinga argues that play is deeply ingrained in our cultural psyche, with various forms of culture originating from ludic actions (Huizinga, [1938] 2016: 46–47; Rodriguez, 2006: 6; Ward, 2022; Zimna, 2010). He states that despite refined cultural appearances, art, science and philosophy all share an element of playfulness. This suggests that traces of play can be found in every aspect of society. Huizinga encourages us to explore the hidden meaning of play and its cultural effects, as he states that cultural achievements depend on a deep yearning for ludic activity rather than rational thinking. Huizinga's insights led me to explore the profound meanings of play as part of my investigation. Consequently, this shed light on the significant elements of playfulness that are embedded within the professional activity of artists and scientists, whose disciplinary activities are practice based and process driven, and who use cutting-edge technology to construct images. It drew attention to the differences and overlaps between these two fields, and their connection to logic and playful thinking.

Huizinga suggests that play influences comprehensive behaviour patterns and encourages learning through speculation and risk-taking. Play, therefore, enables us to experiment with various strategies that we can use to encourage learning (Huizinga, 2016: 1). He argues that play is a fundamental part of our being and exists because it is good for us, and views play as progressive, affecting rules and conventions (Huizinga, 2016: 1). It is a vehicle we can learn from instinctively by simply putting ourselves into a mindset and position to play (Huizinga, 2016: 1; 3–4). Play makes sense to the players, because they are aware of the objectives and rules. Huizinga asserts that despite the potential for illogical play, and fluctuation between exploratory and intentional actions, this all amounts to a form of reasoning. Both aspects appealed to me because I wanted to push the boundaries of what was feasible for both my colleagues' and my own methods of learning about science and technology, and subjects that are invisible to the human eye. In short, from the vantage point of an artist studying science, I wanted to explore the concept of play as a progressive strategy by examining how it influences rules and how it may challenge established norms.

Huizinga's work explores the concept of the "magic circle" – a separate sphere where we examine an experience as we engage in play within specific limits (Huizinga, 2016: 20). This occurs by simulating an explicit temporary boundary, with a clear beginning and end in which a momentary suspension of everyday routine reveals opportunities to identify several fleeting systems of engagement (Huizinga, 2016: 13). This separation, often on a game board or stage, is essential for performative games as it determines play and protects the players. Breaking the "magic circle" (Huizinga, 2016: 20) undermines the fundamental nature of play, as the boundaries serve a socially necessary function, providing a context for safe and reliable gratification of our play-drives. Huizinga's concept of the "magic circle" (Huizinga, 2016: 20) challenged me to investigate safe places to study the function of play. Huizinga's reference to performative games inside the "magic circle" (Huizinga, 2016: 20) underlined the relevance of directing play to challenge my creative activities to obtain new insights within the safe zones I carved out.

To shed light on the value of creative activities in scientific labs, I researched the work of English paediatrician and psychotherapist Donald Winnicott. Winnicott (2005: 74) emphasised the importance of playing to understand how humans develop creative, inventive approaches to the world, as he came to believe play provides agency. He contends that play is the only vehicle for individuals to engage in social relationships, allowing them to develop their creativity and social skills, and thereby better themselves (Winnicott, 2005: 71; 73). Winnicott's (2005: 64) position is that adults' desire for play stems from the pleasure it provides, despite potential anxiety due to its complex, unpredictable and potentially dangerous nature. To demonstrate how play affects assumptions, Winnicott contends that knowledge of play's purpose enhances our understanding. This understanding, in turn, enables us to take on his claim that knowledge may transform a hesitant player's position of incapacity to play into one of playfulness.

Winnicott's ideas challenged me to act as a conduit (an artist–researcher working in conjunction with scientists) and devise play-promoting strategies whilst conducting individual and group play activities. Furthermore, Winnicott's (2005: 69) emphasis on the possibilities of unconventional surroundings as opportunities for cultural enlightenment strengthened my focus on evaluating where individual and group play took place. According to Winnicott, such places can reduce rigidity and stimulate playful behaviour, which prompted me to conduct research in a variety of settings to delve deeply into the relationship between real-life experiences (with scientists) and scientific phenomena and technology, in order to examine play's knowledge-generating potential.

The German philosopher Hans-Georg Gadamer's overarching goal in *Truth and Method* (1994) was to provide a means of presenting assertions, ideas and judgements made in the arts and humanities in ways that cannot be reduced to, or explained away by, natural scientific approaches. Rather, such assertions necessitate an interpretation theory that, according to Gadamer, enables a comprehensive ontology of how humans interact with their environment – what he calls 'hermeneutics'. The origin of hermeneutics is the Greek word *hermeneuein*, which means to interpret, and dates to classical antiquity (Lawn, 2006: 45–58). Hermeneutics, according to Gadamer, is both the foundation of human life and a way of understanding. To understand how we interact, one must be open-minded, contemplative and conscious of one's own prejudices and preconceived notions. Gadamer's hermeneutics differs from that of others (see for example, Schleiermacher (1768–1834) and Dilthey (1833–1911) as he believes understanding a text is more dialogical and interactive, relying on a collective version of understanding rather than focusing on the interpreter alone. This perspective is rooted in the influence of German philosopher Martin Heidegger, who argued that being is fundamentally shaped by understanding and interpretation. Contemporary hermeneutics is thus significantly informed by the ideas of Heidegger and Gadamer, as well as by thinkers like Paul Ricoeur (George, 2020, Grondin 1994, Schmidt 2006, Zimmerman 2015), creating a rich dialogue that continues to evolve our understanding of interpretation. The shift from theory to interpretation is a move towards practical activity. The theory behind it is that the types of interpretation we use in our daily visual encounters indicate fundamental and permanent patterns of our being in the world. This was a crucial consideration, since I planned to gain practical, technical and theoretical knowledge from undertaking research at three core-imaging facilities, and from my observational, written and visual interpretation of their data, to answer my research questions.

Gadamer (1998: 106–107) states "all playing is being-played": it is immersive and cyclical. He explains that the game itself holds the player in its spell, drawing them into play and keeping them in it. The game's distinct identity is established by its rules and regulations, which dictate the design of the field of play and the structure that governs the game's movement from inside its borders. Within these borders, Gadamer (1998: 102) states play can be a form of seriousness, where players acknowledge it is only play and that it exists within a world determined by its serious purpose. He believes seriousness is necessary for play to be wholly play, as it does not allow players to treat play as an object, rather a mode of being (Gadamer, 1998: 103). This was essential because I was defining the field of play where I wanted to play, while also resolving any challenges that might arise. I treated play as a strategy for inquisitiveness and enquiry, while also addressing the serious aspects of play I encountered in the game I devised, as described in Chapters Three, Four, and Five.

Gadamer (1998: 22–28; 1994: 101–121) is also concerned with the connection between art and play, and emphasises the experience of art, highlighting its transformative nature. In *The Relevance of the Beautiful and Other Essays*, Gadamer explores art as a cultural phenomenon, focusing on the whole picture of action, events and concepts, and acknowledges that art can fracture the cultural sphere in exceptional circumstances (Gadamer, 1998: 123–130). He categorises innovative art methods as excellent creative periods, highlighting their unique characteristics and ability to adapt to change (Gadamer, 1998: xv). Gadamer's (1998: xx) study suggests that understanding and imagination have a crucial role in developing visual concepts in modern art. He clarifies how creative representation, as a process of interrogation, does not require concrete answers, as artworks can respond to the world differently (Gadamer, 1998: 126; 128).

In his examination of art as play, Gadamer addresses the question of translation, attempting to capture art's desirable characteristics, which he describes as bountiful (Gadamer, 1998: xiii). Gadamer (1998: 126) refers to the work of art as "gebilde", which implies that the work becomes a self-sufficient creation since it evolved in a unique and unrepeatable manner, and we should take the word of art as our point of departure from which to innovate. My goal was to transform ideas for artist and scientist by investigating the desirable qualities of image data and develop inventive visual approaches for comprehending scientific knowledge. I also wanted to disseminate my results to a wider field.

At this point, I turned to French scholar Roger Caillois, who integrated literary criticism, sociology, ludology and philosophy to get a thorough understanding of various play genres. Caillois (2001: 33) defines kinds of play and techniques of playing in *Man, Play, and Games.* Like

Huizinga, he describes play as a voluntary activity that takes place in a pure environment, cocooned from the rest of life, i.e., within a "magic circle" (2016: 20).

Caillois (2001: 12–26) identifies four primary criteria for play: *Agon*, which involves competitive games based on speed, power, stamina, recall and skill; *Alea*, driven by luck and chance beyond the player's control; and *Ilinix*, which aims to evoke vertigo and a temporary loss of stability, often inducing fear, as seen in rituals like the Mexican Voladores ceremony (UNESCO, 2009). The most pertinent to my study was *Mimicry,* wherein all play requires the temporary acceptance, if not of an illusion, then of a confined, conventional and, in some ways, fictitious reality. Since play is such a broad term, I will briefly describe the type of play I mean. First, it entailed performative play, which included acting out scenarios, imitating the actions of others, and assuming the identity of a different profession, such as a scientist playing the role of instructor and a documentary photographer – shedding one's individuality to impersonate another or a thing. This requires faithfully duplicating others' activities to understand the factors driving their decisions. One is met with a broad set of expressions, all of which have one thing in common: the person believes or makes others believe he is someone other than himself. The game's unique rule is it must captivate the audience while avoiding making a mistake that would break the spell. The audience is supposed to perceive in something more real than reality itself for a certain amount of time; thus, they must submit to the illusion without questioning the artifice, as the strict boundaries of play prohibit alienation (Caillios, 2001: 49). According to Caillois (2001: 21), mimicry embodies all aspects of play, such as freedom, convention, suspension of disbelief and delimitation of time and space. Imitation is a dynamic concept that challenged me to investigate the performative actions of myself, and artists and scientists, as we interacted with each other.

Furthermore, it directed my attention to the visual interpretation of an image, where copying helps understand its structure and meaning. As Caillios (2001: 19) asserts, play takes foresight, vision and conjecture, which necessitates calculation and introspection. He discusses rules and the liberty that play affords. He indicates that the absence of clear rules enables rule makers to invent imaginary scenarios and adapt them, leading to fresh assessments that reshape our comprehension of a particular topic. The actions are carried out by means of re-interpretation. This is a key aspect that I test in this study, as discussed in Chapters Three, Four and Five.

Caillois (2001: 29–31) highlights the importance of risk and speculation in various forms of play. He suggests experiencing tension to invest in uncertain outcomes (Rodriguez, 2006: 2). He asserts that the concept of play encompasses free, solitary and collaborative activity, highlighting the need for introducing specific conditions for play-based activity. This pushed me to research actively the benefits of playing in various settings (free, solo and group activities) to improve my cognitive skills and to determine the most effective play scenarios and the potential ways to integrate play into the framework I was creating, as covered in Chapter Two.

Situating practice

Academic Anthony Downey (2007) argues that Nicolas Bourriaud's book *Relational Aesthetics* (2002) focuses on perceptive, experimental and participatory models, which align with the ideas proposed by Enlightenment philosophers of the 17th and 18th centuries, Pierre-Joseph Proudhon (1809–1865), Karl Marx (1818–1883), the Dadaists (1915) and Piet Mondrian (1872–1944). Art writer Toni Ross (2006) states Bourriaud's concept of *Relational Aesthetics* was an influential framework for understanding disciplinary crossovers in art of the 1990s. I examined relational art's attributes, which Bourriaud roughly characterised as co-operative, participatory, interventionist, research-driven and community-based endeavours, as I wanted to foster interdisciplinary dialogue and break down silos. These realisations were helpful because they let me put my own creative work in an interdisciplinary art–science context.

Downey (2007) claims relational art is a subset of creative endeavour that focuses mostly on generating and considering interpersonal relationships and the degree to which these relationships, or communicative actions, might be regarded as artistic forms. Bourriaud highlights the deterioration of inter-human communication as the most pressing issue in post-industrial society, emphasising that relational art's ability is to address and rationalise real-life situations (Bourriaud, 2002). Bourriaud (2002) contends that creative practice, although connected to global capitalist trade networks, also offers open spaces and social experiments that are partially, or entirely, sheltered from or beyond ordinary life behaviours. This logic grounded my reasoning for working as an artist in scientific labs.

Downey (2007: 267–275) indicates that Bourriaud's terms, such as conviviality, dialogue, democracy and politics, require further qualification for political relevance in a globalised, service-based economic environment, where aesthetics is increasingly essential for social change. Bourriaud suggests that rules, patterns and abilities in art evolve based on creative and technological processes, as well as its human context. I was challenged to consider my own use of technology as a result of Bourriaud's (2002: 71) description of two branches of technological knowledge – the computer and the internet – and how these have changed man's relationship to contemporary image, and how we perceive and process data. He asserts that maintaining that evolution of innovative technologies leads to new areas of sociability (Bourriaud, 2002: 25). Bourriaud (2002: 11, 18) saw *Relational aesthetics* as a game that was constantly evolving. Following Bourriaud's guidance, I developed a game to test whether my study of cutting-edge technologies and the parallels and divergences I found would have an impact on how I engaged with scientists and their tools. It was yet another reason to embrace play.

Art historian Grant Kester discusses socially engaged art practice. He focused on works produced outside institutional spaces like museums, galleries, or biennials. He emphasised the value of in-person creative interactions and contemporary artists' concepts (Kester, 2013). Kester (2013: 2) suggests that contemporary art should challenge conventional experiences and knowledge systems by examining the roots of contemporary aesthetics through what he terms dialogic aesthetics. Kester (2013: 59) argues that hybrid practices, as dialogic practices, possess their own positive visual content and are more than mere supplements to the authentic work of painting or sculpture. Drawing on sources from aesthetics, political philosophy, art theory and history, he aimed to create a paradigm for closely examining endeavours relating to or in the form of dialogue (Kester, 2013: VvIII). He emphasised the significance of purposeful problem-solving in artistic and creative work, as well as duration, over instant gratification by highlighting the contextual potential of collaborative processes.

Kester (2013: 9) discusses contemporary artists and art collectives whose focus has been on fostering communication across disparate disciplines. He considers artists who have shifted away from object-making traditions and towards a performative, process-based methodology. He cites work such as Allan Kaprow's happenings and performances in the United States, as well as artists such as Stephen Willats and the Artists Placement Group (John Latham and Barbara Steveni) in the United Kingdom. According to British artist Peter Dunn, these artists are "context providers" as opposed to "content providers" (Kester, 2013: 1). Their work involves the creative arrangement of co-operative interactions and dialogues that take place beyond the formal walls of a gallery or museum. In doing so, they expand the critique of art into a series of positive activities aimed at the world outside the gallery walls, connecting new forms of intersubjective experience with social and political action. Kester's comprehensive analysis and emphasis motivated me to promote interdisciplinary communication and experiment with working in non-traditional environments as part of this research project.

Stallabrass's (2006) discussion of the Young British Art (YBA) movement helped position my research outside of commercial settings. The 1990s shift of art towards business, driven by declining state funding and museum commercialisation, provided a departure point as I focused on introducing art into non-traditional settings for the mutual benefit of myself and the scientific communities I collaborated with. I explored unconventional locations for non-commercial purposes, investigating art as an instrument of inquiry rather than sales. My approach is not an attack on the system, but a softer participation in line with Kester's (2013) perspective.

My study was conducted and structured in terms of dialogue, relationships and trade, which was influenced by the approaches of Bourriaud, Kester and Stallabrass. This allowed me to develop my methods for creating connections, while serving as a conduit (an independent artist–researcher working in conjunction with individuals and small groups of scientists; see Chapters Three, Four, and Five).

Interviews with cultural producers and cultural brokers

To further contextualise the understanding of the significance of art–science collaboration, I interviewed three influential cultural producers and cultural brokers on their position on the value of art's contributions to science.

Based on their extensive experience operating at the interface of Art and Science, I approached Ken Arnold, Head of Public Programmes at the Wellcome Collection (WC) and Creative Director at the Medical Museum at the University of Copenhagen; Daniel Glaser, Director of the Science Gallery (SG), London; and Rosie Stanbury, Head of Live Programmes at the WC (see Appendix Two). They offered insight into institutional strategic vision, their views on play as a concept and their current public-engagement strategy (see Chapters Three and Five). Whilst their position enabled a strong understanding of current positions on the role of art within science, importantly, their points of view shaped my research development in collaborative practice, with play as an alternative method of disseminating science. For example, Arnold advocated that artists should take risks and employ forms of showmanship alongside an instinctual approach and that they will not deliver what is expected of them. At the same time, Arnold stated that the Wellcome Trust is a health-based organisation, with its focus and remit on highlighting global issues and the impact of science. Arnold stated:

> *Yet, I think we are mature and interesting enough to know that health is not just about objective, statistical, biological [facts] – it's not just about atoms and molecules and organs. And it's an incredibly important part, it's about human beings with personal experiences and that art is sometimes an interesting way of excavating that aspect of it, so in our efforts to bring the subjective and objective together sometimes doing that in the company of artists can very much enrich that interest, that range of interests.* (Arnold 2018).

This holds significance as it provides insight into the Wellcome Trust's advocacy, which maintains that communicating the implications of scientific discoveries and complicated global issues requires a comprehensive strategy that incorporates both empirical and human-centred methods. Wellcome believes that everyone will gain from communication about science's capacity to preserve and enhance health. Arnold provides an excellent example of the Wellcome Trust's selfless purpose by showing how knowledge can be conveyed in both subjective and objective ways, and how using a variety of techniques may expand the effect and its audience.

Contemporary artists

The research focuses on four main themes of knowledge derived from the contemporary artists I discuss next. The themes are as follows:

- Drawing's Multifaceted Role
- Interdisciplinary Collaboration
- Exploration of Complex Scientific Concepts
- Innovation and Technological Integration

The thesis discusses these themes in detail, along with the contributions of the research to different fields. Ethical considerations are addressed in Chapter Two.

Curator Bernice Rose (1992) describes how drawing since the 1960s has seen a shift from a traditional medium into an expanded field. According to Rose, a new visual arts vocabulary emerged in the 1960s–80s, based on the use of technology, new disciplinary connections and a wider range of drawing activities. Rose divided historical drawing techniques into two categories: conceptual and autographic. At this point, drawing as a primary medium of the authorial gesture was brought into question and reframed. According to Casey and Davies (2020: 33), conceptual drawing eliminated the personality related to the mark and presented drawing as a mechanical procedure. Conceptual drawing simply left a trace of the actual action. According to Rose (1992: 11), since photography became a viable medium for documenting an artist's basic concept, technology has saturated the environment; likewise, the arrival of mass media and its practices has undermined the significance and practices of traditional art. Rose stated that self-expression and control over our fate are sometimes attacked as cultural myths owing to media's emphasis on conformity and societal pressure. When addressing conceptual drawing, the artist's agency in the process was questioned and dismissed as deskilling, repetition and as a mechanical way of drawing. Yet these methods paved the way for the growth of collaborative drawing techniques in which actions and gestures, such as riding a bike or piloting an aircraft, are exhibited as drawings. When considering drawing as a form of artistic expression that imitates events or creations and allows for interactive engagement, this perspective of drawing as performative and interactive goes beyond mere representation and offers new opportunities for creative and liberating exploration. The thought of an artist using drawing as a method to duplicate processes and procedures physically or mentally transformed my thinking; it opened a method to improve my understanding of scientific discoveries. According to Casey and Davies (2020: 34), the expanded field of drawing refers to the concept of looking at one discipline through the lens of another. From this vantage point, I saw I could use art to re-represent empirical data through reinterpretation. Part of my motivation was to extend my drawing investigations beyond the visual arts and invest in digital modes of transmission. Tamarin Norwood, in *A Companion to Contemporary Drawing* (2020), highlights the radical differences between analogue and digital drawing as a medium, emphasising how these distinctions can reshape our understanding of artistic expression. This exploration allowed me to engage with new possibilities and challenges, enriching my practice and exploring and expanding the boundaries of drawing.

Another driving force was to examine the effects of drawing on our cognitive abilities, such as communication, problem-solving and observation. I intended to employ drawing as a learning technique in my studies, which is why I looked into the work of Princeton researcher Judith Fan. Her studies on education and cognitive science have demonstrated that drawing increases learning throughout the curriculum (Riley and Darlington, 2022: 116). Fan argues for the expansion of the role of graphical literacy in science education, because it can better convey to students – and, I would argue, to scientists at all stages of their careers – the dynamic and inquiry-based nature of scientific thinking in contexts where visual representations have historically been subordinated to linguistic and numerical representations.

Practitioners of influence

In this next section, I summarise contemporary practitioners who have influenced my research approach and informed my practice. From their positions at the nexus of art and science, each artist has contributed important viewpoints that have led to ground-breaking findings that have helped me better understand my own role. I begin with artists who have included technology in their drawings in a variety of ways, before turning to artists whose main focus is technology.

Susan Aldworth's (born 1955) experimental work in print, drawing, installation and time-based media challenges personal, medical, medicated, scientific and philosophical narratives that underpin our sense of self. In 1999, she experienced a brain aneurism. Her diagnosis and effective treatment shaped her involvement in the field of neuroscience. From this experience she has utilised her graphic design ability to expose a wide range of previously unknown medical problems that impact the body and brain (see Chapter Three and Five). Her work alludes to states of opposites and seeks to eliminate the difference between the subjective experience of a living individual and the medicalised view of the condition (Casey and Davies, 2020: 62). She uses techniques and materials from computerised tomography (CT) scanning, X-rays, historical illustration and human brain material as a way of understanding the body. She employs materials like cyanotypes and collages to generate a responsive method of graphic communication. Her work combines logic and purpose, but creates dichotomies as it reveals "associations and incongruities" via a process of cut-and-paste collage (Casey and Davies, 2020: 60). Her graphical work creates an illusion of a deep space that you could dive into – it is oddly vacant and yet practically packed with the materials needed for imagination and sequential monoprint drawing, as in Figure 2.

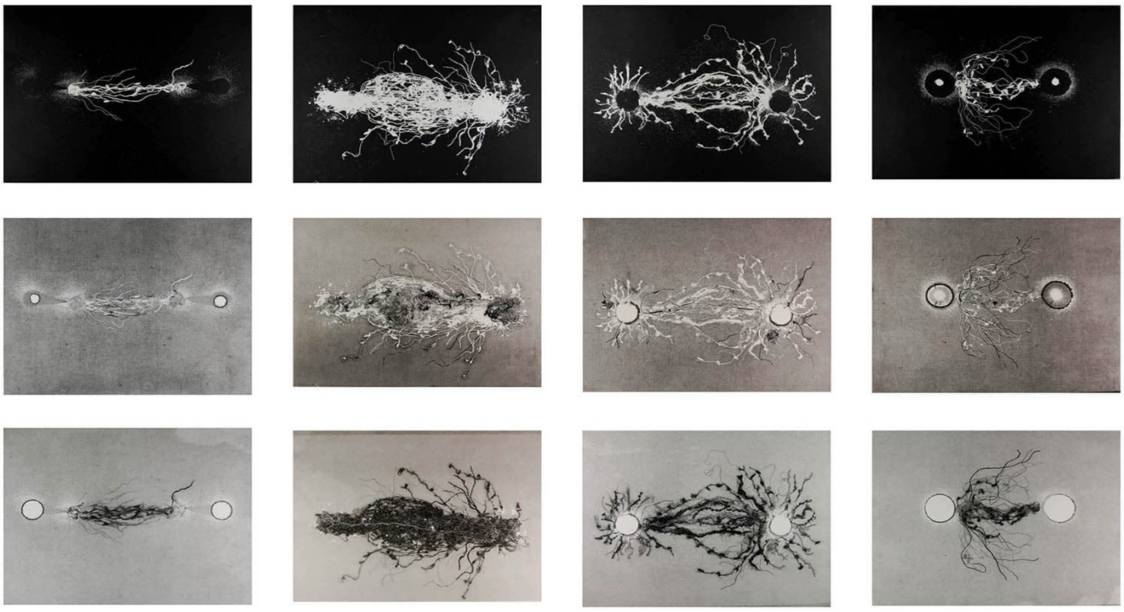


Figure 2. Aldworth, S. Out of Body, installation of 12 monoprints, 304 x 168 cm, 2009. © Susan Aldworth.

Gemma Anderson-Tempini's strategic reimagining of phenomena (morphological, taxonomic, mathematical, free association) illuminates a subjective (personal and intuitive) and objective (verifiable) approach (Anderson, 2017; Anderson-Tempini, 2023; Casey and Davies, 2020: 70). She constructs drawn reproductions for the purpose of identifying and analysing patterns of connection (Berger and Savage, 2005: 3). Her drawing serves as a bridge between various research spheres, aiding in knowledge transfer and collaboration. Anderson-Tempini's exploration of complex scientific and mathematical concepts is analytical in nature, linking process, structure and imagination with quantitative inputs; it is therefore analogous to the history of both scientific and artistic painting and drawing. Her most recent publication *Drawing Processes of Life: Molecules, Cells, Organisms* (2023), co-edited with philosopher of science John Dupré, draws on Isabelle Stenger's (2017) concept of 'an ecology of practices'. Throughout this publication, individual practitioners brought their expertise and commitment to undoing disciplinary structures that constrain thinking across distinct practices. Unforeseen conversations, surprising connections, imaginative challenges and drawing through co-operation correlated with my own objective, which was to break down barriers and set up a series of activities in which various fields might learn from one another. Unlike Anderson-Tempini, I concentrated on computer-generated techniques, which I describe in Chapters Three, Four and Five, as a counterintuitive drawing method.

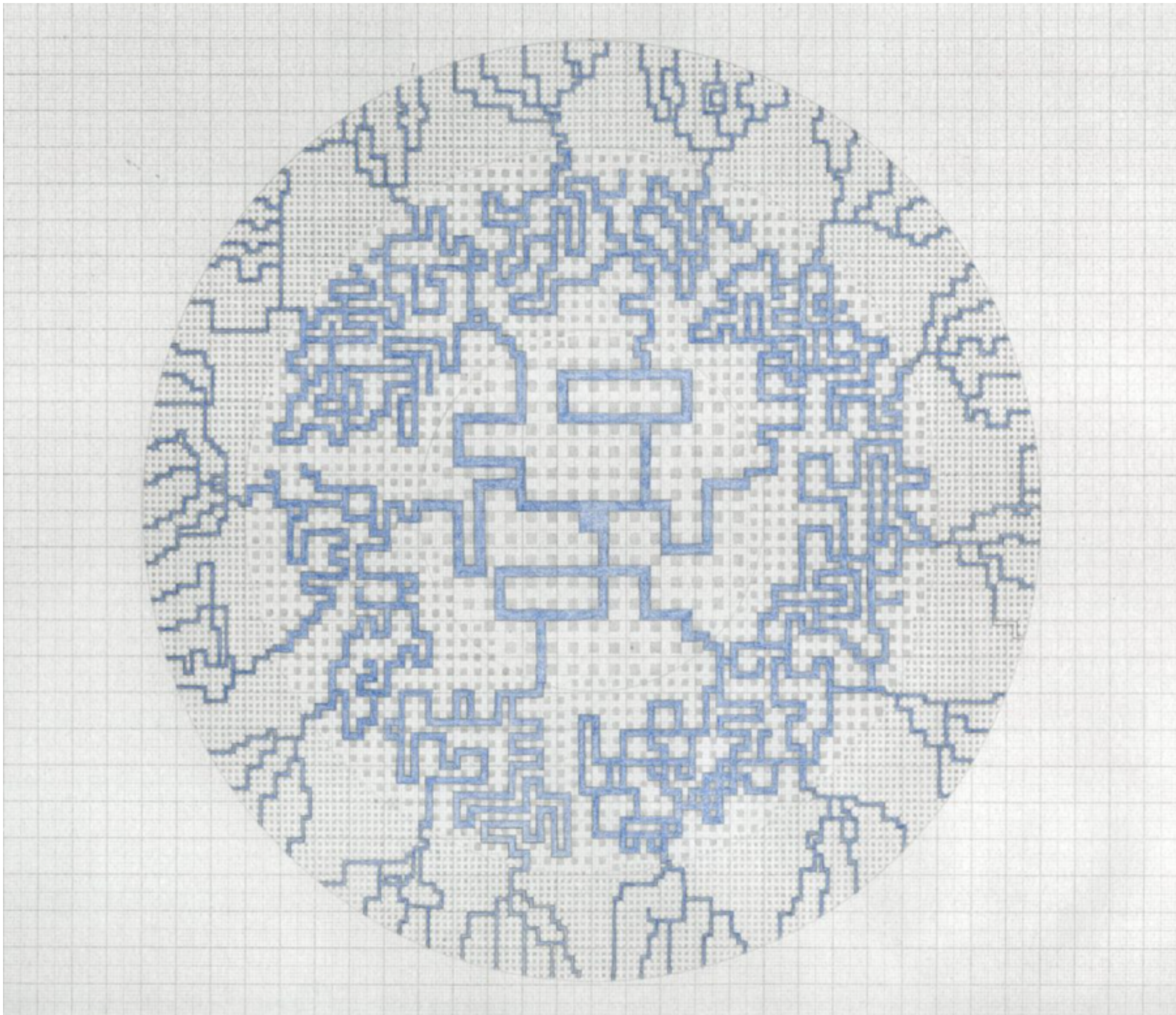


Figure 3. Anderson-Tempini, G. (2022) Garden Forking Path (series 7/11). © Gemma Anderson-Tempini

In *Delineating disease: a system for investigating Fibrodysplasia Ossificans Progressiva,* Lucy Lyons (2009; Casey and Davies, 2020:56–58) analysed Fibrodysplasia Ossificans Progressiva (FOP), a rare congenital condition where bone (ossified) progressively replaces muscle and connective tissue, generating extra-skeletal or heterotopic bone that restricts mobility. Her PhD research explored a particular drawing technique which she termed delineation (Lyons, 2009:1–2). The term delineation was originated by Sir Robert Carswell, a 19th-century pathologist (Lyons, 2009:8–15). Lyons defined it as a realistic drawing system based on observation. Delineation emphasises relevant detail without embellishment, providing clarity for both the delineator and viewer. Lyons' collaborative and dialogic approach and her application of drawing in the context of diagnosis, treatment and the detailed mechanics of human anatomy, offers valuable insight into FOP, while preserving dignity and respectfulness. Lyons' approach aligns with my focus on experiential learning and using drawing to capture the essence of a subject using line.

Figure 4. Lyons, L. (2006). Delineation 25. 8149 (Detailed Profile) 28/03/06. © Lucy Lyons

Andrew Carnie's (2008; 2023; Bright, 2015) artistic endeavours revolve around long-term interdisciplinary collaborations with scientists. The self and the brain as an ever-changing vital organ are two of his prevailing themes, alongside genetic disorders and human physiology. His integration of high-tech artistic processes and his emphasis on blending new and old media, including animation software, digitised video, photography and slide installations, with techniques from 18th- and 19th-century pre-cinematic multi-media (dioramas, panoramas and camera obscura) are central to his artistic practice. This interdisciplinary approach not only showcases the convergence of art and science, it also highlights Carnie's role as an artist committed to investigating complex scientific concepts through innovative artistic methods combined with technological integration (Kwint, 2010). His most recent work *Being Human: Works in Progress* (Carnie, 2023) continues his creative exploration of the human body and expands upon his interest in the visual representation of the body and nature.

Figure 5. Carnie, A. (2023). Solo exhibition at West Downs Gallery in the UK features an inflatable set of works using weather balloons and sensors, showcasing the human body in action. © Andrew Carnie.

Robert Kesseler's work revolves around the construction of technologically sophisticated large-format photographs and multi-frame images, utilising cutting-edge imaging techniques such as electron microscopy (EM) and energy dispersive X-ray spectrometry (Jackson, 2020; see

Glossary). He traces his interest in microscopy back to Hooke's publication *Micrographia* (1665) and botanists from the 1600s, such as Nehemiah Grew (1641–1712) and Carl Linnaeus (1707–1778), (Kesseler, 2010: 121–169). Through his exploration of microscopic materials, Kesseler delves into the creative potential inherent in the unseen world, integrating formal visual considerations like scale and colour alongside digital reproduction methods. In doing so, Kesseler's artwork is advancing visual knowledge within the realm of art practice while highlighting the intersection of art and science in innovative ways. Kesseler's work has informed this research by exemplifying a long-term interdisciplinary collaboration. His obsessive exploration of complex scientific concepts and his use of scientific technology is similar to my exploration of scientific visualisation, as discussed in Chapters Three and Four.

Figure 6. Kesseler, R. (2008) Phy-topic. © Rob Kesseler

Additionally, Chapter Five briefly discusses Anna Dumitriu's extensive exploration of the ethical implications of art–science collaborations, particularly through the *Trust Me, I'm an Artist* project (2011–2017) and *Trust Me, I'm an Artist: Developing Ethical Frameworks for Artists, Cultural Institutions and Audiences Engaged in the Challenges of Creating and Experiencing New Art Forms in Biotechnology and Biomedicine in Europe* (Dumitriu, 2018). Collaborating with ethicist Bobbie Farsides, Dumitriu organises events to examine ethical issues at the intersection of art, science and biomedicine, highlighting the intricate dynamics of interdisciplinary collaboration and emphasising the essential ethical considerations for navigating these intersections. Ethical considerations are addressed in Chapter Two.

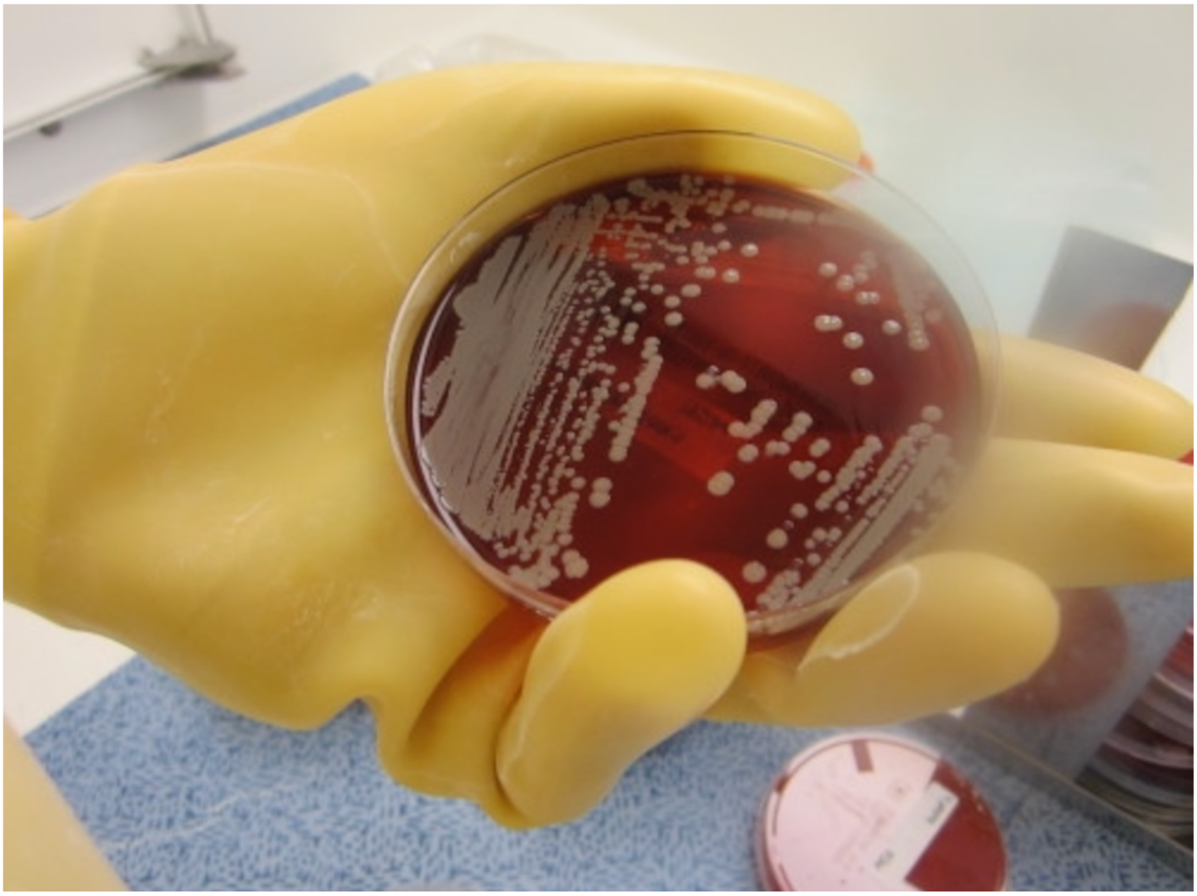


Figure 7. Dumitriu, A. (2012) Trust Me I'm an Artist: Towards an Ethics of Art/Science Collaboration. © Anna Dumitriu.

In summary, like all the artists I have cited in this chapter, the research I have undertaken crosses boundaries between disciplines and contributes to art–science interdisciplinary collaboration. My divergence is that my research is centred on investigating play as an insightful concept to elicit other data. To do this I have considered human and non-human elements, such as optics, technology and scientific subject matter as possibilities for serious play, which I then used to expand my practice outputs.

The philosophers cited in relation to why play exists focused my attention on how play can contribute to cultural enlightenment. Huizinga (2016) pushed me to consider the importance of performative games and the setting in which I played. Winnicott's (2005: 51) emphasis on how playing together leads to creativity and well-being, demonstrated through its use in psychology, challenged me to examine how I might direct myself and others into a state of being able to play. Gadamer's (1998, 1994) examination of the ways in which play may be utilised to improve our understanding of art and ideas through interpretation led me to re-evaluate and expand upon my artistic practice methods. The four primary play categories named by Caillois (2001) and the importance of creating specific conditions for play-based activities changed the way I thought about using structured play to develop a play-based framework to navigate and communicate alternative approaches to science. The methodology and methods employed so that knowledge emerged are described in the next chapter.

Chapter Two: Research design

Participatory Action Research (PAR)

In this chapter, I outline my position as an artist–researcher as I developed a model and framework for conducting art–science research. I adopted Participatory Action Research (PAR) (Gray & Malins, 2004; Smith & Dean, 2014) as a methodological approach, specifically to explore how scientists conceptualise image-making, creativity and technology. In doing so, I drew on Revans' (1983) action learning principles, which emphasise that meaningful learning arises from addressing real-world problems through cycles of action and reflection. This approach aligned closely with my aims, supporting my intention to embed my inquiry within practice and to engage collaborators in a process where knowledge was generated not through instruction, but through purposeful, experience-driven questioning, action and reflection. My objective was to extend the scope of creative research, stimulate interdisciplinary innovation and challenge rigid disciplinary boundaries. To support this, I adapted Reason and Bradbury's (2008) community health model, with its emphasis on social communication and active participation. This was originally developed to foster collaboration and reflective practice within a medical setting, bringing together health professionals, community members and other stakeholders. Its cyclical process of planning, action, observation and reflection aligned closely with the methodological principles of my project. To facilitate effective participation, I took a pragmatic approach, ensuring that scientists were actively involved in both the practical and dissemination stages of the research process. This model enabled the identification of issues as they arose and allowed for a more holistic analysis, acknowledging that scientists often face time constraints and cannot always contribute data consistently.

As Black et al. (2023) observe, there remains a persistent lack of understanding within the sciences about how the arts engage in their own distinct forms of inquiry – an issue exacerbated by disciplinary language barriers that complicate cross-sector collaboration. In direct response to these challenges, I strategically advanced my art-practice by reinterpreting and applying a PAR framework as a contextually relevant and epistemologically bridging methodology (Gray and Malins, 2004; Smith and Dean, 2014).

To ground this inquiry further, I positioned my methodology within the lineage of ‘post-studio’ practices. These included socially engaged art, and dialogic and participatory forms, as discussed in Chapter One. A key historical precedent is the Artist Placement Group (APG) (1965–1980s), whose members embedded themselves in industrial and governmental settings. APG arranged over nineteen artist placements across the U.K. and Western Europe. Initially, the group focused on prominent industries, including Garth Evans’s placement with the British Steel Corporation (1969–1971) and Andrew Dipper’s placement with Esso Petroleum (1970). A major turning point came in 1972, when Barbara Steveni negotiated the Whitehall Civil Service Memorandum with the U.K. government, enabling artists to work within government bodies. This led to placements such as John Latham at the Scottish Office (1975–1976) and Ian Breakwell at the National Department of Health and Social Security (1975). To help reshape and broaden how the artists’ roles were understood, APG began referring to artists as “Incidental Persons” (Steveni, 2020).

The APG’s approach has similarities with Kester’s (2013) concept of dialogical aesthetics, which emphasises collaboration, ethical engagement and sustained dialogue between artists and communities. Simultaneously, I considered and accepted British art historian and critic Claire Bishop’s (2012) critical perspective on participatory art, particularly her interrogation of the tension between ethics and aesthetics. I shared her argument that disruption can be a generative force, central to meaningful engagement. Both perspectives reject traditional gallery-based models in favour of embedded, socially responsive practices situated in real-world contexts. Kester's (2013: 24–25) focus on agency and collective authorship, where participants help shape both the aims and methods of the work, resonated closely with my own methodological commitments.

Importantly, PAR offered a research structure familiar to my scientific collaborators, with its iterative cycles and emphasis on data collection, albeit qualitative. It resonated with scientific approaches to inquiry, while ensuring that the research process remained inclusive and adaptive. This overlap helped bridge epistemological differences and fostered mutual understanding, making PAR particularly suitable for artist–scientist collaborations.

1) Research:

I focused on collecting a wide range of data across various scientific specialisms, emphasising flexibility. I deliberately designed my approach to be flexible, enabling me to adapt effectively my methods and research strategy to different situations – whether collaborating with new scientists, integrating into existing research groups, or working across three distinct core imaging labs. This included contextual research to situate my practice through a comprehensive review of literature spanning science, art and philosophy of technology. I examined how contemporary artists generate knowledge and explored relevant scientific literature to frame the scope of my inquiry (see Introduction, and Chapters One, Three, Four and Five).

2) Action:

Drawing from my professional expertise, I strategically employed *play* as both a conceptual framework and strategy to investigate ways of understanding and developing interconnections between art and science. I set out to test whether play could be used strategically to foster collaborative relationships with scientists, through direct learning and critical engagement with scientific methods and processes. I positioned play as a catalyst for creativity, encouraging the emergence of the unusual, the tangential and the less empirical, in order to uncover the 'happy accident' and to look beyond purely scientific results. This approach is supported by a review of existing literature on theories of play, as introduced earlier and explored in detail in Chapters Three, Four and Five. Central to this approach was my engagement in art-practice research through PAR**.**

One of the requirements for successful PAR is to draw together stakeholders and multiple sources of data from relevant domains. To achieve this, I utilised semi-structured interviews and surveys with collaborators and cultural producers, as well as systematically and thoroughly documenting research across both scientific and artistic activities. In order to maintain a critical awareness of the diverse perspectives of peers and experts across the domains of art, science and technology, data gathered includes scientific measurements and qualitative reflections, gathered through various forms of engagement, such as participant observation and informal conversations. This blend of approaches from multiple vantage points allowed for the emergence of insights, not only through structured interaction but also through embodied experience and relational dynamics, encouraging a holistic approach to knowledge generation.

To make sense of this complex, practice-based inquiry, I drew on Donald Schön's *The Reflective Practitioner* (2013), which deepened my understanding of tacit knowledge in action. Schön's work underscores how skilled practitioners often operate with a form of knowing that exceeds what can be easily articulated – an idea that resonated with the iterative, intuitive aspects of my own methodology. Building on this, Professor Judi Marshall's (2001: 433–439) concept of "open frames" supported a reflexive, context-sensitive inquiry process. I visualised this through “magic circles” (Huizinga, 2016: 20), i.e. overlapping spaces of play and experimentation, detailed further in the next section (From PAR to research framework).

This perspective aligned with the cyclical, non-linear nature of PAR, where phases of action, reflection and consequential adaptation evolve dynamically. Within this framework, I came to view art as a reflective process integrating theory, experience and embodied knowledge, expressed in both creative acts and their outcomes. These are explored in Chapters Three to Five.

Central to my approach was UNESCO’s definition of art as research and particularly Klein’s (2017:1) strategies of art as a creative, systematic process, alongside strategically selected approaches by Frayling (1993), Borgdorff (2010), and Dombois (cited in Klein, 2017). These all frame research *about*, *for* and *through* art. Following Borgdorff, I placed creative practice at the centre of my inquiry, treating theory and practice as interwoven.

Guided by Klein’s (2017) strategies of seeking, modelling and intervening, I actively positioned myself as an artist-researcher critically engaging with scientific discourse and technologies. In line with qualitative principles (Myers & Avison, 2002), I prioritised verifiable, observable data captured through fieldnotes, photography, diaries and film. This yielded dialogic, ethnographic and process-led insights (Glaser and Strauss, 2017), as discussed further in Chapters Three to Five.

3) Collaboration:

My approach centred on Bourriaud’s (2002) idea of acting as a conduit while working as an independent artist in a scientific lab. Being a conduit facilitated role-play, dialogic discourse, mimicry and conversational exchange with scientists who conduct research based in core imaging labs. These activities reflected and enacted the principles of cross-disciplinary collaboration, encouraging innovation, not only within the laboratory, but also through the dissemination of findings. PAR enabled this by supporting diverse data-gathering techniques through direct face to face collaboration. Alternative modes of presentation, such as co-presenting alongside scientists at academic conferences, further activated a socially engaged art practice, legitimising the artist's role in scientific contexts and aligning my methodological choices with broader shifts in contemporary art.

Working in unfamiliar fields, with different norms and expectations, it was important to pick up on nonverbal cues to gather different forms of data. To support this I drew on Fontana and Frey's (1994: 371) research on nonverbal communication, which informed how I conducted interviews and observations. I integrated their four categories of nonverbal cues into my data collection methods: proxemic (interpersonal space), paralinguistic (tone and pacing of voice), chronemic (use of timing and silence), and kinesic (body movement and posture). This attention to embodied communication contributed to the iterative and reflective cycles of inquiry at the core of my research. Its impact became increasingly clear later in the research, especially during Art Project Three (see Chapter Five), where the performative nature of participants' actions became a central part of my visual analysis.

Adaptation of a PAR model

To structure and implement this complex methodology, I customised an existing PAR model into a flexible, project-responsive system (see Figure 8), designed to collect efficiently and categorise data while remaining adaptable to different contexts. The model's flexibility proved crucial in navigating the methodological challenges inherent in collaborative research, particularly those related to group dynamics and the potential influence of conflicting values, expectations and objectives. By actively negotiating these tensions, I preserved the integrity and authenticity of participant engagement.

At the same time, I critically engaged with ongoing debates about scientific rigour, reproducibility and objectivity – issues often raised when PAR is compared to more conventional empirical methodologies. Life sciences, like many other disciplines, have long upheld quantitative methods and controlled experiments as benchmarks of validity. These standards are deeply embedded in institutional practices, peer-review systems and scholarly publishing. Yet, to foster a more inclusive and responsive research culture, it is vital to reconsider these norms. Researchers Professor Yunseok Kim and Professor Jeffrey M. Stanton (2016) study the social and ethical dimensions of scientific data sharing and collaboration in the context of information studies. They note that scientific behaviours around data sharing and collaboration are influenced by social and ethical factors that are often overlooked in traditional research frameworks. My research took this on board by proposing a broader, art practice-based understanding of rigour – one that incorporates reflexivity, relational aesthetics (Bourriaud, 2002) and situated knowledge. As this was developed within the context of a scientific lab, this approach was positioned as an additional yet essential contribution to scientific research and understanding, grounded in the perspective of the art practitioner.

Recognising that trust and sustained engagement are fundamental to collaborative inquiry, I invested significant time in building relationships with small groups of scientists. I deliberately kept specialist boundaries fluid (conceptualised as porous circles of broken lines), allowing modes of engagement and analytical focus to evolve in response to the specific needs of each project. This adaptability included revising interview questions, refining performative interventions, responding to emergent data and adjusting to the diverse expertise of my scientific collaborators. I also tailored procedures to incorporate a variety of scientific tools, software, imaging techniques and processes.

This flexibility reinforced the collaborative ethos at the heart of PAR. It enabled a comprehensive, adaptive approach to knowledge generation, so that I could move fluidly across disciplines and institutional contexts. Most importantly, it provided a bridge between the scientific emphasis on validity – rooted in replicable data and quantitative analysis – and a more situated, reflexive mode of inquiry grounded in the perspective of the artist-practitioner. By using the model I customised (see below), I tested my hypothesis: that integrating play into art–science research could establish an innovative collaborative model, that promotes critical reflection and fosters meaningful multidisciplinary interaction.

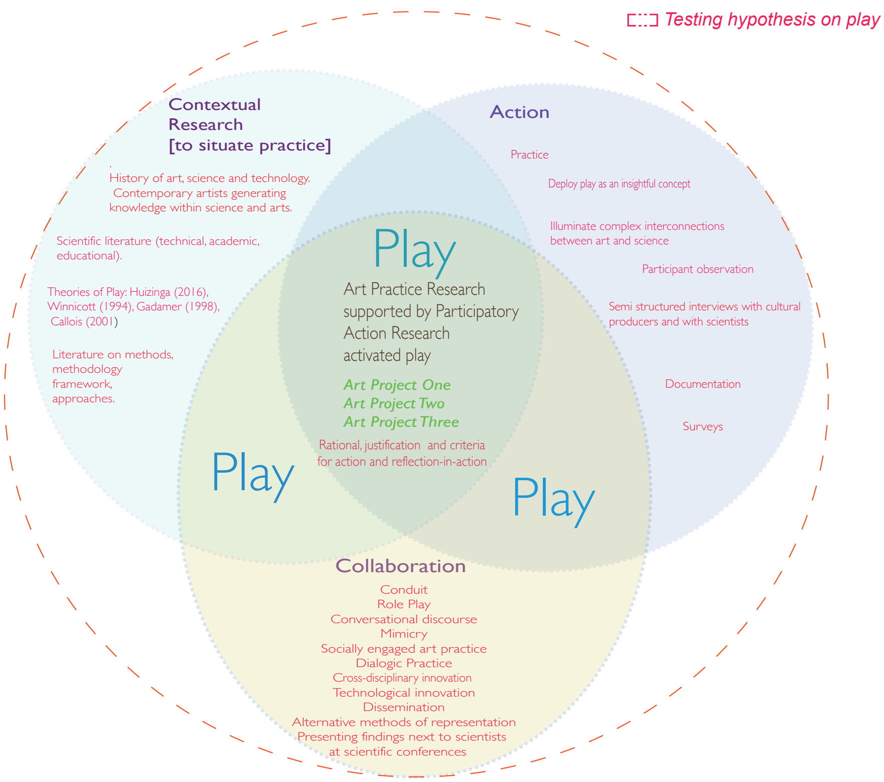


Figure 8. Berry-Frith, J. (2020) The relationship between participation, action and research, established by adapting the model for Action Research in Health Care (Reason and Bradbury, 2008: 385). It includes semi-structured interviews with three cultural producers from the arts and sciences who worked outside the lab. © Jo Berry-Frith.

From PAR to research framework

Figure 9 presents the reflexive framework, based on cycles of action, practice and reflection, that I developed and implemented as an artist, as a result of my research-design model. Figure 10 describes the three individual art projects through which I tested and developed my framework for a cyclical, reflective practice. This four-stage integrated framework demonstrates how art practice can be meaningfully embedded within scientific contexts through the lens of *play* – an exploratory concept applied across these three art projects. The framework was underpinned by art-practice research as a creative and systematic process of inquiry (see also Garner, 2008; Gray and Malins, 2004; Macleod and Holdridge, 2005). It incorporates both theoretical and contextual foundations as outlined in Chapter One and is applied in detail, as shown across Chapters Three, Four and Five.

The framework integrates key research strategies, based on PAR (Reason and Bradbury, 2008 and 2011; Gray and Malins, 2004), and using direct observation and a combination of unstructured and semi-structured interviews for data collection. This adaptable approach supported a deeper exploration of the dynamic relationships between art, science and play in collaborative settings.

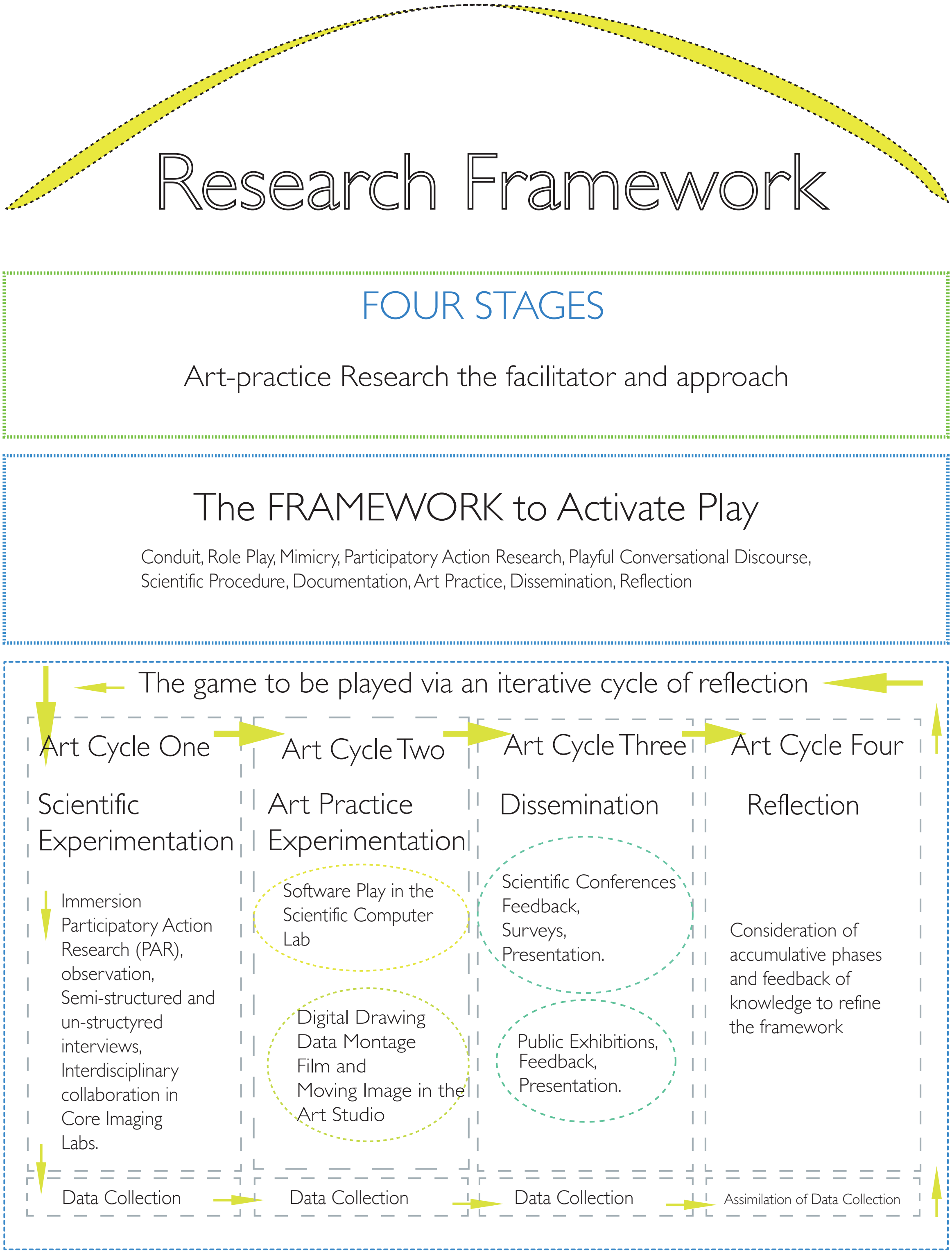


Figure 9. Berry-Frith, J. (2024) The reflexive framework detailing how art practice may be incorporated into science using play as an insightful concept. © Jo Berry-Frith.

The game I played via an iterative cycle of reflection

Art Project One – Cycle One

Centre for Membrane Proteins and Receptors (COMPARE), University of Nottingham

Data collection and relationship-building with scientists.
Trained in CM, LM, and SRM.
Studied pharmacology and cell signalling.
Applied a PAR
Invited scientists to share personal insights.
Used play to challenge disciplinary boundaries.

Cycle Two -Solo Play

Scientific Computer Lab – University of Nottingham and Art Studio Practice

Focused on solo, process-led exploration across lab and studio
Built a digital archive through data reprocessing
Engaged in software play in the lab (Zen Blue, Zen Black)
Developed three core techniques:
• Pixel-based digital drawing (from CM and SRM).
• Data montage
• Moving imagel
Positioned art as a way to interpret biomedical complexity.

Cycle Three – Dissemination

COMPARE Annual Research Symposia 2017: East Midlands Conference Centre
2018: Queen's Medical School, University of Nottingham.

Cycle Four – Reflection

Collaboration reciprocal engagement with scientists, enabling shared learning and mutual nfluence.
Visualisation offering new ways to see and interpret cellular and molecular data.
Disruption I introduced creative disruptions that unlocked novel modes of thinking and experimentation.
Critique empirical rigidity encouraging scientists to value intuition, speculation,and subjective engagement with data.
Revealing previously unnoticed patterns and enriching both artistic and scientific processes.
Playfulness inspired by Huizinga's "magic circle," my use of play challenged rigid lab culture and made space for exploratory and iterative experimentation.
Innovation the project led to methodological innovation — in the lab and in my art practice—through new tools like pixel quantification and adaptive software use.
Redefining scientific data as creative material and proposing new forms of communication and meaning-making.

Art Project Two – Cycle One

Imaging and Analysis Centre (IAC), Natural History Museum (NHM), London

Trained in SEM
Studied 3D visualisation of unicellular organisms (e.g. Radiolaria).
Engaged in solo and collaborative play with scientist Dr. Ball.
Adopted scientific frameworks, to enable mutual knowledge exchange.
Produced non-standard visual research new to IAC.
Created a semi-systematic, fragmented data collection method independent of standard scientific models.

Cycle Two –Solo Play

Scientific Computer Lab (University of Nottingham and Art Studio Practice

Limited software play.
Created digital drawings from SEM monochromatic images, exploring structural complexity.
A labour-intensive drawing method to explore phenomena at the edge of visibility.
Solidified identity as a graphic artist, building on knowledge from Art Project.

Cycle Three – Art Project Two

Key Platforms for Dissemination:

Cumulus Conference – Hong Kong (2016)

Varoom Lab Journal (2016)

Big Data in the Arts and Humanities: Theory and Practice (2018)

Solo Exhibition – Art–Science Interplay, The Coningsby Gallery, London (2023).

Received critical feedback through external exhibitions, talks, and publications.

Cycle Four – Reflection

One of five artists conducting research at IAC.
Used (SEM) as the main imaging tool.
Collaborative play with Ball led to rule-breaking experimentation and imaging innovation.
Produced unconventional SEM visuals (e.g. beam drift, multi-focal framing, visual aberrations).
Challenged reliance on systematic observation and standard scientific imaging conventions.
Highlighted drawing as a powerful tool for shared understanding in a tech-dominated field.
Developed 3D digital drawingsof Radiolaria that acted as counterpoints to SEM images.
Inspired by Latour's Actor-Network Theory (ANT) I explored human–non-human interactions.
Disseminated work via exhibitions, publications, and conferences, broadened impact.
Set the stage for a final comparative survey across all cycles to complete the project's arc.

Art Project Three-Cycle One

SkinResQU (Biomedical Photonics group, the Centre for Cellular Imaging (CCI), University of Gothenburg), The Biofilms Research Centre for Bio-interfaces (BRCB), Malmö University, Sweden, and industry partners.

Worked in a foreign lab with biotechnology and microscopy experts.
Explored skin cream effectiveness using Multiphoton Microscopy (MPM)..
Immersed in lab life through interviews, observations, role-play and mimickry.
Reintroduced creative experimentation into science through artistic practice e.g., "happy accidents" in discovery.
Highlighted often-overlooked elements of scientific work.
Collaboration facilitated ethical discussions.
Face-to-face, instructional play used build trust, openness, and risk-taking..

Cycle Two –Solo and Two-way Play

Scientific Computer Lab (Sahlgrenska Academy and the University of Nottingham) and Art Studio Practice

Conducted collaborative two-way instructional software play with Fernandez-Rodriguez.
Investigated biological data using analogies like mimicry and refabrication.
Reconstructed skin data by remapping pixel information and integrated documentary images to connect representation, science, and tech.
Collaborated with composer Edmund Hunt.
Gained awareness of how technology shaped my creative choices.

Cycle Three – Dissemination

14th Annual Workshop of Biofilms, Research Centre for Biointerfaces and Biomarkers in 2018.
70th Annual Meeting of SCANDEM, 2019.

Sole non-scientific researcher at two international conferences presenting research and exhibiting artwork, sparking dialogue on art–science collaboration.

Contributed to discussions on bio-interfaces, encouraging alternative thinking and communication

Faced logistical challenges exhibiting art at scientific events, highlighting a need for flexibility. Exhibition obstacles led to professional growth and deeper understanding of disciplinary differences.

Cycle Four – Reflection

Hands-on training where mimicking scientific procedures, deepened my understanding of biomedical design and this lab context.
Exploring non-rational, creative aspects made science more playful.
Developed reciprocal collaboration model enabling role-switching between artist and scientist, fostering trust, disrupting hierarchies, and enriching the process.
Software play reshaped both artistic practice and the definition of a finished artwork—from raw data to creatively reimagined visuals.
Haptic, auditory, and experiential elements, merging documentary footage, raw data, and processed outputs into digital drawings, data montages, and experimental films revealed complex bio-technical-human interconnections.
Disseminated work through conferences, exhibitions, and live performances, engaging diverse audiences and demonstrating an artist roles in science.
Artistic methods enriched scientific discourse, offering new visualisation techniques beyond empirical norms, validated by international, multidisciplinary feedback.

Figure 10. Berry-Frith, J. (2025) My reflexive framework detailing how my art practice was incorporated into science using play as an insightful concept. © Jo Berry-Frith.

Art cycle one of the framework is an **investigative stage** based on my knowledge as an art practitioner. This investigative phase was driven by research questions 1 and 2: How could I use the philosophy of play to understand the value and role of play-based art practices while working alongside scientists in the lab? And how could gathering different forms of data help advance art practice? By the end of this investigative stage, my aim was to have gathered sufficient data to reflect on the scientific techniques, activities and the broader implications of interdisciplinary engagement. This was required for cycle two – art practice.

In line with my research questions, the study explored the concept of scientific-image visualisation as a form of artistic image-making. Scientists were engaged as research participants, and their predominantly positivist approaches were examined through a combination of literature review and PAR. While a limited set of pre-formulated questions was used, the interview format allowed space for divergence and the emergence of new insights. Ethics relating to the research approach is discussed in the next section.

The study's face-to-face interactions aimed to illuminate both the scientists' areas of specialisation and the structured dynamics embedded in the creative, play-based activities (role play, dialogical discourse, fun, mimicry, artist and scientist swapping roles) I introduced and observed within laboratory settings. Initial data collection was conducted through practical and in-person observational documentation, including film, photography, audio recordings, lab notebooks and continuous sketching. All video footage and photography were captured by me, reflecting my commitment to collecting primary data grounded in direct observation and personal experience. During moments when I needed to focus on scientific experiments (e.g., at the bench), I discreetly positioned a video camera on a tripod to minimise disruption to the workflow. This combination of continuous in-person observation and unobtrusive video recording significantly enriched the depth and perspective of the data collected. These practical methods were distinct from the statistical data provided by scientists (Gray and Malins, 2004; Mitchell, 1983). Scientists wrote notes and created graphs related to scale, optics, cellular and chemical structures, which were shared openly despite no prior agreement. As a non-scientist, I constantly asked questions to gain insight, but at this stage, I refrained from forming any solid hypotheses about what was vital (May, 2011).

In my own lab notebook, each observational entry was accompanied by possible conversation prompts for future meetings. Additionally, I conducted in-person, semi-structured interviews with three cultural producers working at the intersection of art and science (see Chapter One and Appendix Two). Prior to each interview, participants were emailed the following guiding questions, sourced from The Wellcome Trust and the Arts and Humanities Research Council:

1. What value and distinct approach to understanding and communicating ideas do artists bring to science? (The Wellcome Trust, n. d.)
2. How can artists illuminate and challenge perceptions within society? (The Wellcome Trust, n. d.).
3. What roles do culture, imagination, argumentation, creativity, discovery and curiosity play in scientific inquiry? (AHRC, 2015.)

Although this is not a social-science research project, the questions were essential to understanding how both institutions (i.e., The Wellcome Trust and The Science Gallery, London and the Science Gallery Network) support and commission artists. I wanted to examine how their organisational structures have changed over time, in order to situate my research within the contemporary cultural landscape.

To analyse all the data I gathered, I drew on and adapted principles of thematic analysis as outlined by Naheem et al. (2023: 2) and Achiam et al. (2025: 4), both of whom propose a six-step process for conceptual model development in qualitative research. Although originating in the social sciences, I found this framework useful for structuring my art practice research. Their models helped me consider how to work across different kinds of material, from transcripts to visual data and process-based evidence, without reducing the complexity of practice to data alone.

I transcribed audio recordings verbatim and reviewed them to build familiarity, while also examining transcripts and visual documentation for recurring elements such as *play, drawing, pixel granularity, technology, dissemination,* and *the reimagining of scientific image conventions* (see Appendices Two and Three). These elements shaped the direction of my analysis and helped me address the research questions 1 and 2.

By adapting thematic analysis, I was able to iteratively move from raw material to thematic insights that illuminated the role of play within scientific collaboration, while also supporting the conceptual development of my artistic framework.

Art cycle two of this framework, **an explorative creative practice phase** was driven by question 3: How could art practice disrupt scientific image conventions in a mutually beneficial way, to advance art and science practice?

To achieve the overarching aims in this stage I engaged my artistic, creative and interrogative art-practice research skills to disrupt scientific image conventions and create a secondary set of data. I sought opportunities to extend my software (Zen, Fuji Image J, Q-capture Quo) and data experimentation in the scientific computer lab and remastered data. I then developed digital drawings – a surface-based investigation of image-data – and data montages to examine larger data sets and experimented by creating multi-layered moving-image work.

Art cycle three is a dissemination stage, centred around question 4: How could an artist navigate and communicate alternative approaches to science's use of advanced imaging and microscopy, and what insights could scientists gain from this informed by philosophical theories of play and technology?

To achieve the overarching aims in this stage, the cycle involved promoting interaction and dialogue through the dissemination of visual art works. At this stage I examined the role of art in visual communication and its influence on art and scientific communication methods. My aim was to explore the potential of playfulness in science contexts, supported by exhibitions, presentations, surveys and feedback to create a third data set.

Art cycle four, the reflective stage, was designed to consolidate findings, conclusions and reflections, evaluating intellectual, practical and communicative tools to construct a comprehensive response to research questions. It was also used to summarise and offer recommendations based on new insights.

In summary, this four-stage framework was created to generate diverse theoretical insights that evolve over time. It is easy to replicate as a process because it is open to reinterpretation and adaptation.

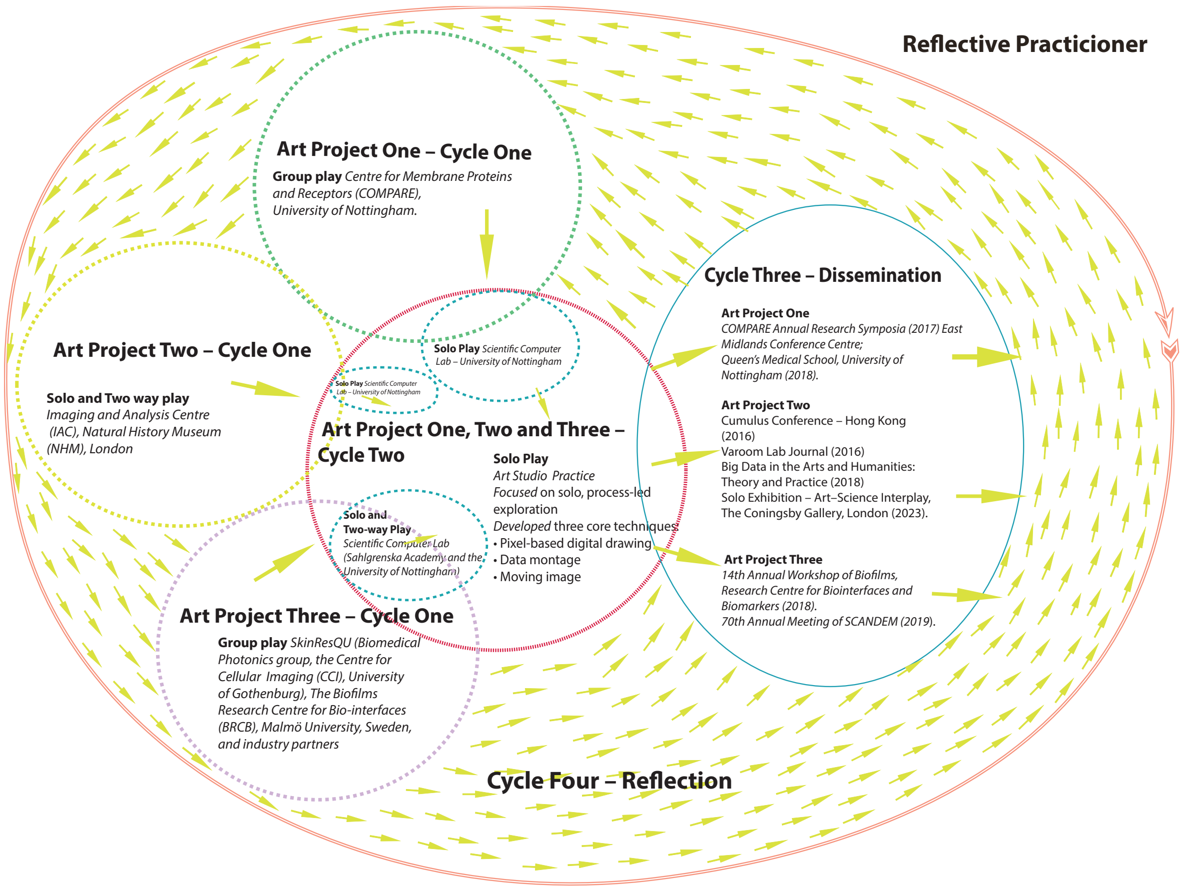
Developing the magic circles of art practice

Figure 11 illustrates the cycles of art practice and the creation of special, delineated spaces –what Huizinga (2016: 20) calls "magic circles" – established during each of the three art projects discussed in Chapters Three, Four and Five. The diagram summarises the distinct cycles of play explored across these projects. The three art cycles from Figure 9 and 10 are mapped onto this and visualised in a more organic way.

- **Cycle One** occurred in three separate scientific laboratories.
- **Cycle Two** involved practice-based research conducted in both scientific computer labs and the art studio.
- **Cycle Three**, the dissemination phase, took place across both scientific conferences and non-scientific public venues.
- **Cycle Four**, reflection both during each cycle and at the end of each art project shaped art ongoing practice.

In the diagram, I illustrate the interconnectedness and overlapping nature of the three cycles and associated art projects. Each cycle is enclosed within a large blue circle, symbolising the reflexive and iterative processes of action, practice and reflection that I implemented as part of my research design. This visual represents an ongoing exchange of information that is the reflective feedback loop which continuously shaped and reshaped my inquiry. This approach aligns with Schön's (2013) concept of the *reflective practitioner*, in which learning emerges through both *reflection-in-action* and *reflection-on-action.*

Grounding my research in cycles of inquiry shaped my thinking, allowing me to work more adaptively and flexibly. This approach enabled me to respond to varying contexts, foster meaningful collaborations, and sustain creative experimentation across and within disciplinary boundaries. My systematic documentation through notebooks, computer notes, and art practice of each reflexive cycle including key decision-making processes and methodological shifts, contributed significantly to the transparency and analytical rigour of the framework. I have included this diagram in the research design section as a representational map of my commitment to reflection as a key part of the action–reflection principles.



"Magic Circles" (Huizinga 2016:20), the spaces I set-up to play during Art Projects One, Two and Three within four cycles of practice

Figure 11. Berry-Frith, J. (2024). The magic circles of my practice-based research © Jo Berry-Frith

Ethics and research

Given the nature of the project, it was essential to consider ethical factors in the research design, in addition to academic, organisational and institutional ethical requirements. Furthermore, all published research complies with the ethical standards and guidelines set by Birmingham City University (BCU), including the completion of the BCU Ethical Review of Research Self-Assessment Form (Stage One) and the Ethical Review of Research (Stage

Two). I considered personal ramifications, health and safety permissions, the laboratory environment and its people. As soon as the research institutions and participants agreed to take part, I devised a protocol for working with adult participants and recording qualitative data derived from direct observation, in order to follow ethical behaviour. Each participant was asked to sign a consent form before being asked questions (see Appendix Six). I provided each participant with a synopsis of the research topic with an explanation of how I intended to use the data obtained. The information included the rules of usage, which encompassed an assurance that their comments would only be used for research purposes and that they would be notified beforehand if their name was to appear in any publication. Additionally, it was said that meetings would be filmed, photographed or recorded audibly. The responders were sent transcriptions of interviews and meetings for approval. This allowed me to use their remarks, recordings and data in line with the information sheet. In addition, it confirmed that they might resign from the study at any moment. The scope of their participation and potential uses of the data were addressed. Where appropriate, I made sure that participant identities and responses were anonymised to preserve their privacy. Throughout the sessions, I placed a priority on collaborative efforts and the collecting of scientific data. Due to these factors, interviews and collaborations were conducted at the participants' places of employment. Importantly, no biological evidence was collected throughout this inquiry. The participating institutions allowed the use of scientific materials and data for artistic purposes, and all contributions to image data are appropriately credited to the respective institutions or participants. All researchers – both staff and doctoral students – will receive appropriate credit and participants will be re-contacted to confirm their continued consent regarding the permissions they initially granted.

The management, storage and protection of personal or confidential data, as well as their potential future use were carefully considered in the research design. Records are maintained using date and location identifiers to support traceability, while ensuring confidentiality. All digital research data and materials (including raw data, films, photographs and audio recordings) are securely stored on a single encrypted hard drive with restricted access, provided by BCU. When research findings are published, participants' anonymity will be preserved in accordance with these ethical standards.

I began by establishing the selection criteria, identifying the necessary data, determining the primary data-gathering techniques and evaluating the most effective methods for acquisition. Data management was a central component of the research design (see Glossary). A key objective was the development of a comprehensive data management and archiving system to ensure rigour and consistency across the research. To maintain process continuity, each art project adhered to the same methodological framework and employed an identical data-collection system. Each project generated data through the framework of four structured cycles of practice, ensuring comparability and coherence throughout the research.

Conclusion

This chapter establishes the use of PAR as the methodological foundation and methods for data-collection over the course of the three art projects presented in the following chapters. It outlines how I adapted a standard model to conduct my research and the development of a four-stage reflexive, practice-led framework that positions artistic inquiry as a critical and generative mode of research within scientific contexts. I needed to be in lab environments as I considered these to be creative spaces, full of technological visualisation techniques I would not have access to. In the labs, and later, in my art studio, I create environments to explore how play could function as both a methodological strategy and subject of exploration, guiding activities such as semi-structured interviews, role-play and collaborative presentations, in order to investigate how scientists perceive image-making, creativity and technology. My strategy integrated literature from science, art and technology to contextualise my own practice. By adopting my PAR model (see Figure 8) I was able to explore how play – as both a philosophical concept and a practical strategy – might disrupt disciplinary boundaries and foster innovative modes of collaboration, communication and new knowledge production. Drawing on Reason and Bradbury's (2008) cyclical model, and Schön's (2013) reflective practitioner model I was able to combine cycles of action, observation and reflection. I created a flexible, reflective structure that accommodated scientists' varying levels of involvement and supported evolving research needs.

Creative art practice was placed at the centre of my inquiry, with theory and artistic production treated as deeply interdependent. Through creative, dialogic and process-led engagement, iterative making and critical reflection, I examined how scientific image-making and research processes might be reinterpreted through an artistic lens.

The "magic circles" (Figure 11), inspired by Huizinga's (2016: 20) concept, represent the distinct cycles of practice formed during each project phase, highlighting feedback loops and interconnectedness. The resulting four-phase reflexive framework I developed, illustrated in Figure 9, is adaptable, replicable and designed to support interdisciplinary knowledge-making. It provides a viable model for interdisciplinary research that values responsiveness, experimentation and ethical integrity. Figure 10 summarises my reflective process.

PAR was integral to this art-practice research and the development of a research framework, exploring how artists can meaningfully contribute to interdisciplinary knowledge production, both theoretically (e.g. through the introduction of play within the "magic circle" (Huizinga, 2016:20) and materially (through art practice).

Chapter Three: Art project one

Cycles of art project one: overview

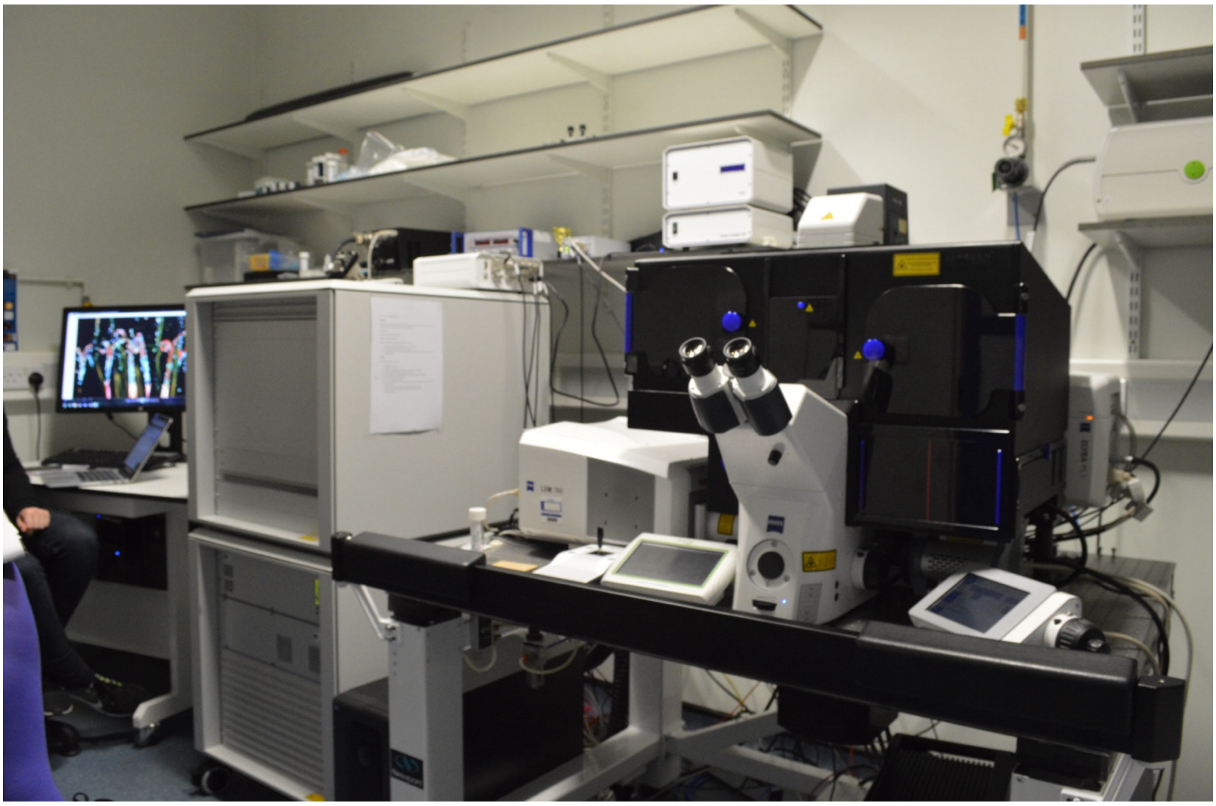


Figure 12. Berry-Frith, J. (2018) The Super Resolution Microscopy (SRM) Lab. 14.8 x10.5cm. © Jo Berry-Frith.

This chapter focuses on collaboration with the Cell Signalling and Pharmacology Department at Nottingham University, which is part of the Centre of Membrane Proteins and Receptors (COMPARE) – a partnership between the universities of Birmingham and Nottingham. COMPARE aims to connect leading scientists to develop innovative solutions, specifically in visualising individual membrane proteins and discovering strategies for diagnosing and treating cancer angiogenesis, cardiovascular disease and respiratory diseases.

My scientific collaboration ran from 2015 to 2019. This project comprised four cycles of art practice. In cycle one I embedded myself in the School of Life Sciences at Nottingham University, actively participating in activities in this lab. My practice centred on face-to-face participatory research with 17 scientists. My aims were to establish myself as a valuable member of the scientific team by contributing to external engagement within a broader field, to disseminate knowledge across art and science disciplines, and to enhance my understanding of cutting-edge imaging and microscopy techniques. I narrowed my selection to six scientists who were available for discussion and allowed me to follow their experiments from hypothesis to conclusion, and share their raw data. I prioritised collecting and using high-quality data, including live-image movies and Z-stack imaging experiments (see Glossary), which provided optical sections of cells and enabled detailed three-dimensional representations of drug interactions. This focused approach deepened my understanding of cell signalling experiments. It also opened compelling opportunities for reimagining the data through artistic methods by critically engaging with their work. In cycle two, the objective was to expand my creative skills based on data collected in cycle one. Cycle three aimed to conduct a comparative visual survey of scientists' raw data, offering new ways to understand and communicate my art practice research to colleagues and scientists at scientific conferences. The intention behind this was to enhance their understanding of the artist's role in cell signalling and pharmacology, while also highlighting the aesthetics of the scientific images. The aim of cycle four was to generate reflective insights into this cyclical process, using the information gathered to refine my research questions. I also sought to introduce and interrogate the concept of play within this context, integrating play as an insightful concept in art–science research, fostering creative teamwork and interdisciplinary interaction.

Cell signalling experiments occur in restricted imaging labs with limited access. However, the pilot phase (see Introduction) ignited my interest and opened new opportunities. Despite challenges such as obtaining permissions, addressing ethical considerations and securing access, I invested significant effort in groundwork, preparation and networking to ensure a successful and productive experience in this lab. As mentioned, pioneering organisations such as the Artists

Placement Group (1966) served as valuable reference points, as they sought to redefine the artist's role within a broader social context, engaging with both government and commerce. They also highlighted the marginalised status of artists within professional communities during the 1960s and 1970s (Tate archive, Nd; Bishop, Nd.). The limitations I encountered during project set up became a driving force for my exploration, motivating me to deepen my understanding of scientific methods of observation and image creation. By integrating my artistic practice with the lab's daily operations, I found inspiration to pursue research that extends beyond the traditional confines of the art gallery. The lab's emphasis on empirical inquiry reshaped my approach to creativity. Limited time and restricted access to specialised equipment demanded efficiency and resourcefulness. By embedding myself in the department's daily operations (as discussed later) and adapting to lab protocols – structured systems guiding scientific activity – I balanced autonomy with discipline, using the experience to refine my artistic intentions, while collaborating with scientists.

The lab's highly specialised scientific techniques operated within a complex environment of biological instruments, scientific materials and constant human activity. Purposeful unpredictability defined the space, where creativity and rigour coexisted amid cluttered workbenches and humming instruments, driving exploration and discovery. Key facilities included Category II suites in Cell Signalling Imaging (CSI) at the School of Life Science Imaging (SLIM) core on the Medical School's C Floor and the Centre for Biomolecular Sciences (CBS) at University Park Campus. CSI supported university researchers and external collaborators with advanced imaging resources, focusing on pharmacology and live cell imaging. Its core units – Fluorescence Imaging, High Content Imaging and High Throughput Screening – offered cutting-edge tools. CBS featured advanced systems like the Zeiss 780 confocal and super-resolution setups, employing techniques such as SIM, PALM and STORM (see Glossary).

Building on ‘Hijacking Natural Systems’ (2010–2012) and insights from artist–scientist collaborations (Chapter One), I sought to explore this dynamic, visually stimulating lab environment. I focused on scientists employing novel technologies and open to collaboration, balancing lab work with studio reflection and remaining receptive to unexpected insights. Drawing on Gadamer’s assertion that arts and humanities address ideas beyond the scope of natural scientific methods (1994), I developed a PAR approach, framing art as research (Macleod and Holdridge, 2005). To advance my engagement with scientific imaging and data interpretation, I approached the process through the lens of play, aligning with Huizinga’s perspective on play as a fundamental mode of human culture and existence (2016). This method fostered interdisciplinary exploration, where the fusion of art and science challenged norms and generated innovative outcomes.

Art cycle one

At the start of the first cycle of art project one, I generated interest in my research from key people who welcomed me back into this lab, such as Chief Imaging Officer Tim Self and Principal Research Fellow Steve Briddon, whom I met in 2010 during ‘Hijacking Natural Systems’. They helped to create further interest in my research and organised collaborations with scientists working in this department. They believed that my continued presence in their labs while undertaking doctoral research would be advantageous by allowing scientists at various stages of their careers to discuss their findings intelligibly with an expert from a separate field. They wanted to demonstrate to their scientific group the value of an artist’s participation in their work, to help them appreciate what they were researching within a framework beyond science. Briddon and Self aimed to enhance scientists’ communication skills by encouraging the use of lay terms instead of technical jargon, helping them better convey scientific concepts to non-specialists.

Briddon and Self wanted the research they conducted to be relevant and easily communicated to the public, service users and other NHS staff. Self (2015) was frustrated that his research group's audience was not "old men in wards having limbs amputated" or "sophisticated young people"; instead, his research group was communicating exclusively with pharmacologists and medical students. Briddon wanted me to understand the essence of what he as a research fellow, the research group and the wider field of science were trying to achieve. Briddon explained his role as Principal Investigator (PI), his research group's remit and how common themes were linked to the novel imaging approaches that he used to detect receptor signalling and cell surface receptors (Miller et. al., 2023; see Glossary). We addressed how important imaging is to the group's work and how many individuals utilise it. He discussed sixteen principal investigators (PIs) who oversaw the research group's interests. These investigations revolved around cell signalling, proteins, and the interactions between drugs and membrane proteins with specialised expertise in pharmacology. He discussed the trajectory of his research group, academic freedom and the research group's shared interests in quantitative evaluation and pharmacology. He mentioned intense rivalry and pressure to gain funding with a 10–15% success rate. Briddon detailed his function as project manager to train PhD students to become scientists by learning how to use the lab, examining two or three distinct approaches and utilising the appropriate technical instruction. He claimed that nine times out of ten, PhD students end up doing things they did not expect, as things evolve and a scientist must follow the findings. However, as an artist, I sought to constructively question those findings, approaching pharmacology from a different perspective.

As a pharmacologist, Briddon's objective was to get his research reviewed by pharmacologists, but he felt that his scientific freedom had been taken away as output criteria were key to keeping the good reputation of the school, which brings a particular pressure. He claimed that scientists must collaborate with industry and other scientists, but I noted these scientists rarely collaborate with artists or with people in other fields. Conversations like these helped me recognise the strain these scientists were under, and I realised that my role as an artist–researcher could serve as a counterbalance. In investigating the human, creative and visual dimensions of pharmacology, I sought to reintroduce the playfulness that is often overlooked in the laboratory environment due to the pressures from institutional objectives. However, I also observed that playfulness was inherent in the creative atmosphere of this busy research lab, particularly within the practice-based and process-driven activities of these scientists.

Self and Briddon were convinced that the public did not understand or value their research and both wanted to address this perceived problem. They believed that my presence in their lab and the research I was conducting could be used to convey scientific findings in a more creative manner. This was yet another reason the scientists in this department, as well as myself as an artist, valued my contribution to the domains of pharmacology and cell signalling, which are unrelated to my area of expertise. Yet, I encountered naysayers and tension, with time constraints playing a significant role in people's decisions not to collaborate. For instance, PI Nick Holliday was simply too busy to contribute. Another PI, after our initial discussions, felt that my presence observing her work would not add any value to her research. One PhD student did allow me to interview her and document her final experiment, but she was so focused on completing her PhD that she could not assist further. These challenges made it clear how critical effective communication and shared goals are in fostering collaboration, especially when everyone is under pressure.

To engage more deeply with my colleagues' work, I immersed myself in the lab, collaborating with scientists conducting cell signalling experiments. Adopting a hands-on approach – "getting my hands dirty", as bio-artists Oron Catts, Ionat Zurr (2002: 365–370), and Anna Dumitriu et.al., (2021: 210–211) advocate – I emphasised the lab's transformative potential as a space for both scientific and artistic innovation. Working directly at the bench, I engaged with scientists' positivist methodologies rooted in pharmacology, such as receptor characterisation (Kenakin,

2008) and compound application for imaging results (see Glossary). These methods informed research on cellular responses to drugs, while dialogue and collaboration enhanced my understanding of complex medical concepts, deepening my insight into scientists' daily operations. I received training in techniques like serial dilutions and applying fluorescent labels for cell labelling, enriching my pharmacological knowledge. The process was invigorating – its complexity, precision and technological intricacy created a dynamic, immersive learning experience. This hands-on engagement not only deepened my understanding of cell signalling and pharmacological principles, but also allowed me to explore how incorporating play could push the boundaries of both art and life sciences, aligning with my overarching goal of conducting innovative, interdisciplinary research.

My intention to blend play and creativity with scientific inquiry aligns with biologist Sir Patrick Bateson's insights in *Play, Playfulness, Creativity, and Innovation* (2014). Bateson argues that playful engagement is intrinsically linked to creativity, which drives human innovation. He emphasises that generating new ideas requires a mindset distinct from the practical application of existing concepts. Through play, new perspectives or tools may emerge, which can later be combined to tackle novel challenges. For example, Alexander Fleming, who discovered penicillin's antibacterial properties, was known for his playful approach to research. His boss criticised him for treating research as a game, but Fleming responded, "I play with microbes", noting that the enjoyment came from breaking rules and uncovering ideas others had not considered (Bateson, 2014: 108). Similarly, physicist Richard Feynman, when disillusioned with physics, reflected, "Physics disgusts me a little bit now, but I used to enjoy doing physics. Why did I enjoy it? I used to play with it... whether it was interesting and amusing for me to play with" (Bateson, 2014: 108). Feynman's return to a playful approach led to significant contributions to physics. Inspired by these examples, I sought to embody a similar playful mindset in my research, believing that embracing playfulness in the face of scientific complexity could spark innovative insights and lead to meaningful contributions.

Briddon acknowledged that, in the past, play had a more prominent role within scientific study, who was not under the same pressure to produce or secure funding. He noted that, while his creativity was now constrained by pragmatic and budgetary concerns, creativity remained a fundamental aspect of science. Like Bateson (2014), Briddon viewed creativity as an intellectual pursuit – an ability to use imagination to develop tools that address a research topic. He explained that the level of inventiveness depended on the individual executing the task and the significance of the research question. He admitted that scientific play occurs in “our heads” as a “filtering out” method. It can also be a conversational device, as “they bat around ideas in play”, when scientists gather at presentations and ponder whether they might adopt a strategy with a certain cell. However, he noted that this type of creativity does not manifest in the lab itself.

I observed that many of my pharmacology colleagues struggled to grasp the concept of play, as it was not typically integrated into their analytical approach. As an artist, however, I engaged with science more creatively, adopting an imaginative and curious perspective. Through a hermeneutic lens, which emphasises interpreting experiences in context and meaning, I identified the limitations of positivism, with its rigid focus on the scientific method that has long dominated the human sciences. By contrast, I viewed play as an essential component of my artistic research, offering fresh insights into the dynamics of scientific work within the lab.

Convinced that scientists often overlooked the imaginative, playful and aesthetic aspects of their work, I explored the rhythm of play – both in the lab and during collaborative activities – and the spirit of the ‘collaborative game’ we engaged in (Gadamer, 1998: 66). Drawing on Sicart’s (2014) argument that play requires context, design, structure, stages and material, I developed a strategic framework that integrates play and creativity into lab-based research. This approach fostered new opportunities for collaboration and discovery, illustrating how the integration of artistic methodologies could transform lab practices. Despite my efforts to engage informally with scientists and foster meaningful conversations, I recognised the immense pressures they faced. These included addressing empirical research questions, securing funding and meeting stringent sponsor requirements – challenges that often left little room for embracing alternative, playful approaches.

To navigate this, I embraced Huizinga's concept of the "magic circle" (2016: 20), establishing defined spaces where play could be examined within clear boundaries, fostering a temporary suspension of routine. By simulating a temporary boundary with a clear beginning and end, I systematically documented all activities during my lab enquiries. This intentional demarcation created opportunities to explore dynamic systems of engagement and foster deeper interactions with the scientific process.

The "magic circle" served as a focal point for performative role-play, transforming the lab into a separate realm from my daily routine. It supported the play-based strategies I adopted while ensuring the safety of both myself and my scientific collaborators. As Huizinga (2016: 20) argues, breaking the "magic circle" undermines the essence of play, as the boundaries provide a socially necessary function for fulfilling play's intrinsic drives. In my research, this framework structured the scientific setting as a space that permitted flexibility, experimentation and creative exploration without disturbing the lab's core objectives. The "magic circle" reframed the lab environment – not solely as a site of empirical enquiry, but as a dynamic arena where creativity and play could be safely and effectively integrated.

Within the safe zone of the lab, I – as the player – immersed myself alongside scientists, including post-doctoral researchers and senior imaging technicians. I saw the lab not just as a workspace but as an underutilised resource offering opportunities to expand my understanding beyond a singular perspective. My focus was on the unfamiliar techniques scientists employ to produce distinctive images and the advanced microscopic systems they use. These explorations revealed the lab as a dynamic setting where human and non-human interactions – between scientists, technological devices and biological subject matter – could be seen as forms of play. Role-play, mimicry and play-centred dialogue emerged as creative ways of engaging with the scientific process, intersecting experimentation and exploration to foster new insights, while challenging conventional methodologies.

My goal was to identify and investigate the creative, inventive and technical aspects of scientific work while embedding myself in the pharmacology department's culture. Working as an artist–researcher enabled face-to-face communication with collaborators and the broader scientific community during routine tea and lunch breaks, lectures, meetings and interactions with industrial partners like Zeiss engineers. These engagements enriched my understanding of the lab's practices and culture.

During the first cycle of my art practice, I engaged in participant observation and role-play at the scientific bench and in advanced imaging laboratories. By working alongside scientists as they carried out practical activities, I facilitated discussions around scientific protocols, procedures, attitudes and roles. This process fostered a deeper connection between me as a researcher and the scientists, enhancing our mutual understanding of their research processes. My aim was to collect a diverse range of data and extract insights from both qualitative and quantitative sources, as outlined by Silverman (2013), in order to identify trends and synergies. This structured approach to data gathering sought to highlight distinctions, construct concepts and generate new hypotheses, directly addressing my research questions (Lincoln and Guba, 1985).

Figure 13. Berry-Frith, J. (2018) The light-filled pharmacology lab. 14.8 x 10.5cm. © Jo Berry-Frith.

In the light-filled labs, I worked effectively alongside scientists at the bench, observing their manual techniques and following assay protocols (see Figure 13). This allowed me to witness their rigorous approach, such as how they meticulously recorded results in their lab books. Drawing on methods I developed during ‘Hijacking Natural Systems’, I documented every step of the scientific process – whether in my lab notebook, or through video, photography, or drawing – and encouraged my collaborators to contribute their own notes, drawings, diagrams and graphs. This approach helped to capture visually compelling aspects of the scientific method, with criteria for selection evolving organically throughout the process.

By immersing myself in the lab, I observed scientific experiments unfold in real time, witnessing the entire process – from hypothesis formulation to data analysis. This provided firsthand exposure to methodologies I had not previously encountered, deepening my understanding of experimental procedures. Assuming the role of a research scientist, I actively engaged with the work, asking scientists to explain complex concepts in accessible ways. Through activities such as note-taking, sketching cellular formations, recording findings, posing unconventional questions and collecting raw data, I fostered unplanned yet insightful conversations between artist and scientist. These exchanges revealed new perspectives that might not have otherwise emerged.

Figure 14. Berry-Frith, J. (2018) The darkened space in the FCS imaging lab. 14.8 x 10.5 cm. © Jo Berry-Frith.

I investigated the dynamics of play as they unfolded in the lab, responding adaptively to varying conditions and circumstances. For example, by shadowing PhD student Richardson during a Fluorescence Correlation Spectroscopy (FCS) experiment, I gained valuable insights into her visualisation methods. She explained how the FCS microscope, equipped with single-photon-sensitive detectors, facilitates fluorescence fluctuation spectroscopy. I observed how she used visual estimation to precisely aim the laser beam, carefully documenting the 90-minute cellular imaging procedure. Sitting beside her in a small, darkened room (see Figure 14), I watched her correlate the wavelength of light with photon emissions. I was captivated by the random motion of molecules and noted how Richardson quantified light intensities at individual pixel points. These intensities were represented as graded pixels, derived from varying photon intensities. This firsthand experience deepened my understanding of pixelation, which was a critical concept for visually representing complex data.

This exposure significantly influenced my research, especially during cycle two when pixelation became central to my exploration through digital drawing, where I reinterpreted these scientific visualisation methods through an artistic lens. As discussed in Chapter One, Kester's (2013) emphasis on performative, process-based approaches, alongside art's role in problem-solving, shaped my research methods. I prioritised in-person communication and collective problem-solving, enabling me to engage deeply with both the scientific and creative aspects of the lab. Drawing on relational aesthetics (Bourriaud, 2002) and technological philosophy (Latour, 2010; Verbeek 2005, 2011), I examined how my relationships with scientists and technology fostered new forms of engagement, enriching my practice. This is exemplified by my work with Richardson and in all my interactions with scientists throughout the project.

To deepen my understanding, I explored the work of contemporary scientists collaborating with artists, including Professor Roger Kneebone (2024), a doctor and trauma surgeon I interviewed in 2023. Kneebone's realistic simulations of clinical scenarios, using methods like Hybrid Simulation (integrating actors and models), Distributed Simulation (low-cost, portable environments) and Sequential Simulation (mimicking clinical pathways), resonated with me. These approaches highlighted the intersection of science, craftsmanship and performance, aligning with my exploration of precision and technical skill in the lab. Kneebone's work helped me recognise the potential of blending scientific techniques with performance, mirroring my artistic practice where technique and creativity converge.

Echoing Schön's *The Reflective Practitioner* (2013), Kneebone argues in *Expert: Understanding the Path to Mastery* (2020) that skilled practitioners often understand more than they can articulate. He identifies three stages of progression: apprenticeship (developing skills), journeyman (finding one's voice), and master (teaching others). As I immersed myself in cell signalling and pharmacology, I found myself in the apprenticeship stage, acquiring scientific knowledge. Drawing from Kester (2013), Bourriaud (2002), Kneebone (2020) and Schön (2013), I prioritised tacit, visual and experiential understanding, expanding my focus to the role of play in fostering cultural insight. This approach allowed me to engage with science and technology in an innovative way, distinct from my scientific collaborators.

By adopting the role of a scientist in the lab, I bridged the gap between my artistic perspective and the scientific community. Through "masquerading" (adopting the scientist's role via attire and behaviour), I was able to integrate seamlessly into their world, gaining trust and fostering collaboration. Wearing a white lab coat in the lab and a blue one in the imaging lab, I mimicked scientific actions like aspirating cells and conducting experiments with precision. Working alongside collaborators, I highlighted the creative aspects of science and showcased my artistic skills in documenting and interpreting research (see Chapter Two, methodological framework).

In contrast, during my Light Microscopy experiments in the histology lab, I worked independently, which led to frequent interactions where researchers would ask, "Are you the artist?" or comment on the fusion of art and science, sparking new conversations within the labs. My experiences in the lab mirrored Kesseler's (2010) work with botanical scientists and molecular biologists. Like Kesseler, I found my interactions with scientists both enjoyable and insightful. While Kesseler focused on botany, we shared similar experiences working at the scientific bench, examining cells under the microscope and engaging multiple senses: cognition, sight, hand–eye coordination and even smell. These sensory and intellectual engagements formed the foundation of my interdisciplinary approach. As I immersed myself further in the scientific environment, my training deepened my understanding of scientific methods and refined my imaging techniques. Over time, I began to view scientific imaging not just as a technical tool but as a powerful medium for visualisation. This shift in perspective earned me recognition as an artist–researcher, reinforcing the potential for meaningful collaboration between science and art.

Collaborating with scientists at various stages of their careers gave me an insight into their training and the hierarchical structures within the lab. I was particularly keen to understand the empirical parameters and variables that shaped their experiments, learning from both their successes and setbacks. Through this process, my collaborators consistently pointed out patterns for comparison and offered straightforward explanations of their methods, which reinforced the value of systematic, evidence-based inquiry in scientific practice. Combining hands-on learning with my artistic perspective helped me bridge the gap between the worlds of art and science in a meaningful and engaging way.

As I integrated more fully into their work, I noticed a shift in my collaborators' attitudes. They became more receptive to my artistic approach, while I challenged their purely systematic, evidence-based methods, particularly as my interest in the human side of science grew. This shift became evident during my observation of post-doctoral researcher Soave, who was conducting a two-day, thirteen-step Immunocytochemistry ECL2 Competition Protocol, a radioligand binding experiment (Soave et al., 2018). He explained that radioligand binding measures drug affinity for receptors by tagging drugs with radioactive labels to observe binding patterns, with higher affinity correlating to lower dosages. This protocol is also used in diagnosing cardiomyopathy, a condition that can lead to heart failure.

As I recorded his actions and commentary, I gained insights not only into the function of β-Adrenergic receptors (β-AR) in cardiac regulation but also into Soave's work as a scientist. Observing the inevitability of human error, such as when Soave accidentally added the wrong amount of compound to the wrong row of a 96-well plate, highlighted the challenge of maintaining accuracy in research. To mitigate such errors, he explained how scientists document their dilutions on the lids of cell culture plates and microtube vials (see Figures 15–16), a labelling method that I found visually striking. His systematic notation of drug concentrations with a black felt-tip pen was a direct and straightforward way of recording information. This approach reminded me of artists like Agnes Martin (1912–2004), whose use of square-grid structures in her work parallels the grid-like arrangement of the plate. Both reflect a similar emphasis on uniformity and order, much like the pixelation in digital imaging (Glimcher, 2021). This square-grid method became a key digital drawing technique I developed further in the second cycle of my practice. Throughout the experiment, Soave remained focused, remarking, "If I screw up, I'll exclude it", while strictly adhering to his 13-step protocol.

Comparing Soave's strict adherence to protocol with my artistic training revealed key differences in our approaches. Soave, trained to avoid mistakes, followed procedures with precision, while my artistic training encouraged viewing failures as opportunities for deviation and exploration. I observed that even experienced scientists like Soave were prone to errors, often driven by enthusiasm and the fast-paced nature of their work. His bench was cluttered, and he moved quickly from task to task, embodying a dynamic, sometimes chaotic environment. This vibrancy deeply inspired me. As I wrote in my lab book, "I like labs; they are creative hubs".

These experiences highlighted how I saw play manifesting in the lab – something I viewed as a serious and purposeful activity (Gadamer, 1998: 130). I began to understand our collaboration as an interpretive, context-driven expression of knowledge shaped by ongoing dialogue. I came to see the scientific hypothesis not only as a structured, process-driven framework but also as a dynamic structure that engaged us as ‘players’, guiding the progression of our work. This perspective allowed me to monitor and guide the development of our research while embedding artistic inquiry within the scientific method. Through this interplay between systematic scientific investigation and creative exploration, I fostered a deeper, more integrated understanding of both scientific practice and my own artistic research. Each illuminated the other by comparison.

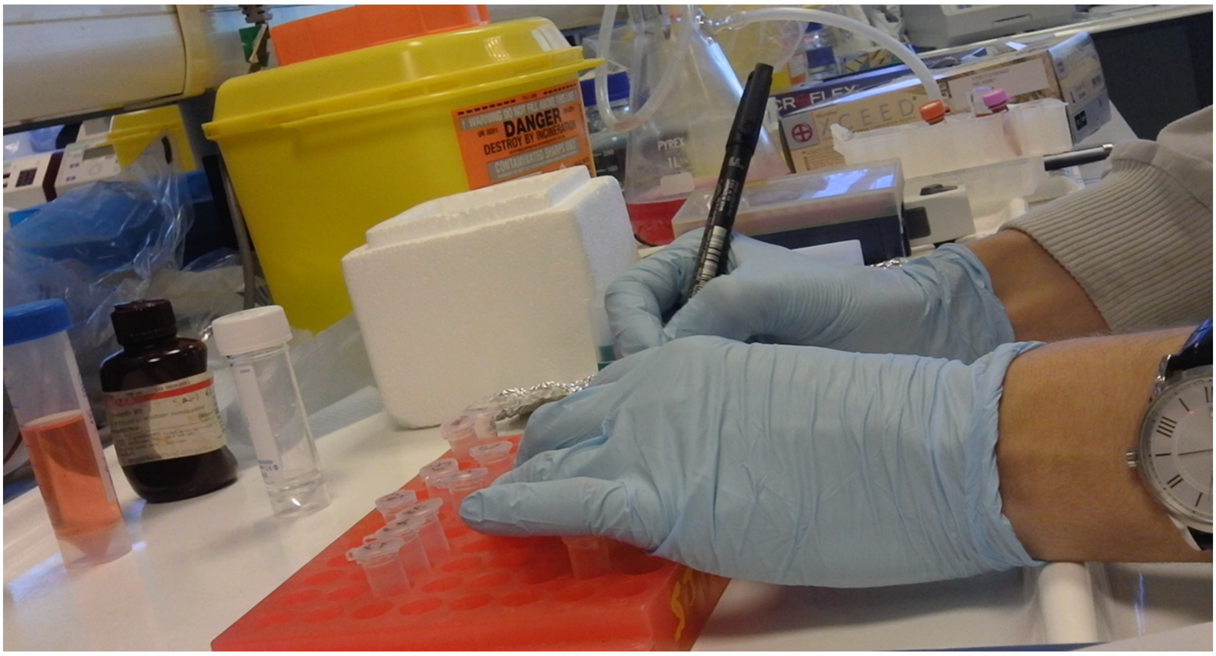


Figure 15. Berry-Frith, J. (2018) Soave writing concentrations on the vials with a black felt tip. 14.8 x 10.5cm. © Jo Berry-Frith.

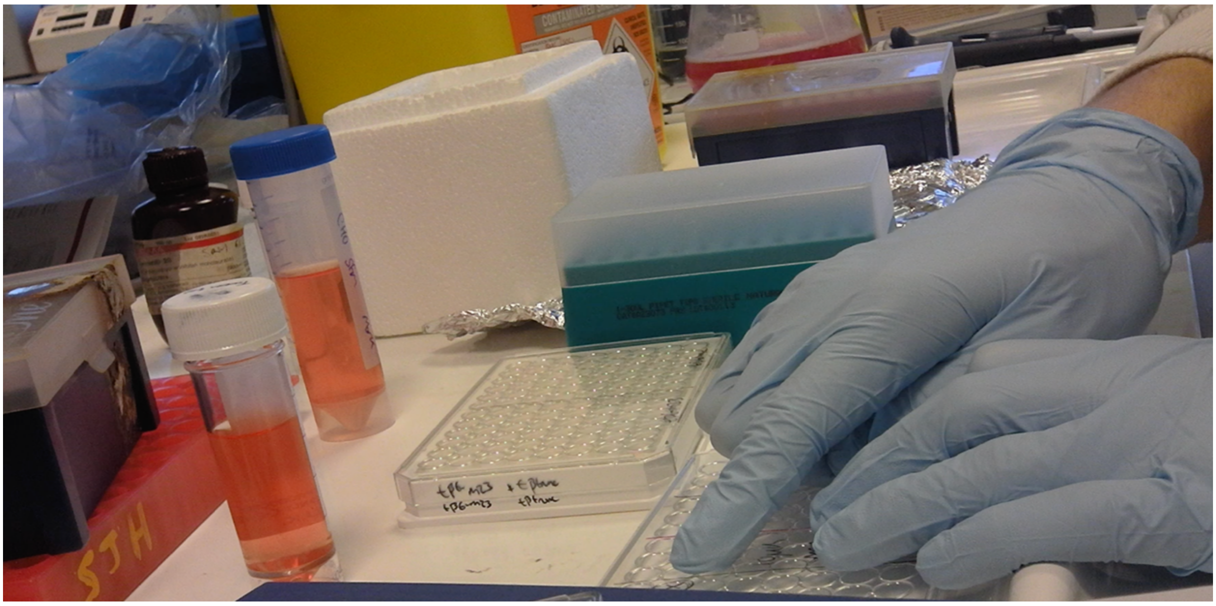


Figure 16. Berry-Frith, J. (2018) Soave pointing to concentrations of the drug on the cell culture plate.

As scientists grew more accustomed to my presence, their level of trust increased and they began expressing more speculative, non-empirical hypotheses regarding their unpredictable investigations. My collaborators started to identify what was atypical or visually compelling about each imaging technique and dataset. For example, Golding explained each stage of her experiment in lay terms. I asked numerous questions – both scientific and non-scientific – about what she was trying to discover as she compared the cellular shapes of a human stem cell's cardiomyocytes. Golding was focused on capturing images systematically and recording results for her research group, whose goal was to create a reliable model to test new drugs for heart disease. She provided me with valuable materials such as patient responses, graphs she drew in my lab book, YouTube videos and email correspondence (see Appendix Three).

During several experiments, we shared our impressions as we examined cellular activity. I observed Golding's skill and expertise in imaging, which she saw as an art form that becomes more intuitive with practice. She explained that when you start, nothing works as expected, but that's part of the learning process. As an apprentice, I was fascinated by the state-of-the-art visualisation methods she used. Her realistic approach and clear focus on her job left a deep impression on me, extending far beyond the initial purposes of my research. Consequently, I understood how scientists approach risk and speculation as part of their systematic methods. This allowed me to establish connections between play and scientific inquiry, even when the outcomes were not as expected. By developing my observational skills, I was able to monitor the unexpected and analyse every discrete occurrence during real-time cell experiments. Golding's curiosity about my re-interpretation of her data and her enthusiasm for my research led her to invite me to exhibit at COMPARE (see cycle three).

Golding imaged cells on a single plane, as they typically formed layers atop one another. As we discussed the delicate qualities, shape, colour and form of each cell, I noticed how much time she devoted to selecting the finest specimens for capture. My focus, by contrast, was on the fluorescent colours, amorphous forms and scale of the human-stem-cell-derived cardiomyocytes (see Glossary), which she imaged using a CM (see Figure 17). I was surprised to find that the cells did not respond as expected and was intrigued by the fact that these genetically engineered cells had the potential to differentiate into various forms. The cell surfaces appeared coated in a glitter-like sheen, and they reminded me of tightly packed squids – an admittedly unscientific and visually simplistic comparison.

David Rothenberg (2013), a musician, composer and philosopher-naturalist, explores in *Survival of the Beautiful* how art can uncover deeper meanings in the natural world, offering new perspectives on its complexity. Drawing on the work of evolutionary scientist Richard Prum, Rothenberg argues that focusing on beauty allows us to transcend rigid thought systems, embracing the strange and unexpected aspects of science and nature. I adopted this perspective while studying intricate cellular forms – the fundamental units of life in all organisms. However, I was also aware that the cells I was examining were artificial neutrophils, engineered to replicate the functions of native neutrophils.

Through my research, I gained an understanding of the technical and technological skills required for imaging experiments, particularly in observing the fluorescence and dynamic changes of drug-treated, fabricated cells. This realisation was crucial, as I began to grasp that much of scientific work is, at its core, a process of fabrication – whether in creating models, manipulating materials, or constructing experiments. This awareness became a key point of connection between my work and that of scientists, highlighting the shared processes of construction, manipulation and creation in both digital art and scientific visualisation.

This shift in perspective was transformative. It allowed me to approach scientific imagery not just as a technical tool, but as a medium for capturing the beauty and complexity of a highly specialised, fabricated world – one that, in many ways, mirrors the philosophies about beauty that Rothenberg (2013) discusses. Just as Rothenberg suggests that beauty reveals deeper meanings and transcends rigid scientific frameworks, I began to see scientific imagery as a means to capture not only the technical aspects of cellular life but also the aesthetic and conceptual dimensions of the processes at play.

As I became more immersed in the imaging lab, I grew increasingly aware of how proximity and mediation – both human and non-human – enhanced the visualisation process. The compact, collaborative space of the lab contrasted with the more expansive, instrument-filled environment of the scientific bench, where data collection often felt more distant and detached. By engaging directly with the lab's dynamics and closely interacting with both the scientists and the technologies they used, I developed a deeper understanding of how visual data are generated. These experiences also prompted me to reflect on the role of mediation in scientific creativity, increasing my appreciation for how cells, technology, pharmacology and scientists each play a part in the process.

I was particularly struck by the interest I shared with my collaborators in using visualisation to explore previously unseen phenomena, revealing an intersection of scientific and artistic creativity. Recognising that this observational and dialogical activity required improvisation, empathetic conversation, analysis and reflexive evaluation – skills essential for fostering cross-disciplinary understanding – was key. These attributes developed within the "magic circle" (Huizinga, 2016: 20) of the lab, evolving as the framework shifted and new data emerged through several empirical inquiries (Denicolo, 2014; Denicolo et al., 2019; Glaser and Strauss, 2017).

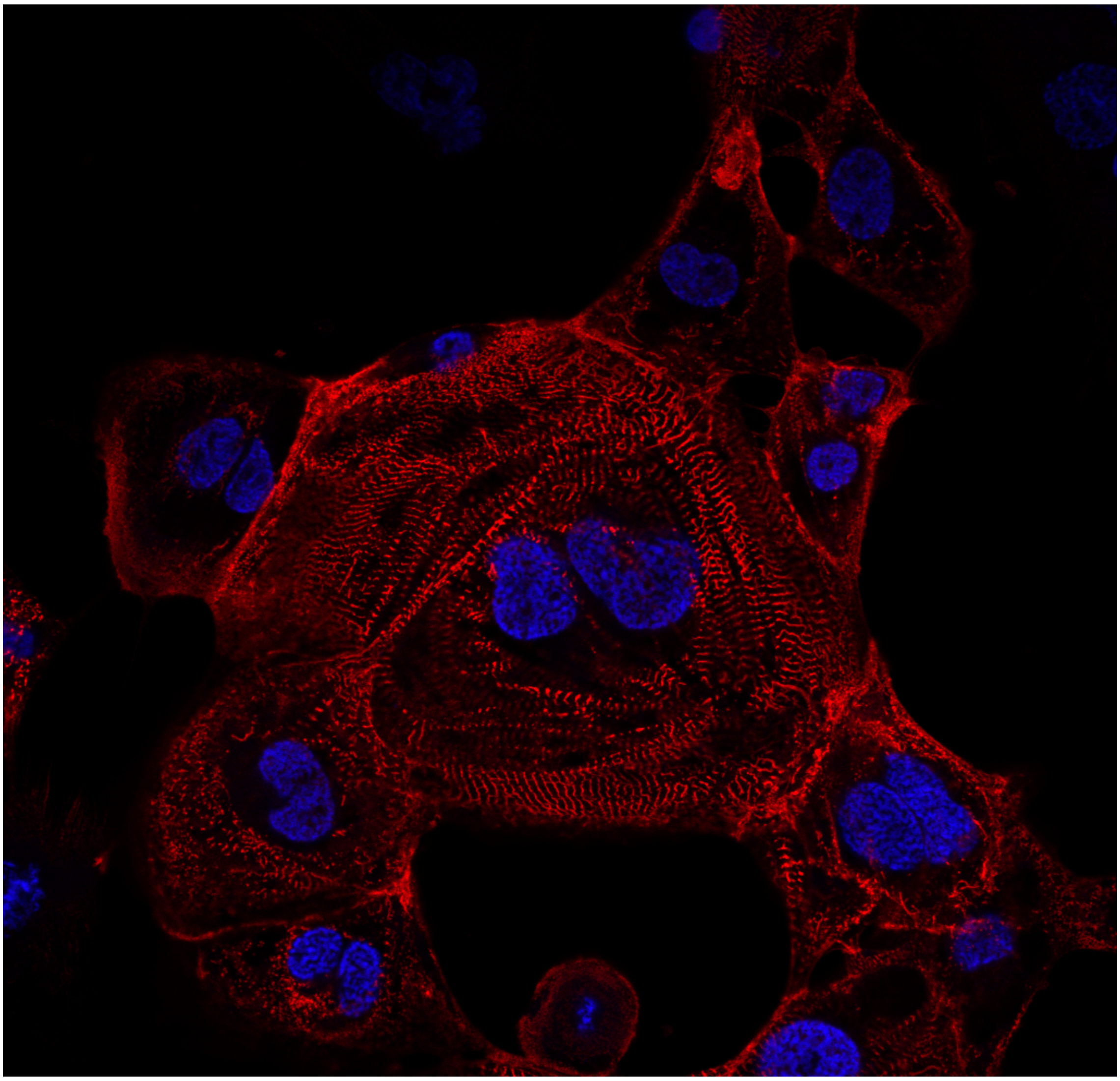


Figure 17. Golding, J. (2015) W3CMSNP2a.tif © Joelle Golding.

Eager to explore the functioning of microscopy and biological systems, I studied several technologies available in the lab to understand better their underlying processes. At this stage of inquiry, I was particularly interested in interrogating scientists' technological expertise as they conducted wide-ranging imaging experiments. I selected data from various techniques, including FRET, FCS, EM, AIPF, CM, SRM and LM, before narrowing my focus to CM, SRM, and LM (see Glossary). These methods provided high-resolution imaging data that I could use to expand my art practice. As key components of the lab, these technologies presented unique opportunities for data collection that were not accessible outside of the scientific environment.

To contextualise my work and comprehend the techniques, instruments and data collection methods, I explored technical-scientific literature (Kampourakis, 2018). Through sources like DeRose et al. (2013) and Sridharan et al. (2014), I gained insights into optics, laser technology, resolution and fluorescence microscopy. This required learning concepts outside my original training, including physics, mathematics, engineering and biology. I reviewed topics such as cell biology (XVIVO Scientific Animation, 2011), cell types (Laskey et al., 2022), live and fixed cells (Holst et al., 2004), drug interactions (Britannica, 2024), and units of concentration (McDonald, 2009; Pennycuick, 1988). This blend of interaction, study and creative exploration helped me bridge disciplinary divides further and develop a more nuanced perspective on the intersection of art and science.

Understanding and imagination

Over an extended period, I encouraged my long-term collaborator, Senior Imaging Technician Robert Markus (2015–2019), to experiment with various visualisation techniques. Markus became a central figure in my research, setting up SRM and CM experiments for my observation. He taught me microscopy techniques and allowed me to observe his work both independently and in collaboration with other scientists, including Associate Professor Laura Kilpatrick. He provided invaluable data that significantly shaped my research.

Markus was deeply committed to our collaborative approach, which enhanced both his and my understanding of optical visualisation techniques. He conducted experiments with SRM and CM, and developed customised protocols tailored to my research needs. These protocols transcended conventional scientific practices and enabled us to generate unique data. For instance, Markus demonstrated Brownian motion by combining an algae culture with a bacterium labelled with oil dye and DNA, allowing me to observe the microscopic structure of the algae and the constant motion of molecules in liquids. In my laboratory notebook, I recorded that the motion resembled a luminous stream of lights, highlighting the dynamic nature of the microscopic world.

Collaboration with Markus also allowed him to explore further customisation methods in his imaging techniques. For example, he sought to prove how he could target cells with such precision that he could capture a single molecule, and study sub-cellular molecular interactions. Using SRM, Markus studied the light distribution and structural composition of the spinal cord in a mouse, focusing on the depth of neural tissues. He used a 63x-objective lens (see Glossary) for this experiment and then switched to a water-immersion lens to showcase Structural Illumination (see Figure 18), which allowed me to observe individual molecules blinking on screen.

As our collaboration progressed, Markus demonstrated his ability to deactivate the pulsating molecules using advanced scientific imaging tools. At the same time, I described how a precisely timed experiment, when animated on screen, produced unusual pointillist imagery. This reminded me of the reactive sequences triggered by the erratic activity of cells. This process echoed the techniques of Neo-Impressionist painters like Georges Seurat, especially their colour separation theories, which focused on creating visual effects through the juxtaposition of distinct points of colour. In our case, this method was applied in a more intensified, scientific context (Gelan, 2020: 129–136). Our work brought both of us back to a deeper study of the concept of pixelation, as we sought to understand its implications in both visual art and scientific imaging.

My insistence on pushing Markus to customise techniques and critically question his empirical methods allowed me to observe visual phenomena that would have otherwise gone unnoticed or not been produced. Markus would not have fully understood my inquiries or the reasons behind my responses to his image-making process had I not challenged him in this way. This exchange exemplified how my imaginative and reflective approach extended his practice. Our mutual reactions stimulated further experimentation, and as we grew more attuned to each other's creative and scientific sensibilities, we were able to refine and advance our visualisation techniques.

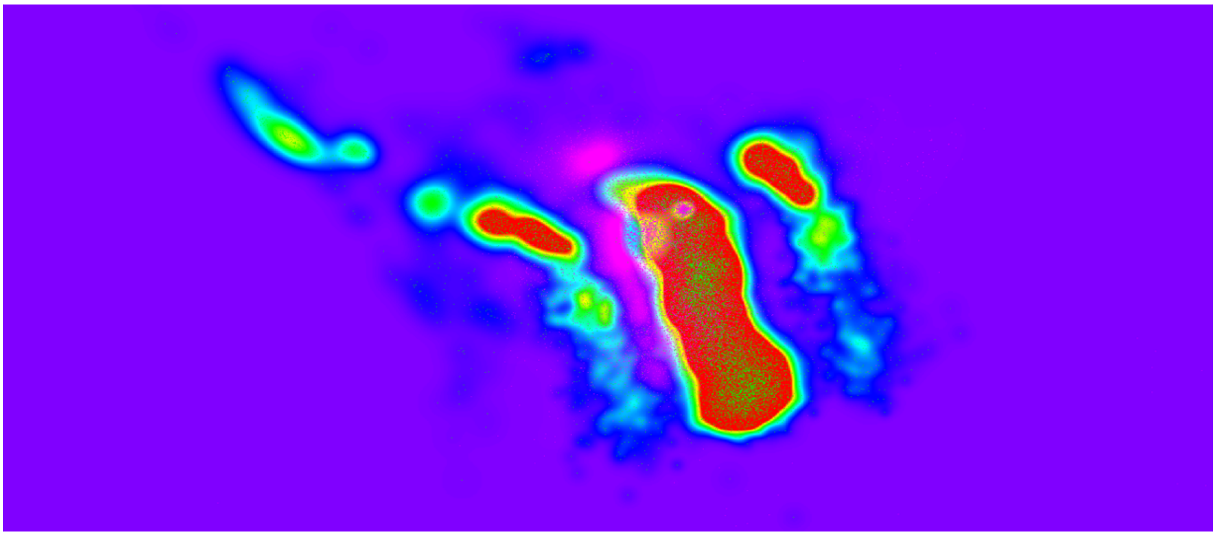


Figure 18. Markus. M. (2015) SpinalCord63xW_7 seq STORM_PALM_MaxZoom.tif. 63.6 x 29.8 cm. © Robert Markus.

Markus also took on the role of documentary photographer. As an avid photographer, he captured images of Kilpatrick and me as we compared SRM with CM images (see Figures 19–20). We then swapped roles, taking photographs of each other. This role reversal was part of a creative strategy I introduced, emphasising play-based collaboration. It added an element of fun and mutual reciprocity, enriching the process and fostering a more dynamic, collaborative atmosphere.

Figure 19. Markus, R. (2018) Swapping Roles – Markus taking photos of Berry and Kilpatrick in conversation in the SRM Lab. 14.8 x 10.5cm. © Jo Berry-Frith and Robert Markus.

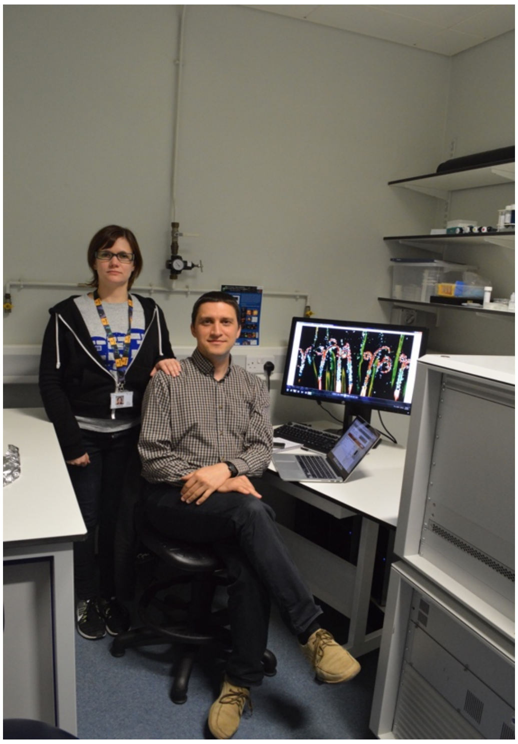


Figure 20. Berry-Frith, J. (2018) A portrait of Kilpatrick and Markus in the SRM Lab. 14.8 x10.5cm. © Jo Berry-Frith and Robert Markus.

Additionally, Markus demonstrated the process of preparing samples, constructing an image (in this case, a 110-slice Zed stack) and fine-tuning both microscope and computer settings to produce, rotate and capture visually compelling images. I observed his intelligent and analytical decision-making in technology and optics as he performed precise mathematical calculations to reduce blur and identify the brightest focal points for achieving the perfect image. His efficiency in scanning the required Zed stack slices and processing the data at the highest resolution showcased a mastery of his craft. Markus explained that while scientists' use of colour and light is governed by scientific principles, perception is key. Enthusiastically, because of my inquisitiveness, he discussed and tested unconventional techniques – such as reducing bleed-through to zero, which resulted in unexpected yellow displays on the monitor – demonstrating how minor deviations could yield insights often overlooked by traditional visualisation methods.

Through sustained collaboration with scientists like Markus, it became clear that we could approach data not only analytically but also imaginatively. My focus on play introduced an artistic lens to his work, gradually shifting his mindset towards more unconventional experimentation. Over time, this led to conversations about the nature of scientific imagery and its creative potential. Markus began to embrace artistic reinterpretation, illustrating how alternative perspectives could enrich both the process and outcomes of scientific visualisation.

By contrast, in my work with Briddon, I saw how his approach to imaging was grounded in the objective, scientific goal of understanding biological processes. Briddon used imaging as a structural tool, designing experiments that were meant to be unbiased and to allow for objective comparisons. This clear difference between his precise scientific methods and my subjective, artistic sensibilities was striking.

Briddon believed that my role as an artist was to enhance the visual potential of the advanced imaging techniques he was using. He often introduced me to creative visualisation methods, expanding my understanding of how art and science could intersect. One memorable example was when he shared the dynamic beauty of moving images of human neutrophils. In that moment, his perspective shifted. No longer confined to a functional or biological view, he began describing them as beautiful – a revealing change that reflected a deeper connection to the imagery. This transformation wasn't purely intellectual; it carried a playful quality. My artistic viewpoint encouraged him to see his research through a fresh lens, sparking a sense of wonder and reinterpretation. Inspired by this collaboration, Briddon moved beyond a strictly empirical approach, incorporating emotional and interpretive dimensions into his work. This new depth underscored how creativity and exploration could drive scientific understanding in unexpected ways. This transformation highlighted how play – allowing room for creativity, emotion, and exploration – could lead to breakthroughs in how science is understood. The process illustrated the potential for collaboration between art and science, where an artist's perspective offers valuable perspectives, and encourages scientists to reassess and reinterpret their work in ways that go beyond the purely analytical, allowing for a playful reimagining of the research itself.

My work with Kilpatrick added another perspective. We collaborated frequently, engaging in stimulating exchanges that contrasted my artistic focus with her positivist, theory-driven approach. My inquiries often prompted her to reconsider her methods, bridging interpretive, aesthetic and empirical perspectives. These dialogues fostered mutual reflection, blending scientific rigour with artistic interpretation to reveal new research pathways. Encouraging Kilpatrick to reflect on routine aspects of her work, I asked her to identify moments of playful engagement. She acknowledged the complexity of this idea, remarking, "I know we mentioned it being 'play' (scientific experiments), but to be brutally honest, you do this job because you love science, as there are many practical aspects of the job that are not necessarily ideal" (Kilpatrick, 2018; see Appendix

Five). Her response highlighted the balance between passion for science and its pragmatic demands. Initially, Kilpatrick found the concept of "play" in pharmacology perplexing. Through our discussions, she came to appreciate its relevance, ultimately incorporating it into our collaborative experiments. For instance, she eagerly demonstrated a NanoBrett imaging method that did not require a microscope. Guiding me into a darkened room to explain the technique, she became notably more animated and enthusiastic – a shift in energy that may not have occurred without our exchanges. This change revealed how our open-ended collaboration redefined play within a scientific context, expanding her perspective on creativity in her work. Integrating play fostered innovation, broke rigid frameworks and sparked new approaches to problem-solving, ultimately enriching our research.

Kilpatrick stated that she found my presence in the lab highly valuable, as it revived her appreciation for the beauty of scientific imagery, often overlooked in routine work. She said that my presence emphasised how non-scientists may view scientific images aesthetically, even when they represent failed experiments. Based on our work together, she strongly supported integrating artists into research environments (see Chapter Six contribution to knowledge and Appendix Five).

All 17 scientists I worked with through PAR acknowledged that rigid scientific methods often constrained creativity. Despite these limitations, I observed subtle elements of playfulness emerging naturally in their work. While the scientific method includes some playful aspects, its strict requirements, such as replicating experiments exactly, limit flexibility and discourage exploration beyond predefined boundaries. By fostering reciprocity, I encouraged scientists to embrace more open, creative approaches, stepping away from rigid positivist practices. This inspired fresh perspectives and demonstrated how integrating play into research could combine scientific rigor with imaginative exploration. This approach enriched the research process, expanded possibilities for discovery, and bridged the gap between structured inquiry and creative freedom. It also encouraged scientists to discuss their work in non-scientific terms, reflecting on their identities and exploring rarely articulated ideas. Markus, for example, sought to convey concepts that transcend traditional theoretical boundaries. He revealed that scientists often wish to share aspects of their work with non-specialists – something that traditional scientific publications struggle to achieve. He emphasised the importance of expressing 'how we [scientists] work, think and approach problems' to communicate ideas that extend beyond conventional frameworks. Through these exchanges, I gained a deeper understanding of the personal, collective and institutional motivations shaping scientific work. This perspective allowed me to look beyond data and experimental norms to appreciate the diverse viewpoints scientists bring to their research. It underscored the importance of presenting scientific ideas in ways that engage broader audiences meaningfully, positioning me to bridge the gap between scientific and non-scientific perspectives and foster richer dialogue about their work's significance.

Through my engagement, I gained a greater appreciation for scientific reasoning, which significantly influenced my approach to understanding the inner workings of cells. This shift in perspective was crucial as it led me to develop a methodology for collecting, analysing and presenting scientific data that differed from that of my collaborators. The concept of play became a key driver of my creative engagement with scientific technologies, materials and data. By introducing playful approaches within the lab, I was able to explore the human elements of research, as I examined interactions between individuals, technology, tools, the environment and cellular processes. This eclectic, multimethod approach not only enhanced my understanding of the scientific process but also highlighted the value of interdisciplinary thinking, encouraging more dynamic, creative and holistic exploration of scientific questions.

In this developmental phase, I established multiple "magic circles" (Huizinga, 2016: 20) through collaborations with scientists, using a variety of advanced imaging and microscopy techniques. However, this phase had limitations. Specifically, I was unable to explore fully the impact of artistic interpretation on scientific data or evaluate the artist's role in presenting alternative approaches to advanced imaging through new forms of visualisation. These constraints highlighted areas for further exploration, which I addressed in subsequent cycles of practice. By building on a reflective strategy, I was able to refine my approach, allowing for a more comprehensive investigation of my research questions in future phases.

The first cycle of art project findings

As the sole artist–researcher in the lab, I occupied a unique position that allowed me to build meaningful relationships over time with key individuals who recognised the value of my presence. My involvement enabled scientists at various stages of their careers to clearly articulate their findings to an expert from an entirely different field, which in turn helped them practice communicating their research to a broader audience.

As scientists grew more accustomed to my presence, genuine interactions flourished between specialists from different fields, fostering trust and collaboration. These face-to-face engagements deepened my understanding of the role of play-based activities in the lab, enabling me to introduce alternative approaches to advanced imaging and microscopy, inspired by my engagement with philosophical concepts of play and technology. In turn, expanding my knowledge of scientific language and terminology beyond my primary discipline enhanced my ability to communicate effectively with collaborators, their communities and industry partners, including Zeiss engineers (Leurs et al., 2005).

Positioning myself within multiple "magic circles" (Huizinga, 2016: 20), I created new modes of engagement through role-play, role-swapping and dialogic aesthetics (Kester, 2013). This approach highlighted the human aspects of science and facilitated the breakdown of disciplinary barriers. By making non-scientific comparisons and asking unconventional questions while working alongside scientists, I gained valuable insights into the intersections of art practice and pharmacology. My understanding developed through reflection on the speculative nature of scientific reasoning and by re-examining each stage of the experimental process. Sharing impressions and acknowledging mistakes became essential elements of this collaborative learning process.

I discovered that, as an artist, I could challenge empirical methods by leveraging my discipline-specific knowledge. By continuously questioning the assumptions underlying each scientific approach, I documented every action to uncover its unique characteristics. This process produced the first sets of qualitative data. As a skilled practitioner, I recognised that much of what we know exceeds our ability to articulate. Thus, I collected a diverse range of data – including visual, tactile, auditory and technological information – which I integrated with qualitative scientific data to inform the creation of artworks, as discussed in art cycle two.

The second cycle of art project one

The scientific computer lab

As discussed in Chapter One, Latour's Actor-Network Theory (ANT) proposes that both humans and non-humans possess agency and can delegate roles to one another within networks. He advocates for a "symmetrical" approach, where human and non-human entities share equal roles and responsibilities (Verbeek, 2005: 150). Reflecting on this interconnectedness, I considered how technology influenced my artistic production. I realised that the software and advanced imaging tools I used not only shaped my creative process but also redefined my understanding of what my artwork could become. These tools expanded the possibilities of visual expression, allowing me to explore new dimensions and techniques that I had not previously considered. By integrating these technologies into my practice, I discovered how scientific methods could serve as a catalyst for artistic innovation, prompting me to rethink the relationship between art, technology and my perception. The experience revealed that my artwork could transcend traditional boundaries, blending creativity with cutting-edge technology to form a unique and dynamic artistic language.

In *Picturing Science, Producing Art* (1998), scholars Caroline Jones and Peter Galison explore the relationship between science and art, focusing on visual culture and the concept of visuality. They discuss Latour's examination of how both fields use visual tools differently, yet both aim to create a language that values all mediators equally. This perspective is crucial for understanding complex relationships, particularly when imbalances exist. Latour suggests excluding extreme elements, such as *res* and *cogito*, and instead emphasising the intermediary "cooking steps" that connect them (Jones and Galison, 1998: 19). He argues that advancing scientific understanding requires separating science from its material forms and reinterpreting it, a process that fosters critical thinking and evolution (Jones and Galison, 1998: 422–428). Latour encourages both scientists and artists to focus on the practical, "active art" of science rather than its abstract, Cartesian notions of objective truths (Watson, 2022). This shift underscores that knowledge is constructed through everyday practices and social interactions.

I was drawn to the idea of focusing on the practical elements of science, especially its "re-representation" (Jones and Galison, 1998: 422–426). This concept prompted me to reflect on how contemporary scientific visualisation aligns with my own visual art practice. My interest in optical effects, colour and amorphous forms (see Glossary) resonated with Latour's viewpoints, highlighting how both scientific visualisation and artistic creation serve to transform and reinterpret reality. This shared process of re–presentation offered an unusual perspective on how artistic and scientific practices could intersect, enriching my understanding of the visual and conceptual possibilities inherent in both fields.

In the "magic circle" of the scientific computer lab (Huizinga, 2016: 20), I examined how scientists used data processing techniques and questioned the criteria they employed to select empirical data. This led me to work with software tools like Q Capture Quo, Zen Black, and Zen Blue, which undergo iterative modifications by technologists. Using my creative skills, I sought to expand the reprocessing of scientific data, transforming it through my artistic lens by enhancing my software proficiency. The scientific computer lab thus became a crucial space throughout my PhD, where I engaged with biomedical data that had already been substantially modified in scientific and advanced imaging labs. This environment allowed me to merge scientific data manipulation with artistic exploration, demonstrating how my practice could function as a bridge between the two disciplines.

In *The Playful and the Serious* (2006), Hector Rodriguez highlights how classical mechanics offer a framework for understanding observable changes, stressing that prioritising testing over rigid rule-based exploration can lead to deeper insights. He suggests that the nature of play intensifies when the topic being studied is inherently playful, and that a player's reasoning confirms play as an effective form of learning. This perspective inspired me to incorporate strategic software play into my creative methodology, challenging traditional empirical boundaries while engaging in dynamic exploration of scientific data.

I approached the notion of observed modification as a deliberate, strategic form of play, using it to generate new data through software manipulation. My experiments involved adjusting parameters like colour values, shapes, or layering techniques, to see how minor changes could produce significant visual shifts. This process allowed me to explore unconventional decision-making, diverging from my original plan, while maintaining professionalism and pushing the creative potential of my work.

I reprocessed raw experimental data multiple times, experimenting with various graphical tools such as colour, offset, view, composition, time, speed, tempo, rotation and scale. Beginning with specific data sets, I made intentional, incremental adjustments before altering the course of events to amplify or diminish effects. This blend of regulated and spontaneous techniques led to innovative visualisations, including topologies, stereo projections, and both two- and three-dimensional representations (see Figures 21, 22, 23, and 24).

In some cases, I pushed the software beyond its intended functionality, capturing animation through mouse-tool movement and fly-through effects. While these experiments occasionally caused the system to crash, I wasn't deterred. The close interaction between software, technology and data construction illuminated how play can deepen our understanding of visual methods. It also demonstrated how adopting a playful mindset could inspire both myself and my collaborators, particularly imaging specialists like Markus and Self, who were eager to see how I could expand the scope of visual effects through creative experimentation. They recognised the potential of scientific visualisation methods beyond their traditional scientific applications. This approach validated the value of playful exploration, fostering continued innovation and expanding the possibilities of my work, enabling me to push the boundaries of both scientific and artistic visualisation.

As I meticulously documented each strategy in my lab notebook, the curiosity of other scientists working with different software and machines interest was piqued. They were not trained to engage with these tools in such a creative, open-ended way, and the approach was outside the scope of their usual, rigid methodologies. This sparked conversations and inspired a sense of experimentation that challenged the confines of their established practices, promoting a broader view of how scientific tools can be used for both precision and creative exploration.

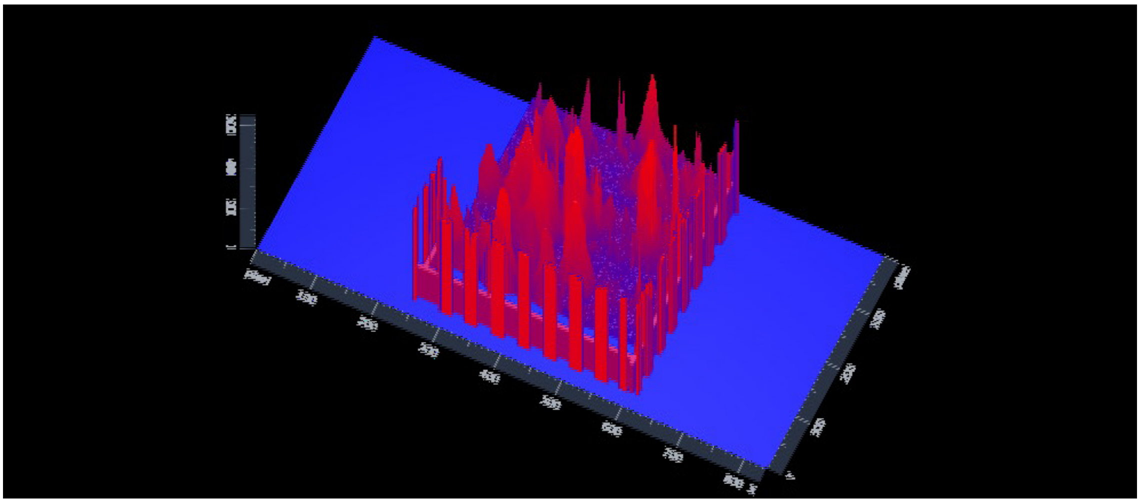


Figure 21. Berry-Frith, J. (2017) Topology: algaesnapchlooildna_5partial turn around 1.jpg © Jo Berry-Frith.

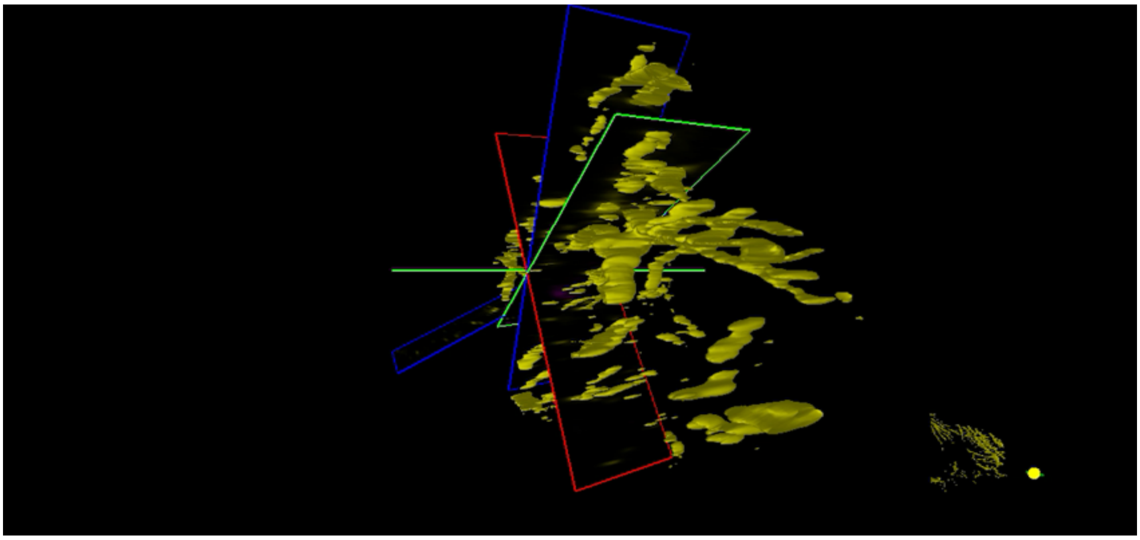


Figure 22. Berry-Frith, J. (2017) Projection Movie: Confocal SpinalCord2ch SeqFrame modesloweddown_Render_Series_Still.jpg © Jo Berry-Frith.

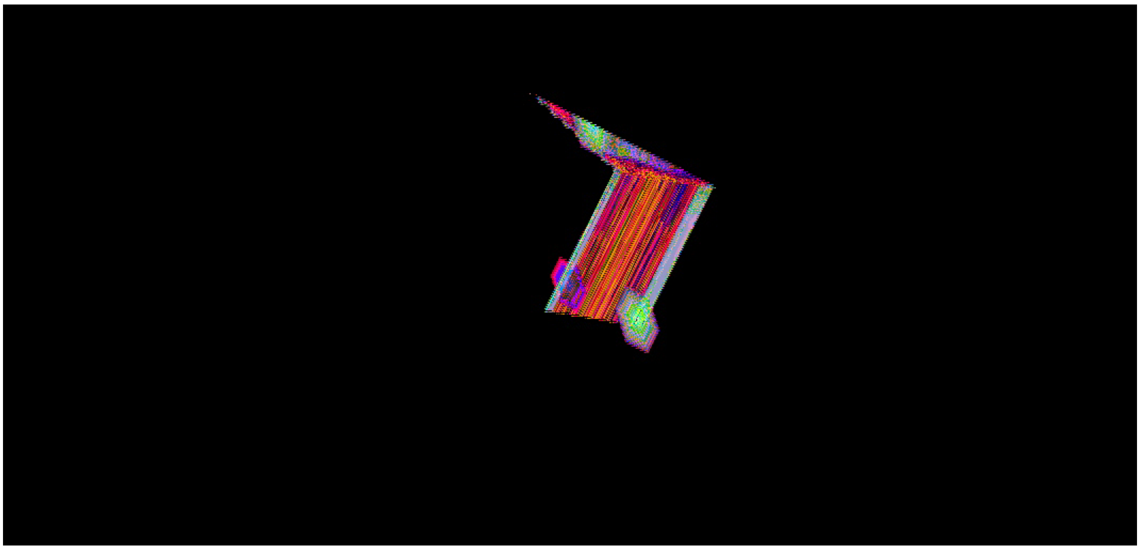


Figure 23. Berry-Frith, J. (2016) Three-Dimensional Visualisation: colourindent.jpg © Jo Berry-Frith.

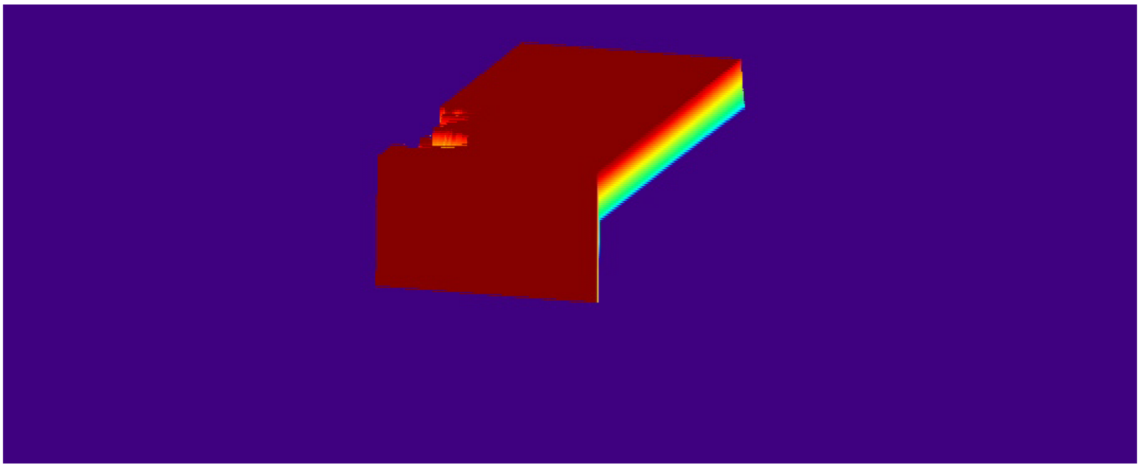


Figure 24. Berry-Frith, J. (2016) Three-Dimensional visualisation: changing colour saturation manually.tiff © Jo Berry-Frith.

Findings from software play

Bringing my artistic knowledge into the scientific computer lab significantly enhanced my computer visualisation techniques and my appreciation for scientific data through creative reinterpretation. By tracking my visual strategies, I identified connections between my artistic practices and modern scientific visualisation methods. This led to new approaches, such as pushing the boundaries of the software to capture animation of data through mouse-tool movements and fly-through effects.

This creative approach not only expanded the potential of the software but also introduced innovative ways to visualise complex data. The images I created helped scientists better understand their experimental designs and offered novel methods for extending raw data, using software in ways they had not previously considered. It was rewarding to see my collaborators' reactions and hear discussions about how they might incorporate these ideas into their projects (see cycle three).

All the software instructions, activities and visual results I produced were straightforward tools that could be easily applied, serving as a guide for generating new data through exploratory techniques. These were documented in lab notebooks and supported by a database, which provided resources for the next cycle of creative practice within the solitary "magic circle" of my studio (Huizinga, 2016: 20). While the images I created may not have directly improved scientists' understanding of experimental design, they did demonstrate novel possibilities for extending their data and using software in innovative ways, particularly for imaging specialists like Markus and Self, who adopted these improvisational techniques.

In the art studio

Within the "magic circle" (Huizinga, 2016: 20) of my studio, practice-based research encouraged me to rethink my methods, exploring sensory experiences – sight, sound, touch – and the emotional dynamics of the lab. Immersed in the labs, I engaged with both human and non-human elements, observing live cellular activity and the responses of scientists. This experience increased my comprehension of intricate techniques and enriched my appreciation of scientific perspectives. Blending scientific inquiry with artistic vision, I developed an integrated approach shaped by image data, conversations and shared lab experiences. From this, I created three, digital-production techniques – drawing, data montage and moving image – bridging artistic practice and scientific inquiry.

Digital drawing

In *The Primacy of Drawing: An Artist's View* (1991: 7), artist and writer Deanna Petherbridge highlights the intrinsic qualities of drawing, such as its universality, economy of means, expressive intensity and capacity to reveal technique and authorship. Sarah Casey and Gerry Davies, in *Drawing Investigations* (2020), position drawing alongside other investigative practices, emphasising its contributions to fields like medical surgery, ecology and contemporary conflicts. I studied several artists who explore drawing's multifaceted role in interdisciplinary collaboration, scientific exploration and technological integration. In Chapter One, I discuss artists like Anderson (2017, 2023), Lyons (2009) and Aldworth (Casey and Davies, 2020: 1–11), who serve as key reference points for my PhD research. Like them, I employ drawing as a practical tool to re-examine and re-represent scientific phenomena. I view drawing as a means of communication that bridges the gap between art and science, providing a visual approach to illuminate interrelated links and the intermediate processes connecting them, as proposed by Latour (Jones and Galison, 1998: 19).

Figure 25. Berry-Frith, J (2011). Hijacking Systems Exhibition, Derby Museum and Art Gallery. © Andrew Robinson.

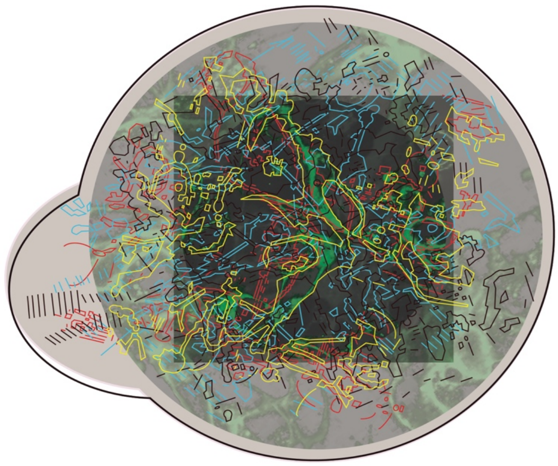


Figure 26. Berry-Frith, J (2011). HEK293ghrelin 100nM: A digital drawing template. © Jo Berry-Frith.

Over the last twenty years, I have created digital drawings as design templates for laser-cut lightboxes, exemplified in 'Hijacking Natural Systems' (2009–2011; see Figures 25–26). During my doctoral studies, I chose to move away from producing laser-cut artworks and instead expanded my digital drawing practice as a conceptual tool for exploring scientific phenomena. The resulting body of work contributes to computer-generated drawing techniques. These drawings (2015–2021) stand in contrast to the methods scientists use to represent data, challenging the "technical non-style" of drawing (Kemp, 2016: 209) and resisting the notion of "mechanical objectivity" (Daston and Galison, 2015: 82).

The drawings I created are technically proficient but intentionally deviate from the precision and realism typical of scientific research. Unlike the work of modern medical and forensic illustrators such as Phil Wilson (2024), or botanical illustrator Lucy T. Smith (2024), my drawings prioritise a surface-based analysis of pixel data captured beyond human vision and rendered as computer graphics. This approach challenges conventional methods of evidencing cellular information captured via photography and advanced imaging technologies (Casey and Davies, 2020: 208–209).

I was particularly captivated by the idea that complex biological formations, as visualised on a screen, are fundamentally constructed from pixel data. Observing the laser scan across a plane of interest, capturing the image pixel by pixel and line by line, profoundly affected my practice. Collaborators such as Markus further shaped my thinking as his observations of the dense pixel grid displayed on a stereomicroscope during cycle one served as a critical influence on my conceptual approach.

I engaged with Jonathan Crary's *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century*, in which he argues that technology is "relocating vision to a plane severed from the human observer" (1992: 1). Crary explores how computer graphic techniques reconfigure the interaction between observer and representation, effectively challenging traditional definitions of viewer and representation. He asserts that the formalisation and transmission of computer-generated imagery differ fundamentally from the mimetic capabilities of media like film, photography and television. These visuals, he notes, are increasingly detached from the observer's position in a "real" optically observed world, instead reflecting millions of pieces of electrical mathematical data that can represent anything.

By contrast, I sought to reverse this detachment by taking data invisible to the human eye – constructed as mathematical code – and reinterpreting it through a real-world perspective that acknowledges its fabricated nature. Using digital drawing as an investigative tool, I examined the visual qualities of biomedical data from SRM and CM imaging experiments. This speculative, detail-oriented approach allowed me to uncover and reframe the essential qualities of the data, offering fresh perspectives on its meaning and aesthetic potential.

I first focused on CM imaging experiments conducted by Golding, which captured human-stem-cell-derived cardiomyocytes (see Figures 17, 28, and 29). I was captivated by the visually striking qualities of these images, used as reliable and characterised models for testing new drugs to treat heart disease. The amorphous, brightly coloured cellular forms displayed supple characteristics and dynamic behaviours that were both scientifically intriguing and artistically compelling. I selected the most detailed images based on their exceptional visual attributes: luminosity, impervious structure, dynamic shapes, size, depth and intensity. These features were aesthetically captivating, but also challenging to articulate or appreciate.

Approaching the study of these visual attributes as an artist, rather than a scientist, provided an opportunity to explore colour, fluorescence, shape and structure, which are part of my study's primary foci. The act of drawing became a method for elevating the status of digital drawing, illuminating its connection to medical research. Through drawing, I mapped the complexity of the cellular forms and reflected on the processes that shaped their visual characteristics – processes that often elude straightforward scientific description.

This process prompted me to think creatively about reinterpreting these genetically engineered artificial cells. I drew inspiration from the Oxford English Dictionary's (2023) etymology of *context* – *con-* (together) and *texere* (to weave) as a framework for exploring the interconnectedness of these cells, their visual representations and my artistic practice. This perspective allowed me to weave these elements into new narratives, enriching cross-disciplinary understanding and fostering innovative approaches to interpreting biomedical imagery.

Digital production began with layering image data from selected stills, serving as the foundation for subsequent drawing work. I initiated a surface-based drawing investigation, translating the complex, nebulous forms of cardiomyocytes into new graphical interpretations. Each image was meticulously constructed by layering and reworking information to create depth and dynamism.

For example, Figure 28 comprises ten distinct layers. The base layer consists of raw scientific data at 100% opacity, overlaid with a duplicate image at 55% transparency and slightly offset. To emphasise spatial structure, four cropped, rotated and masked three-dimensional topologies were integrated within the composition (see Glossary). The cardiomyocyte's pixelated structure was mapped with an orange line using a 0.75-point dashed stroke weight (see Figure 27). This linework was duplicated, pasted and offset three times, each iteration employing varying opacity and stroke weights: 55% opacity with a 0.75-point stroke; white with a 1-point stroke, and mustard yellow with a 1.5-point stroke. The synthesis of these graphical elements resulted in a visually complex and dynamic composition, capturing the intricate spatial and structural qualities of the cellular forms, while pushing the boundaries of my digital drawing techniques.

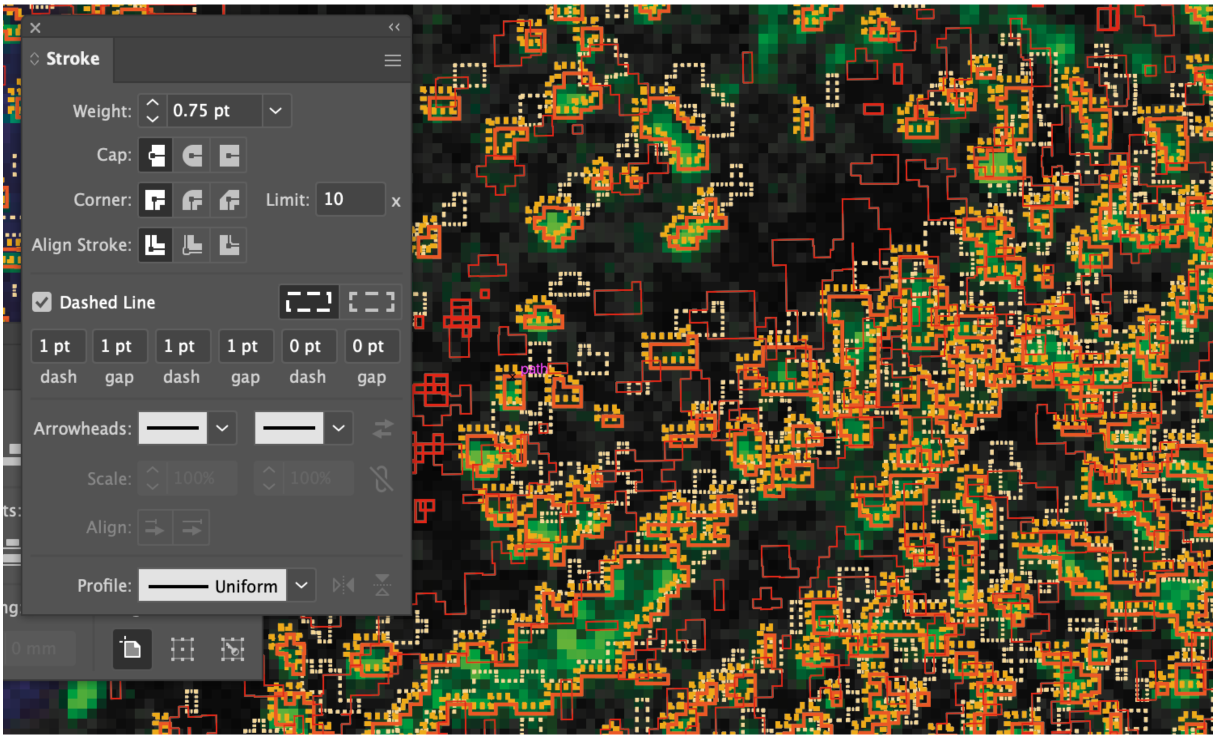


Figure 27. Berry-Frith, J. (2016) Detail of Human-stem-cells-derived cardiomyocytes dashed lines. 100 x 100 cm. © Jo Berry-Frith.

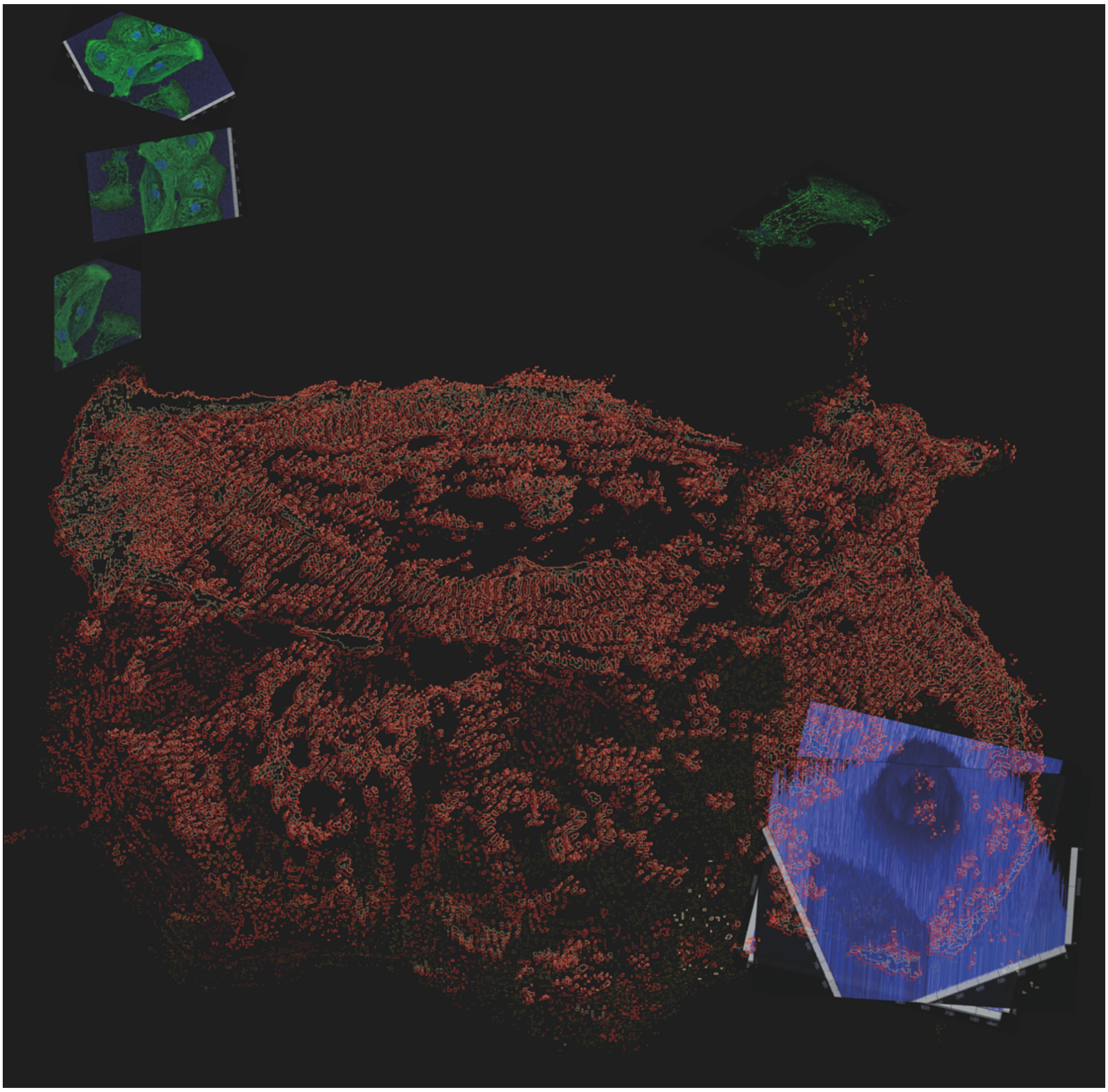


Figure 28. Berry-Frith, J. (2016) Human-stem-cells-derived cardiomyocytes: drawing.ai. 100 x 100 cm. © Jo Berry-Frith.

Manovich (2001) describes computer-generated images as discrete, broken down into pixels, which he suggests makes them akin to a human language. My research extends this idea by using pixel granularity as a creative interpretative tool. I developed a method of mapping pixel detail by zooming in at 2000%, not simply to explore digital image structure, but to reframe and reinterpret data through drawing. I treated pixels as distinct units of information, translating them to engage with and challenge the underlying fabric of scientific image data.

At this stage, I wasn't abandoning play; rather, I was continuously thinking about how to be playful with image construction – literally playing with the images themselves. I engaged optically as I drew, frequently zooming in and out of the illuminated image on the screen. Though the drawings were challenging and labour-intensive, my process emerged from a calculated playfulness within the intellectual framework I had set for myself.

Unlike others in the field, such as Anderson-Tempini (Anderson, 2017, 2023; Casey and Davies, 2020), Lyons (2009), and Aldworth (Casey and Davies, 2020), my focus was on emphasising the unique qualities of digital drawing as my medium. These included its capacity to be discrete, complex and subtle, as well as its potential to subvert the scientifically fabricated realities it represents. During this phase of my art practice, I utilised data, drawings, computers and software as tools to mediate and reinterpret data (Verbeek, 2011).

I focused on a single human cardiomyocyte image visualised on a CM system, selected by a scientist who zoomed in and out on her monitor to identify the most representative version. As I drew, I reflected on the "happy accident" of the cell lighting up, the artificial nature of scientific colours, and the fact that the image I was interpreting had been constructed from mathematical code and chosen from thousands of potential sites. This process of selection and representation underscored the extent of chance in the selection process and the fabricated nature of the data – an idea that increasingly preoccupied me. I became absorbed in the surreal task of reinterpreting an image of a cell that had already been re-processed and modified countless times, each iteration adding complexity to the original data.

As I constructed the drawings, I questioned how much information within an image was truly meaningful to the viewer, as these images contained far more detail than anyone could reasonably need. I fixated on studying and replicating pixel data, letting the drawings evolve by zooming in and out of the picture frame. I recognised that no human eye, screen, or printer, could fully capture the nuances of grey. I was working with concepts – optics, pixelation, mathematical code – that were beyond my complete understanding.

Mapping the pixel data became my way of making sense of it, much like how software experimentation allowed me to reinterpret scientific data. This process revealed new insights and bridged the gap between scientific analysis and artistic expression. I reference Lyons (2009) because, like her, I use drawing as a method of observation, emphasising the individual visual experience over generic representation. Lyons' collaborative approach to illustrating disease resonates with my focus on complexity. However, my approach differs in that I create computer-generated art that mimics the precision of hand-drawing. My drawings are composed of merged vector rectangles and squares, using the interplay of light and dark pixels to capture depth and facilitate deeper engagement with the data.

The tracing method I developed, and the resulting drawings, offered a new way to engage with the image and its intrinsic qualities. Drawing pixel data became a cathartic exercise – a tool to strip the data of its original meaning while retaining its essence as a simulation. It was a novel approach to perceiving and understanding the characteristics of the data. My objective was to hand-draw pixels using limited digital tools, creating subtle interpretations that counter the uniformity of digital representation. This process, though imperfect, led to unexpected and captivating representations of the subject.

Aware of the challenge in replicating dense pixel data, I carefully mapped and selected details to produce large-scale drawings (up to 2 metres). Despite the clumsiness of the touchpad and mouse, they mimicked hand-drawing, capturing the image's nuances. I experimented with layering, rotating, offsetting and applying techniques like juxtaposition, copy-pasting and varying line weights. The overly bright CMYK (not RGB) colours contrasted with the cellular details beneath, highlighting the digital manipulation of the image.

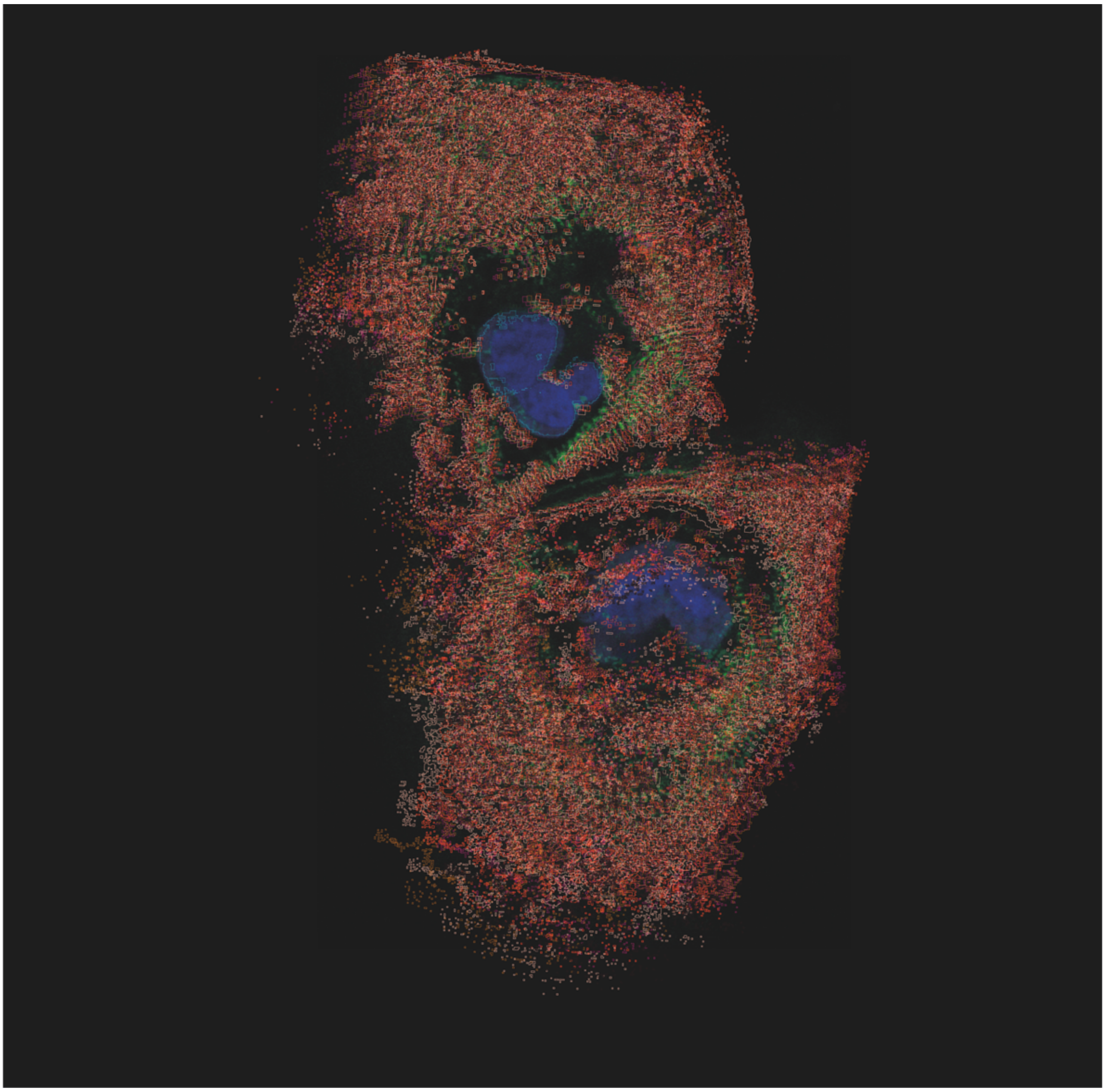


Figure 29. Berry-Frith, J. (2024) Human stem-cells-derived cardiomyocytes.pdf. 100 x100 cm. © Jo Berry-Frith.

Figure 29 is constructed of nine-layers. Raw data of human-stem-cell-derived cardiomyocytes were copied at 100% transparency, then re-copied at 66% transparency and offset. The original time-consuming drawing was copied and pasted five times. Solid and dashed vector lines created the appearance of movement: 1] pink line was 1-point stroke weight, dashed; 2] light orange 1-

point stroke weight, dashed; 3] orange 1-point stroke weight; 4] skin-tone 0.75-point stroke weight; 5] brown 2- point stroke weight, dashed; and 6] the nucleus outline coloured blue at 1-point stroke weight, dashed.

At the same time, I questioned why I was drawn to creating imperfect replications of human-stem-cell-derived cardiomyocytes. Why was it important to develop such a laborious method of tracing zoomed-in pixel detail, illuminated on-screen? This paradoxical, time-consuming approach subtly re-mapped complexity, blending meticulous observation, selection and action to explore how play could generate knowledge. The creative and intellectual game I engaged in while constructing digital drawings was immersive and cyclical, allowing me to discover new ways of thinking through doing. Through this praxis, I came to understand more deeply how I mediated technology and how components emerged organically from the re-mapping process. This dynamic interaction revealed how computer technology intertwined with and shaped my drawing experience, highlighting the evolving relationship between human intention and non-human processes. As I navigated between software tools and visual outcomes, I uncovered tacit knowledge – an understanding grounded in practice and experience, aligning with Verbeek's (2011) views on how technology mediates perception and action.

This reflective engagement also connected with Winnicott's (1989: 92) concept of the "intermediate area", where lived experience, imaginative perception and the latent space between the physical and subjective, converge. I recognised that my drawing practice resided in this space, where uncertainty could be embraced without the pressure to produce definitive outcomes. In this creative and exploratory zone, I could bridge my inner reality with the external world, developing interpretative models and deepening my creative process, much like Winnicott's (2005: 86) emphasis on how play enhances our creativity.

Additionally, Csikszentmihalyi's (2008) notion of play leading to self-actualisation and "flow" helped me make sense of my experiences. I noticed how play and flow-state were deeply intertwined in my work, as moments of intense focus and creativity emerged naturally when I engaged with the adaptability of play. By mapping these flow-states, I refined my process and enhanced both the creative and technical aspects of my drawing practice.

Ultimately, I adopted drawing methods that reflect Goethe's concept of art as a balance between industriousness and play (Anderson, 2017). These drawings became tools for organising data into readable cartographies (Casey and Davies, 2020), evolving into an active, reflective learning exercise. This approach bridged science and art, uncovering new connections that moved beyond traditional data representation, demonstrating how play, flow and technology can combine to deepen understanding and creativity.

Casey and Davies (2020: 7) highlight the significance of subjectivity in drawing, referencing Ruskin's focus on the seen, the known and the felt as a means of expressing embodied experience and situated knowledge. Drawing, in this sense, straddles the internal and external worlds. Similarly, Haraway's (1988) concept of "feminist objectivity" underscores that knowledge is always partial and shaped by context. My art–research process embraced this partiality, rejecting the illusion of detached objectivity in favour of an awareness of the systems and processes through which knowledge is mediated and expressed.

Building on Schön's (2013) notion of reflection-in-action, I transformed objective observation into an imaginative and creative practice. My drawings allowed me to engage deeply with complex scientific concepts in ways that verbal communication could not achieve. This approach reframed my art not only as a personal tool for exploration, but also as a critical method for pushing the boundaries of scientific knowledge through visualisation.

The interpretative drawing technique I employed connected human perception with the nuanced details of scientific phenomena, fostering a deeper understanding of complexity. Through this process, I synthesised observation, technology and imagination, demonstrating how drawing could act as both a bridge and a catalyst for expanding the dialogue between science and art. Inspired by D'Arcy Wentworth Thompson's *On Growth and Form* (2014), which explores the imperfection and constant energy of living cells, I viewed my drawings as similarly evolving and imperfect. My aim was to capture the complexity of these data.

After working on large-scale (portrait) drawings of human-stem-cell-derived cardiomyocytes, I selected images created on the SRM of a mouse spinal cord experiment imaged by Markus. I selected this image as I had not seen anything like it before imaged in this lab. It incorporated several fluorescent-coloured, unusual, shaped forms taken at a molecular level using a 63x magnification objective lens (see Figure 18, cycle one and Figures 30–31).

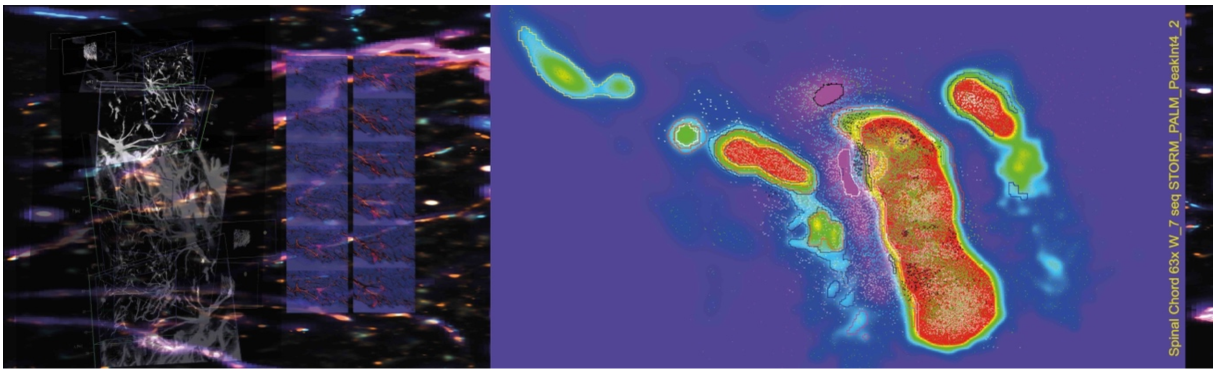


Figure 30. Berry-Frith, J. (2024). Alternative iteration Super Resolution detail. 30 x 100 cm. © Jo Berry-Frith.

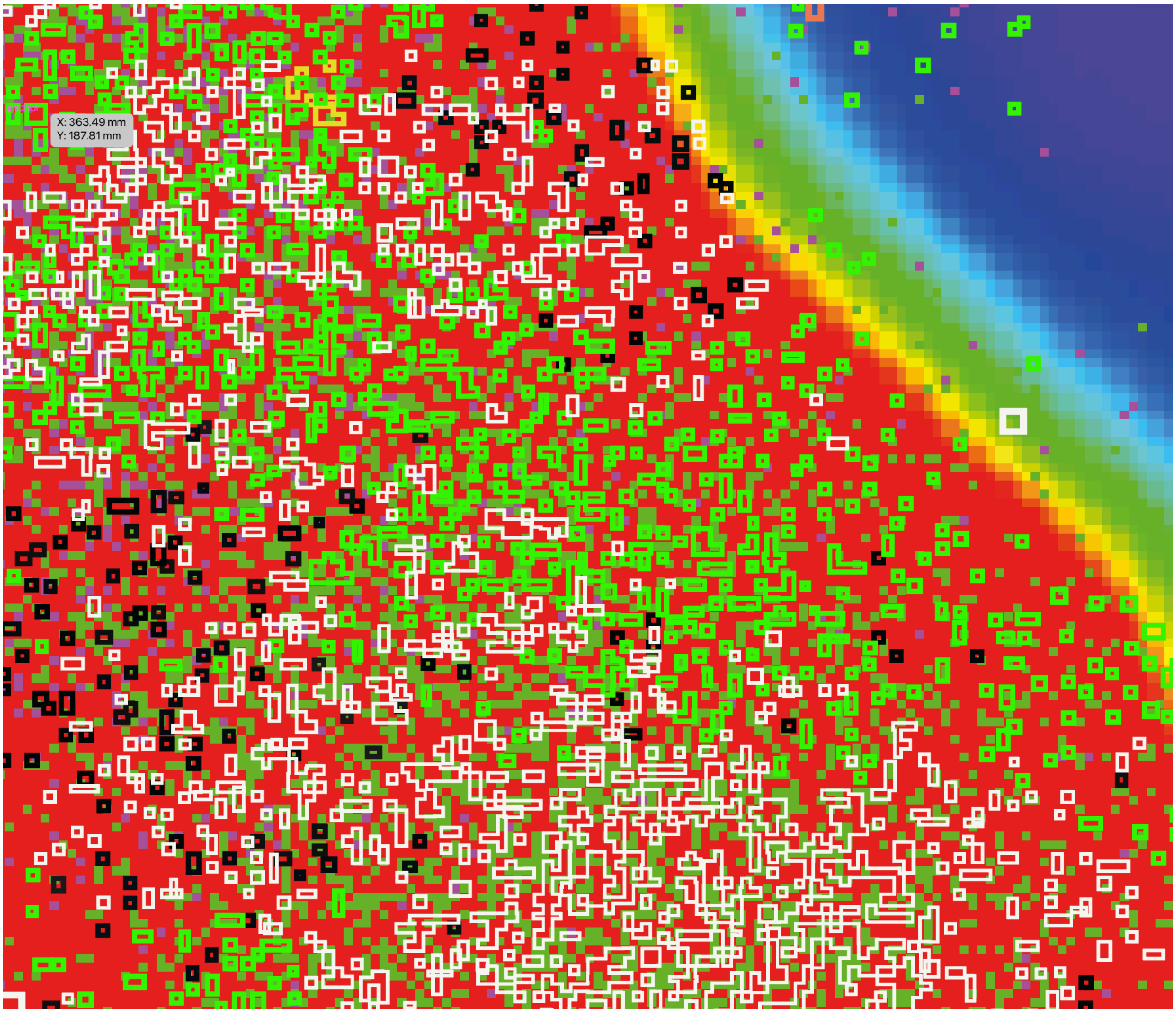


Figure 31. Berry-Frith, J. (2024). Alternative iteration Super Resolution detail. 30 x 100 cm. © Jo Berry-Frith.

Crucially, at this stage of the research process, inspired by ancient scrolls, I began to devise other compositional devices to reframe the drawings I made. The compositional frame shifted from portrait to landscape and the scale changed, enabling me to add more content (sequential framed images, projections and stills from Zed stack experiments) to the picture frame. Figure 30 shows how I incorporated raw data with experimental (software) data sets from the same data set. My intention was to map precisely (using several different coloured and weights of vector lines) infinitesimal pixel detail of an aerial view of molecular activity, while retaining the original data's constituents underneath (aware this was an impossible task). The final drawing outputs have numerous layered meanings that may be inferred and comprehended by a spectator.

This was crucial for my study, as I aimed to establish a connection between the artwork, scientists and others. My objective was to represent visually the intricate complexities of my absorption in the field, drawing inspiration from the philosophical concepts of play and digital technology. The importance of this lay in the way this data was disseminated back to scientists and the wider field, as discussed in cycle three.

Findings from drawing

The computer-generated interpretative drawing technique subtly re-mapped complexity that was difficult to articulate adequately in written form. The inherent properties of the digital drawings lay in their ability to reveal discretely the granularity of pixel data and showcase the visual characteristics of scientific data. This approach enabled the construction of subtle linear interpretations that countered the typically unified nature of digital representations.

Drawing, as a direct means to re-examine and re-represent scientific phenomena, revealed – through both its production and visual evidence – the interwoven nature of industriousness and play. It also highlighted key attributes, such as authorship, universality, economy of means and expressive intensity. Through the analysis and depiction of data, my experiential, situated and reflective knowledge deepened, shaped by the specific circumstances in which it emerged through drawing. Drawing magnified the human element of creative expression and highlighted the important, yet nuanced, relationship between data, humans and technology.

In doing so, it expanded the contribution of digital drawing to both graphic art and pharmacology, bridging the gap between artistic expression and scientific inquiry.

Data Montage

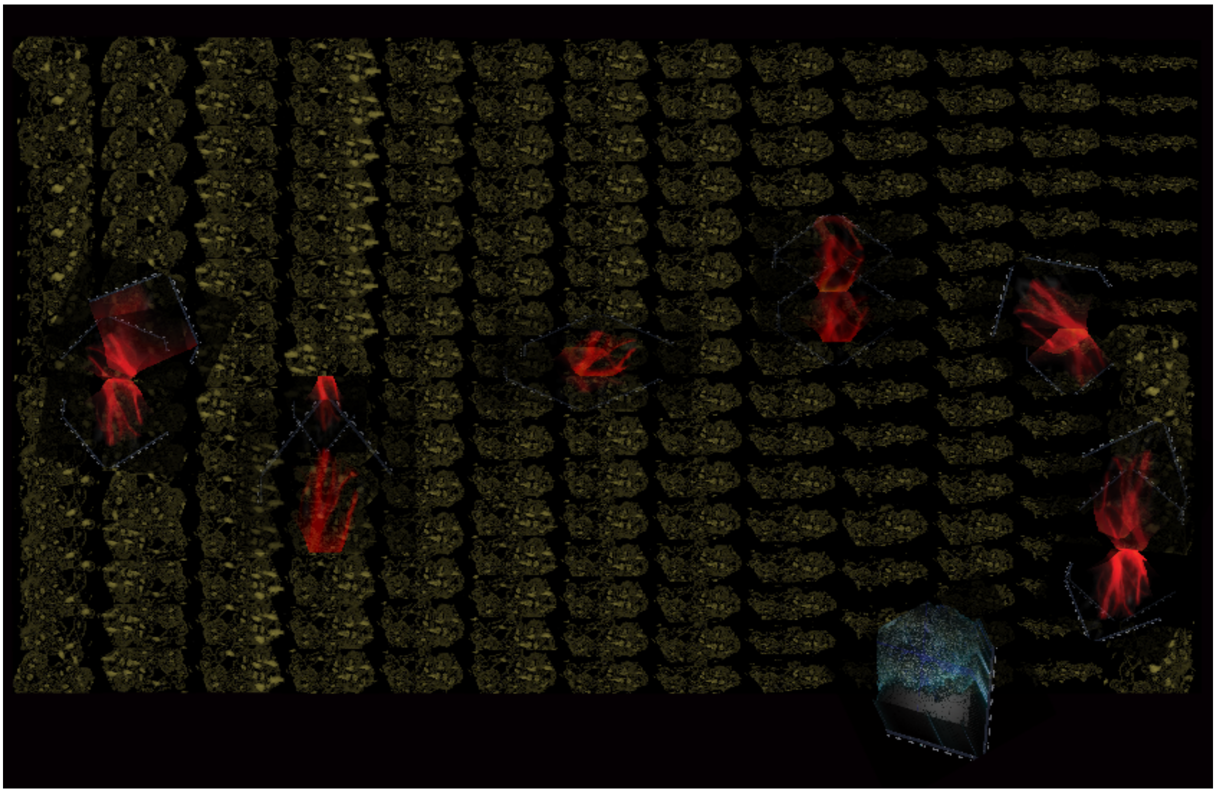


Figure 32. Berry-Frith, J. (2018) April 2018 Sequence Compilation.pdf. 180 x120 cm. © Jo Berry-Frith.

In *Essays on the Blurring of Art and Life*, performance artist Allan Kaprow (2003) discusses the long-standing tradition of integrating play into creative practice, tracing its roots from Dada (Carter, 1998) and Surrealism to Fluxus and the Situationists. As curator Sir Nicholas Serota (Kneebone, 2019) observes, art has the power to unsettle the certainties of science, often emerging from spaces of uncertainty and ambiguity. While I do not reject the modernist traditions of the late nineteenth century, my focus shifted towards using scientific imagery, techniques and materials to create artworks that explore the intersection of science, technology and art in a highly personalised, idiosyncratic manner.

In considering the role of play in art, Gadamer engages with Immanuel Kant's (1784–1804) notion of free play, which has long been associated with the experience of beauty. Kant described the nonconceptual, nonchalant nature of delighting in the beautiful as an emotive mental state, where our thinking and imaginative abilities merge into a form of *free play*. I embraced Kant's (1951, cited in Gadamer, 1998: 127) conception of *free play*, particularly his emphasis on the non-purposive notion of "delight in the beautiful". This perspective highlighted the importance of gratification and "the contribution of the subject" to our visual perception. By adopting this perspective, I sought to create work that fosters a state of creative freedom, one where the boundaries between scientific data and aesthetic experience become fluid, allowing for both cognitive and emotive responses to emerge. My aim at this stage was to transmit aesthetic craftsmanship through creating multifaceted and multilayered data montages, acting as a contrast to the laborious methods I employed when drawing.

I considered Gadamer's (1998: 99) reference to the classical Greek concept of *mimesis*, which pertains to the artistic replication of reality or, in biology, mimicry. Mimetic production does not create something genuine; rather, it offers a representation (Gadamer, 1998: 99). I began making multiple iterations, working swiftly and mixing divergent data experiments – such as topologies and stereo projections – with and without drawing. I considered assets, colour and pictorial elements, and employed computer techniques like rotation, layering, repetition, juxtaposition and sequencing. Through experimentation with various scales (300 x 41.8 cm; 100 x 100 cm; 29.7 x 42 cm), I explored the compositional frame, pushing the boundaries of what could be achieved with the data I was developing.

Figure 32 features stills from a moving-image sequence of amorphous imagery derived from a Cover Slip experiment, which was rotated, overlaid and blended to create a dynamic sense of flow. These elements were layered over a series of Z-stack image sequences of human-stem-cell-derived cardiomyocytes, rendered in a rusty orange hue. A solid, black-and-blue, three-dimensional SIM spinal cord sequential image acted as a compositional anchor, providing a striking contrast to the flowing red topologies. I used Adobe Illustrator's opacity tool to soften the crimson Cover Glass Correction images, seamlessly blending these organic shapes into the overall frame, to enhance the cohesion and depth of the composition.

I drew inspiration from the unconventional image combinations employed by Aldworth in her work (Casey and Davies, 2020: 60). Adopting a responsive approach, I embraced openness and spontaneity, incorporating elements of randomness to create unique, unpredictable visual combinations. Having produced a diverse range of two-dimensional graphical results, I was driven to push further, recognising that moving-image experiments would offer even greater potential for exploration. By developing this model, I sought to engage deeply with the dynamic interactions between form and content, enabling me to generate innovative visual narratives that captured the fluidity and complexity of these relationships. This shift towards moving images allowed me to expand the scope of my practice, creating more immersive and multifaceted representations of data.

Moving image

During this period, significant invention and experimentation occurred through the use of moving-picture datasets derived from raw data, alongside experimental software datasets created in the scientific computer lab. I drew inspiration from the innovative technologies (LM, SRM, CM) I encountered during the first cycle in the lab. I found Carnie's (Bright, 2015) sophisticated creative approach to investigating complex scientific concepts through artistic methods particularly compelling. His work is interdisciplinary and immersive, as discussed in Chapter One, and provided a valuable reference point as I navigated my own process of integrating scientific and artistic exploration. Carnie's ability to merge art and science helped me to refine my understanding of how these fields can intersect and inspired me to experiment further with how data could be reimagined and communicated through visual means.

The movies I created – namely *Heart Valve* and *3DMap 2Frames* – are examples of unfinished test films, each representing a stage in my experimentation with cellular activity through abstract reconstructions. These works, devoid of sound, focused on experimental production methods and the multi-layering of moving-image sequences. I concentrated on key cinematic elements such as time, juxtaposition, scale, opacity and transitions, to foster dynamic visual interactions between data sets. By manipulating these elements, I aimed to highlight the fluidity and complexity of the data, allowing for an expanded range of observable outcomes. In crafting these films, I employed cinematic techniques to structure time effectively, linking disparate visual experiences to create a more immersive and multifaceted representation of the scientific data.

I captured data for Figure 33 using LM in the histology department, employing two slides of a heart valve. Q-Capture Quo (IBM, Nd.) software was used to generate a rapid series of changes. In the art studio, I copied and pasted sections of these data, creating an effect so fleeting that if you blink, it will disappear. The result is the shortest test movie I created, lasting just 0.04 seconds. The creation of this 0.04-second film was significant for several reasons. It demonstrated how quickly experimental filmmaking can convey novel ideas, showing that even the most fleeting images can provoke thought. By using minimal digital tools, I emphasised the power of creativity within constraints, proving that impactful storytelling does not always require advanced technology. This brief film exemplifies how low-tech craftsmanship can transform raw data into meaningful visual experiences, underscoring that innovation can emerge from the simplest tools when approached with imagination and intent.

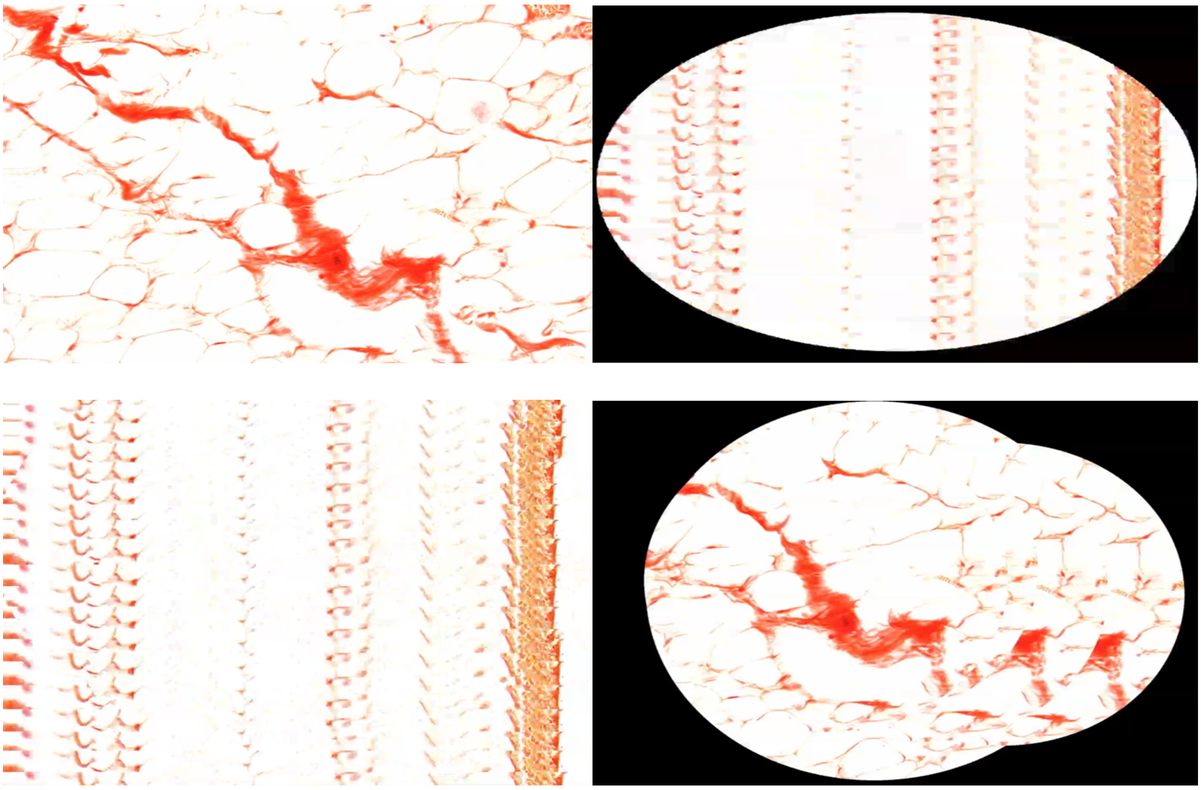
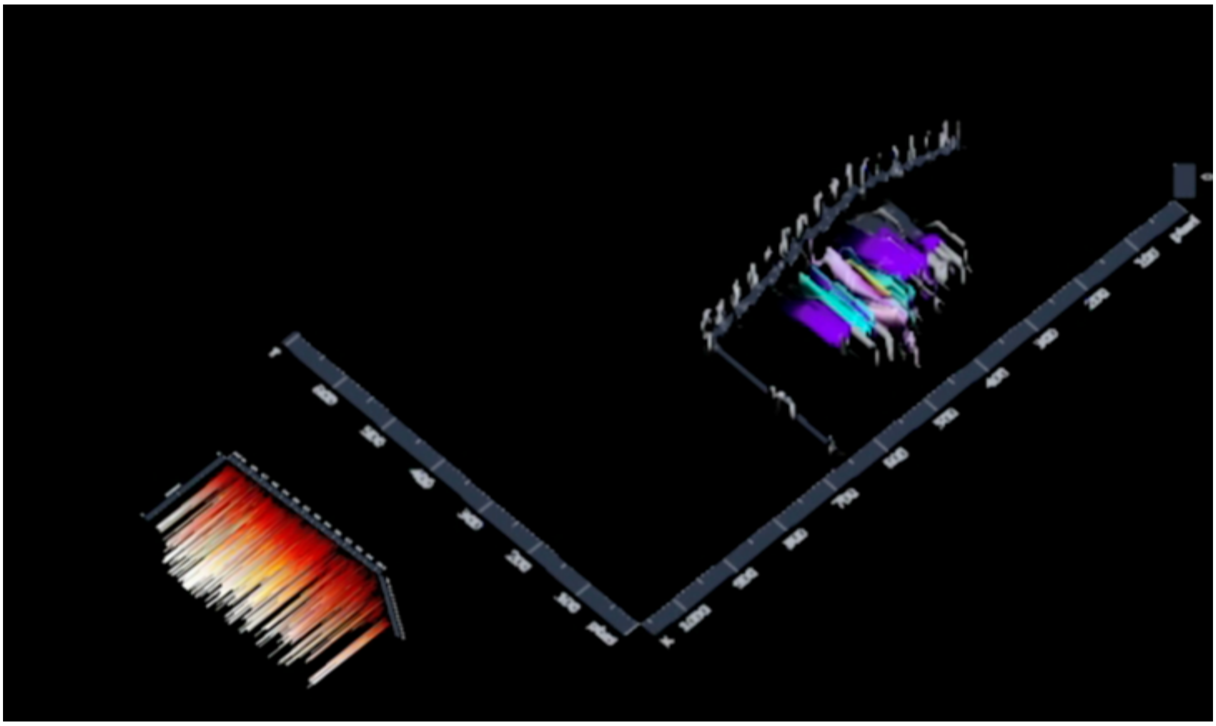
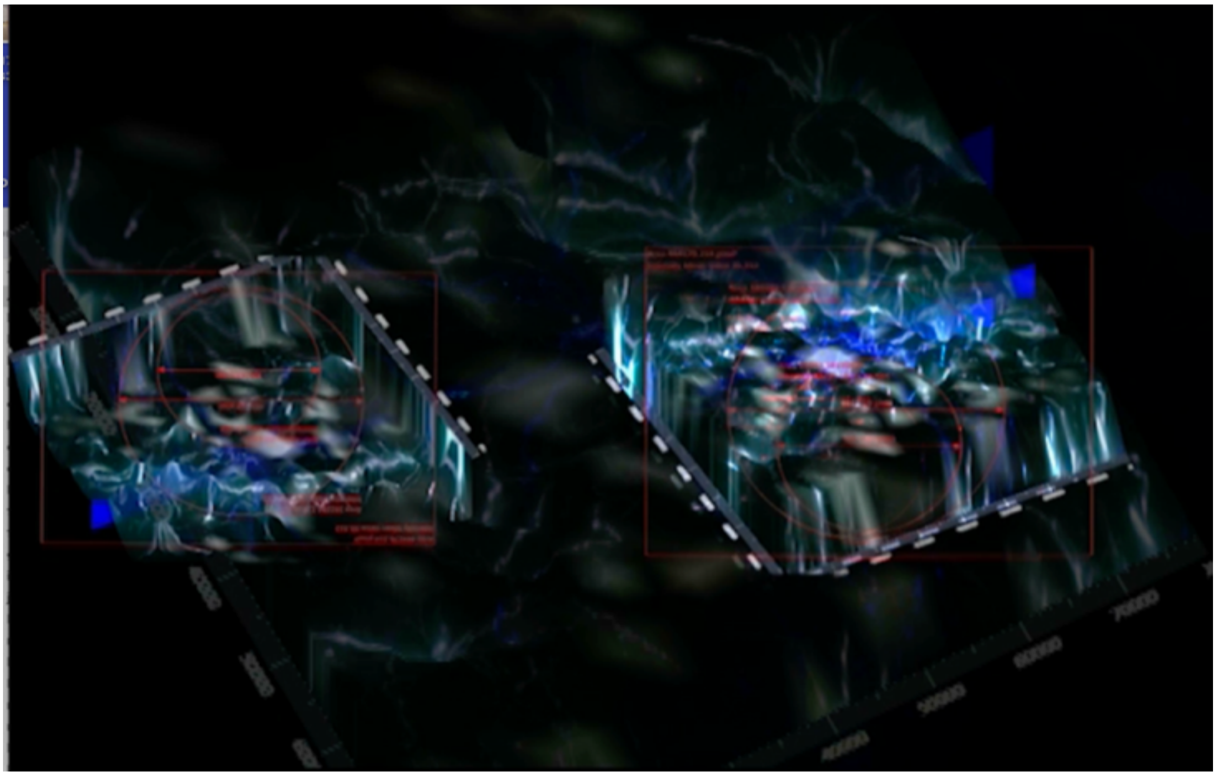
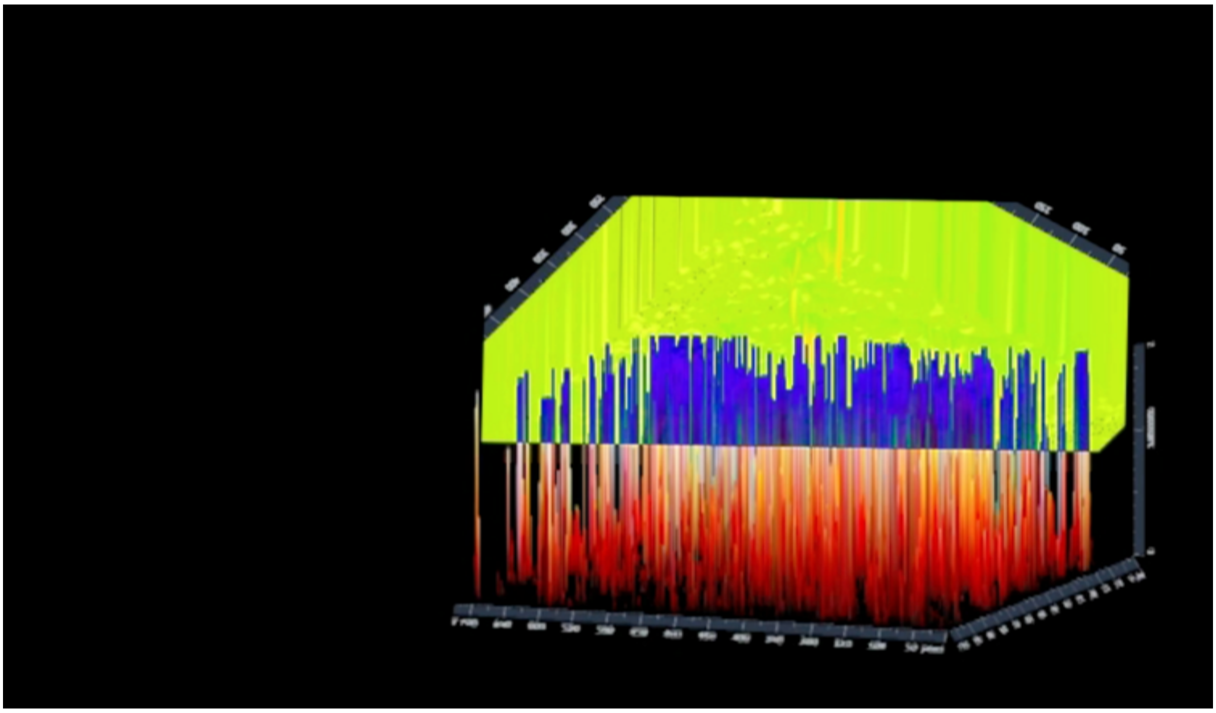


Figure 33. Berry-Frith, J. (2017) Heart Valve l.mov:2 seconds. © Jo Berry-Frith.







Figures 34–36. Berry-Frith, J. (2017) Screenshots from3dmap2frames_1final.mov. 00:03:54:16 seconds. © Jo Berry-Frith.

Figures 34–36 represent an amalgamation of software experiments in which data moves and rotates, with new data fading in and out, dynamically interjecting and fluctuating across the screen in a hypnotic rhythm. The work incorporates sequences of cellular activity, three-dimensional moving topologies and projections, enabling me to focus on the core qualities of the data and prioritise visual storytelling over technical complexity. By emphasising these elements, I crafted an abstract visual narrative that draws the viewer into the data, making complex scientific concepts more accessible and visually engaging. This approach not only highlights the inherent beauty of the data, but also demonstrates how art can bridge the gap between complex scientific ideas and audience understanding, by transforming the intangible into something more tangible and relatable. Through this method, I sought to evoke a deeper connection with the viewer, encouraging them to engage with scientific data as both a conceptual and aesthetic experience.

Developing this model enabled me to craft a dynamic visual narrative that underscored the fluidity of scientific data, transforming intricate cellular processes into engaging and immersive visual experiences. Longer versions of these experiments built on the initial concepts, allowing multiple datasets to interact, illuminate and spin in a continuous flow. This expansion resulted in a rich and complex assemblage of imagery, where data became more than just information – evolving into a visual language that deepened the viewer's engagement with both the scientific content and its artistic representation. By layering and intertwining these datasets, I was able to create a more multifaceted narrative, one that invited the audience to explore the data from multiple perspectives and appreciate the interplay between science, technology and art.

Findings from data montages and movies

Relating this stage of inquiry to Huizinga's (2016) focus on the play element in culture, the data montages and moving-image work significantly deepened my understanding of the value of low-tech digital craftsmanship. Both methods proved highly effective for visualising activities quickly and intuitively, allowing me to embrace a playful, experimental approach to creation. Through this process, I sharpened my critical thinking and creative skills, engaging with deconstruction and appropriation. My production techniques evolved as I experimented with the compositional frame and combined disparate data sets. This approach not only enhanced my ability to create more complex data montages and films, it also increased my understanding of how to transform data into a cohesive and compelling visual narrative, leading to work that was both conceptually rich and visually engaging.

In the next cycle, I tested how my drawings, data montages and moving-image work could contribute to pharmacology, advanced imaging and scientific representation, by exhibiting at scientific conferences. This exploration aimed to assess whether unconventional environments could foster cultural enlightenment and influence traditional scientific image practices. By doing so, I sought to advance both art and science, by enhancing their dialogue and communication. I hoped to challenge established norms and promote a more interdisciplinary exchange that bridged the gap between artistic expression and scientific inquiry.

Third cycle of art project one: Dissemination

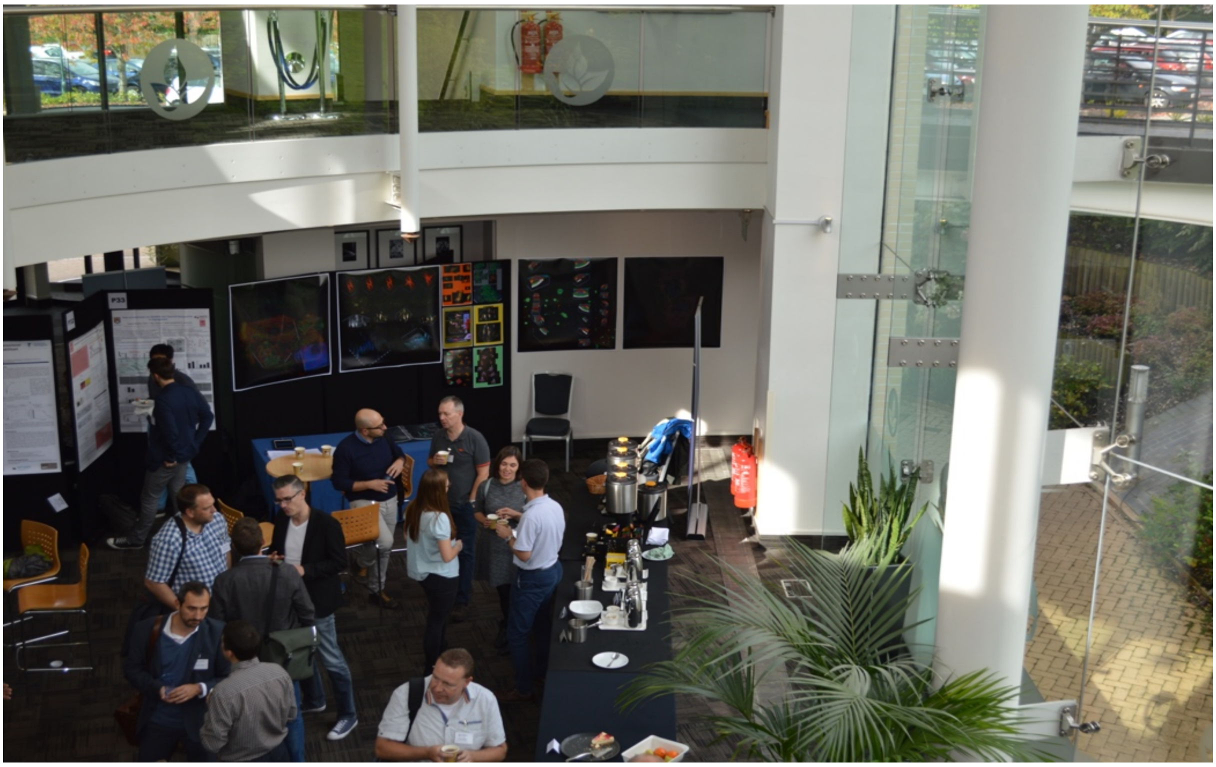


Figure 37. Berry-Frith, J. (2017) COMPARE Annual Research Symposium, 29th September 2017 East Midlands Conference Centre, Nottingham University. 14.8 x 10.5cm. © Jo Berry-Frith.

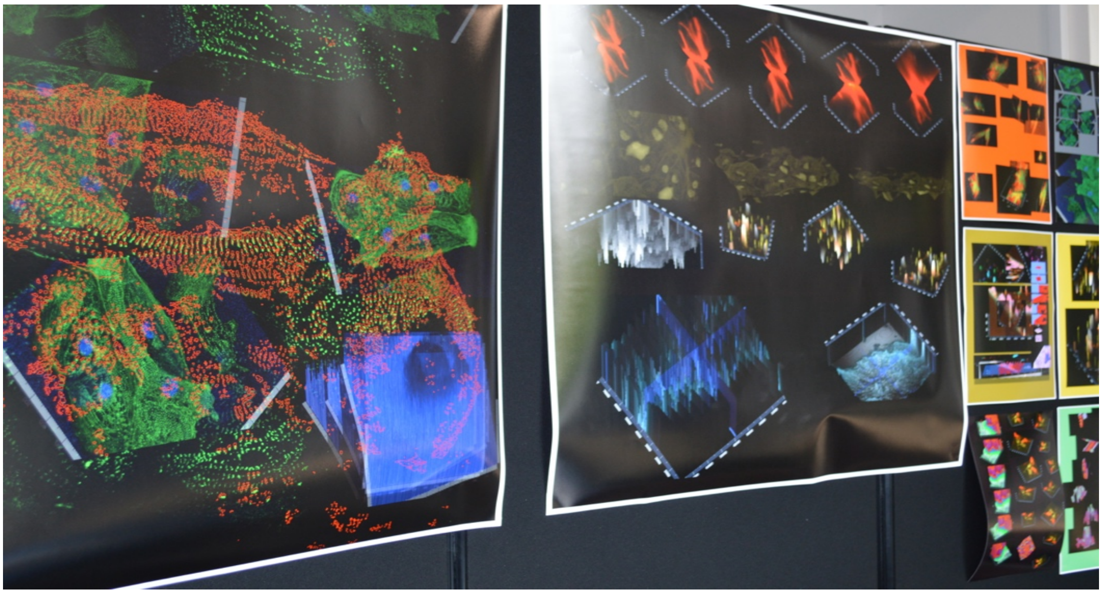


Figure 38. Berry-Frith, J. (2017) COMPARE Annual Research Symposium, 29th September 2017 East Midlands Conference Centre, Nottingham University. 14.8 x 10.5cm. © Jo Berry-Frith

The third cycle of art project one unfolded at the COMPARE 2017 Inaugural Annual Research Symposium (Figures 37–38) and the formal launch of COMPARE 2018 and ONCORONET Research Symposium at Nottingham University (Figures 39–40). At these events, I exhibited my artwork, gathered feedback through surveys, and presented my work to an audience of biomedical experts (including Nobel Prize winner Brian Kobilka, COMPARE Directors, the Royal Microscopy Society, and representatives from companies like GlaxoSmithKline and AstraZeneca). My image outcomes were showcased alongside 38 abstract poster presentations in 2017, and 19 in 2018, with a description and image featured in both conference brochures.

Pharmacology conference events have a distinct cultural aspect, functioning as social gatherings where scientists, including renowned experts and students, come together to exchange research and discuss their findings within their specific field. I attended these events conducting PAR, documenting activities through photography and written notes, and presenting my artwork to this audience. This experience allowed me to understand the framework of the scientific conference and compare its distinctive cultural elements with other distribution platforms, such as gallery exhibition venues. As a result, I gained valuable insights into how I could convey innovative concepts and present alternative interpretations of scientific visualisation through artistic practice.

However, I quickly realised that the "magic circle" (Huizinga, 2016: 20) of the scientific conference was not conducive to my role as an artist, as I was the only non-scientific researcher presenting at both events. This situation required me to set aside my artistic ego and accept the natural flow of the circumstances, embracing my function as an artist communicating research to scientists rather than competing with the established scientific norms.

Unlike exhibiting my artwork in a gallery setting, at both events I had little control over the format and placement of my work. The organisers provided unstable exhibition boards and tables to display large-scale digital prints, scrolls, A2 and A3 portfolios and questionnaires. There were no TV monitors to showcase films or PowerPoint presentations; instead, I relied on an iPad and laptop. I presented non-standard digital artistic representations that required the scientific audience to look beyond traditional academic outputs, which many found bewildering.

I took on a new role as a presenter and had to actively persuade scientists – who were often hesitant – to engage in conversation with me next to my artwork. This experience gave me insight into how scientists might approach and interact with unconventional images, helping me understand how to bridge the gap between art and science. At both events, the contrasting disciplinary methods of communication became starkly apparent. Our discipline-specific visual languages were displayed side by side, revealing that we engaged with images for entirely different purposes. The perceived division between art and science was clearly evident in the way scientists interacted with, and interpreted, my visuals.

Neither event went as planned; there was a lack of interaction and scientists looked tentatively at my work but generally ignored me. I noted attendees were shy and hesitant, preferring to talk with other scientists. I felt out of my depth, assuming they saw my practice as irrelevant. I questioned why I was displaying artwork in such an unforgiving environment, recognising my shyness as a limiting factor. My game plan faltered because I realised that I was showing poorly presented artwork to an unresponsive audience in two unsuitable locations that were not good for exhibitions. I established strong personal connections with only a handful of scientists, as networking was far from straightforward.

At points of awkwardness, I focused on my position as an artist–researcher, wondering what these scientists might think as I sought feedback. I requested support from my collaborators (Briddon, Self, Markus, Golding, Richardson and Kilpatrick) during both events. They offered numerous strategies, some of which I regarded as ineffective and childlike, such as placing sweets beside my artwork to encourage scientists to interact (but on reflection this might have been a good icebreaker). However, they did introduce me to more participants, and these facilitated scientists offering input directly and via surveys. Following Csikszentmihalyi's (2008) recommendation, I employed playfulness (adaptability, light-heartedness asking non-standard questions) to foster meaningful connections between individual scientists via conversational discourse as I stood next to my artwork and scientific posters. Being opportunistic, I was able to build rapport with particular scientists (such as newly appointed professors) and, through conversation, to find out their viewpoints on play, science, art and visualisation. After attending academic poster presentations and conference speeches, I discovered that the most efficient way to engage in conversation with individual scientists was by approaching them and discussing their research. I analysed my own position and behaviour as I built on positive feedback, such as my colleagues' delight in seeing their images used in creative ways. The apposite criticism from my peers and scientific audiences led me to think more about my work and position, enhancing my perspective and strategies for presenting my artwork at other scientific conferences.

Thinking of enticement and sweets, I recalled Bourriaud's (2002: 38–39) account of American visual artist Felix Gonzalez Torres' (1957–1996) installation *Stacks of Sweets*, shown at *This is the show and the show is many things*, (1996) an exhibition about "process, collaboration, chance encounter, and whimsy" (Bart De Baere, Pierre Giquel, and Dirk Pültau, 1996). Visitors were allowed to take items from the piece (a sweet, a piece of paper), but if they did, the work vanished. His work therefore appealed to the visitor's sense of responsibility. According to Bourriaud (2002), this show was a unique example of intelligent and risky experimentation that pushes the boundaries of how a viewer (and artists themselves) might engage inside an exhibition space. Both scientific conferences presented an example of how an artist may actively engage within a scientific conference environment and use it as a testing ground to break down barriers and promote cooperation.

I made some significant adjustments to my strategy as a result of trying to blend in while feeling out of place. For example, I changed my production and presenting techniques in 2018 to foster better communication with the scientific community. One such adjustment was the addition of large-scale scrolls. Unlike a traditional poster, the scroll format encouraged scientists to interact physically with images (see Figure 39).

Engaging in dialogue and performing the dual role of presenter and artist was instrumental in breaking down barriers between artist and scientist. By observing scientists' interactions and listening closely to the questions they posed, I was able to adapt my responses and communicate more effectively. Presenting my findings with greater self-assurance, I grounded my explanations in primary research, which enhanced my credibility and confidence. This approach allowed me to engage more meaningfully with the scientific audience, clarifying how my artistic practice intersected with and contributed to their field. Through this process, I became more able to bridge the gap between artistic expression and scientific inquiry, encouraging a more productive dialogue between the two disciplines.

Experiential knowledge gained from both individual and group critique established meaningful connections with my audience, shaping the future direction of my work. The feedback I received not only enhanced my understanding of how to communicate my ideas more effectively, but also sparked a desire to take greater agency at future events. I recognised the value of deeper engagement with diverse audiences and the importance of expanding my exhibition opportunities. This insight motivated me to seek out more platforms where I could engage with wider perspectives, ultimately enriching both the artistic and scientific dimensions of my practice.

Figure 39. Berry-Frith, J. (2018) presented portable artwork at the COMPARE Annual Research Symposium, including pieces sized 200 x 100 cm and 100 x 100 cm. A large-scale table-top scroll portfolio, measuring 300 x 41.8 cm and 156 x 41.8 cm, was also added. © Jo Berry-Frith.

The sample of questionnaire responses and face-to-face interactions shed light on important issues: to test groundbreaking technology; to observe complex phenomena and interactions that are invisible to the naked eye, and to demonstrate a link between scientific data and aesthetics. Introducing “play” as a concept fuelled discussion and debate. All respondents concurred that scientists should abandon silo mentalities and embrace innovative ideas regardless of their origin. They cited artistic interpretation as equal to scientific reality and appreciated art’s skill at challenging stereotypical views. This was important because it showed how art and science can connect.

Both events offered networking opportunities with scientists at various stages of their career and with international contacts, some from other scientific disciplines. At both events, the Faculty and COMPARE acknowledged the value of an artist exhibiting alternative forms of representation. It served as a direct method for scientists to re-evaluate and reconsider their representation techniques. Observing scientists’ different opinions as they compared their visual expertise to mine taught me a great deal about my expertise as an image-maker and how I might communicate practice outcomes more effectively, while working as an artist–researcher.

I concluded that creative intervention could demonstrate to scientists that their data could be represented in multiple ways, offering insights and illuminating the intrinsic qualities of their image data through art. My analysis as an outsider at these conferences fostered cross-disciplinary communication and reflective evaluation. It enhanced my ability to promote my research to a broader scientific audience, even though the experience did not fully meet my initial expectations.

Importantly, my collaborators were thrilled to see their data interpreted in new ways, sparking fresh dialogues around scientific representation and the value of artists within labs. Both I and the scientists benefited from direct discussions regarding academic displays and presentations, which helped clarify certain pharmacological research issues (fluorescence, optical tricks, pictorial harmony). The scientific audience engaged with and appreciated alternative representations of their data, leading to a deeper understanding of my research. Although the events did not fully align with my initial goals, my presence as a prominent and unconventional participant helped break down barriers between art and science.

Both events underscored the differences between art and science exhibitions, as well as the assumptions of scientific audiences and conference organisers. I needed to adjust my expectations and refine my communication strategies to ensure the most effective engagement with these new contexts.

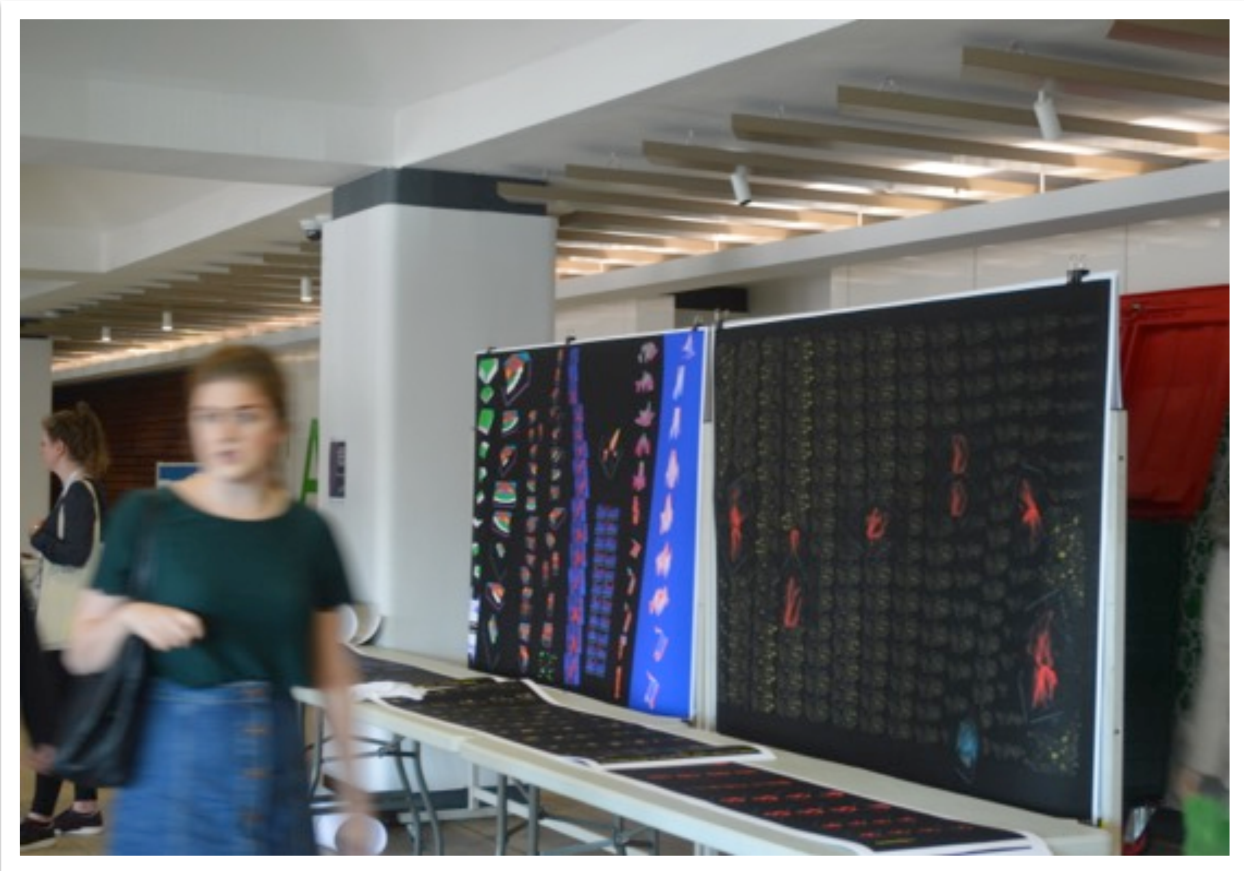


Figure 40. Berry-Frith, J. (2018) University of Nottingham COMPARE Launch, Team Science and ONCORNET Research Symposium and Compare Research Conference, 18th April 2018, Queen's Medical School. 14.8 x 10.5 cm. © Jo Berry-Frith.

Findings from dissemination

I showcased the integration of creative activity within scientific research conferences, though not in the most satisfactory manner. Both instances underscored the complexities of conducting doctoral research and facilitated cross-cultural discussions through face-to-face interactions. These experiences highlighted the value of presenting artistic interpretations within scientific contexts, while also revealing the challenges of navigating such spaces. The strengths – such as networking opportunities and the comparative assessment of my work – were evident, but the weaknesses – such as the timidity of the audience and the less-than-ideal exhibition spaces – were equally apparent. Although these events were imperfect, they played a crucial role in my development as an artist–researcher within the scientific community, offering valuable insights that facilitated critical reflection and informed the direction of my future practice.

In retrospect, I could have taken more initiative and been more imaginative when exhibiting my practice-based research. As Arnold (2018) suggests, artists should bring showmanship and spectacle into their exhibitions, a principle I failed to embrace. I regret allowing myself to become preoccupied with the expectations of conference organisers, collaborators and attendees, rather than focusing on presenting my work more expressively and audaciously. That said, the work itself was an honest reflection of my interpretation of scientific data. Ultimately, I concluded that I needed a more conducive environment to present my artwork, though I now recognise that this was an unrealistic expectation, not part of the original research intent.

My focus on how play could contribute to cultural enlightenment as an outsider and non-specialist exhibitor directly improved my collaboration and communication skills. I adapted to each situation, steadily building knowledge around cross-disciplinary innovation. The challenges I encountered prompted introspection and growth (Groth et al., 2020), enabling me to refine my approach. By learning from these experiences, I constructed more realistic practice scenarios for future events, thereby enhancing my professional research and dissemination skills. This process shaped the adjustments I made in exhibiting and presenting research at subsequent events and scientific conferences, where I generated increased interest and significantly expanded the impact of my work, as discussed in Chapter Five.

The fourth cycle of practice: Reflection

As discussed in Chapter One, in 2018 I conducted semi-structured interviews with three Art–Science cultural producers and brokers: Arnold, Glaser and Stanbury. Their comments emphasised the significance of contemporary art–science collaborative practice. According to Glaser, when considering interdisciplinarity, the disciplines are the initial and key components of a narrative. It is difficult to be knowledgeable about interdisciplinarity unless you have definitive opinions regarding the disciplines. Arnold was interested in artists creating opportunities to investigate several aspects of science, stating it was important to transmit subjective and objective knowledge simultaneously. Stanbury believed that artists who devote time and delve deeply into the understanding of various perspectives on health, medicine and science can have a positive impact on science and society. In effect, artists can become a bridge between the lab or research landscape and the public, or those who are directly affected by the research, such as people who have had an acute lived experience of poor health.

In my reflective cycle, I considered their viewpoints against the backdrop of cycles one, two and three. They highlighted the value of a less empirical approach to scientific culture, and I recognised that this supported my hypotheses that using play to understand the relationship between art and science can create innovation. It became clear to me that they all emphasised the significance of working with artists and incorporating art as an engaging component of biomedical related topics. Each explained that artists have a significant creative purpose, because art can highlight the human element of health and medicine. Each saw art as a powerful, yet sophisticated means of fostering cross-cultural communication, capable of subverting outdated models and reinventing classifications by, for example, rethinking roles and expectations. In line with my experiences through the cycles of practice, their insights illuminated the innovative role of art as a medium capable of combining aesthetics and social activity (Bourriaud, 2002: 95). They were aware that the disintegration of disciplinary boundaries necessitates structural, cultural and financial investment. Their viewpoints justified my position as an artist–researcher learning about scientific experimental terminology, methodologies and visualisation systems, and creating a framework others can follow.

The reflexive part of my framework further guided my research, confirming that my four-stage integrated model (the four cycles of practice) informed how art practice can be meaningfully embedded within this scientific context through the lens of play (see Figure 9 and 10).

I realised that adopting a PAR approach, when working with scientists, allowed me to function as a conduit between disciplines, developing relationships with individuals and small groups that revealed the human aspect of scientific practice. I found that redirecting scientists to voice personal, rather than empirical views about their role as biomedical scientists, helped me understand how scientists work, think and approach problems. Training in empirical techniques and scientific technologies expanded my technical skillset and offered access to novel datasets. Importantly, using *play* as a methodological tool enabled me to disrupt disciplinary boundaries and traditional roles, allowing for more creative experimentation. This play-based approach cultivated collaborative opportunities with scientists across imaging labs and highlighted how interdisciplinary exchange fosters fresh insights. It shifted perspectives, contributing new knowledge in both pharmacology and cell signalling, and expanded my identity as an image-maker operating within a cross-cultural framework of scientific and artistic communication.

In the **second cycle**, I recognised that *solo play* within both scientific computer lab and art studio, was just as important as collaborative play. Embracing what Bourriaud (2002: 96) describes as "the art of forming, inventing, and fabricating" visual concepts, I prioritised the process over final results. In the scientific computer lab, I re-mastered and reprocessed raw data, building a large digital archive. In the studio, I experimented with three production techniques: re-mapping pixel granularity through digital drawing, reconstructing data via montage, and creating multi-layered moving images from merged datasets. These methods allowed me to explore the interconnectedness of complex data systems through both human and technological mediation (Verbeek, 2011). I appreciated how drawing became a vital analytical and imaginative tool, enabling me to navigate the interface between data, technology and creativity. By focusing on surface-based analysis and the pixel as a unit of meaning, I revealed new awareness of cell structure and molecular interaction that extended beyond scientific visualisation. This challenged the principle of 'mechanical objectivity' (Daston and Galison, 2015) and led to a hybrid practice, where art offered an interpretive lens for understanding biomedical complexity.

In the **third cycle**, my artwork became a dynamic agent within scientific conversations. I saw how this created a shift. Exhibiting at the COMPARE Conferences at the University of Nottingham in 2017 and 2018, I introduced art-practice research to scientific audiences, offering alternative perspectives on advanced imaging. This dissemination extended beyond the gallery space and engaged directly with the scientific community, creating space for dialogue and critical reflection. Feedback from scientists (face to face and via questionnaires) indicated that the artworks encouraged them to reassess how and what their data represented. Reflecting on these exchanges highlighted the inherent divide between artistic and scientific ways of seeing, yet also revealed how visualisation methods could be enhanced through interdisciplinary collaboration. For example, Kilpatrick remarked that things changed following my research, noting, "It has also reminded many of us within the research group of the creativity inherent in scientific research (the need for 'blue-sky' thinking), which is often underappreciated in general".

Significantly, when asked about the impact of the work and whether she would now consider employing artists in the lab, she said, “I think your work brilliantly demonstrates the different ways science can be communicated and how it can capture the interest of both other scientists and the general public. It also shows that science doesn’t have to be explicitly ‘functional’ in the traditional sense to have social value. For these reasons, I would absolutely be interested in employing an artist if I were running a research institute” (see Appendix Five).

Through these events, I contributed to changing perceptions around the role of art in science, positioning it not merely as illustrative but as generative and dialogic.

It became apparent through **cycle four**, that I had achieved a conceptual breakthrough. I came to understand the tension between empirical rationality and artistic interpretation from a new vantage point. I developed a framework that recognised a shared yearning between scientists and artists to collaborate, acknowledging that it was acceptable if artist and scientist did not always aim for the same conclusions. This framework highlighted a genuine desire from both disciplines to bridge the divide by working together productively, synthesising our practices. As I extended my understanding of play as a methodological and theoretical concept (Winnicott, 2005), I came to see it as a critical driver behind both scientific inquiry and artistic exploration. My full engagement within this cultural landscape generated novel perspectives on medicine, health and the communication of science.

I realised that grasping the nuances of imaging and microscopy required more time and further knowledge, which led me to appreciate the performative and experimental qualities already embedded in scientific culture within the “magic circle” of the lab (Huizinga, 2016: 20). This inspired ideas for future work, including inviting scientists into my studio for collaborative, playful experimentation, although my immediate focus remained on refining my art practice and extending collaboration with other core imaging laboratories (as described next in Chapter Four).

Art Project One's significance

Art Project One was an in-depth collaboration with scientists at COMPARE. This research aimed to understand cellular responses to drugs and hormones related to cancer, cardiovascular health and hunger. I brought a heightened sensitivity and a performative approach (role-play and role-swapping) to this collaboration, educating 17 scientists on effectively communicating their methods and findings to a non-specialist. In doing so, I observed their tendency to remain constrained by rigid empirical frameworks, which often limited their ability to explore beyond the confines of precision-driven data.

To address this, I introduced creative disruptions to CM, LM and SRM processes. These interventions demonstrated how experimental and individualistic aesthetic imaging approaches could extend their conventional methods, producing unconventional outcomes that revealed new layers of meaning. This knowledge emerged uniquely through my interventions, which challenged traditional lab routines and protocols. By breaking free from established practices, I encouraged these scientists to explore alternative modes of visualisation, blending analytical rigour with creative exploration.

The primary significance of this approach lay in fostering a paradigm shift. Scientists began to recognise the value of expanding their visualisation methods beyond precision and prescribed data representation. My creative disruptions uncovered visual phenomena and patterns that would have remained unnoticed within conventional imaging workflows. This cross-disciplinary exchange enriched both scientific and artistic practices, transforming complex data into more engaging and accessible forms. Ultimately, this collaboration demonstrated that embracing unconventional imaging techniques could lead to breakthroughs in both the interpretation and presentation of data, deepening understanding in ways that transcended disciplinary boundaries.

Through my collaboration with scientists like Markus, I discovered that my interventions encouraged a change. Scientists stepped beyond standard procedural constraints, created customised experiments that led to novel ways of visualising and interpreting cellular structures that were typically confined to empirical frameworks. As a direct outcome of our interactions, Markus adapted his approach to speculative testing of cell signalling protocols. To enhance my understanding of SRM, he visualised individual blinking molecules by quantifying light intensities at each pixel point, adjusting photon intensities to make these intricate processes more accessible. This technique allowed me to observe subtle molecular behaviours and grasp the complex principles of SRM.

The pixel quantification technique, supported by mathematical coding, became a cornerstone of my practice. It enabled me to explore new themes and techniques for visualising scientific phenomena, enriching my artistic methods with scientific precision. Markus, in turn, benefitted from stepping away from prescribed research objectives, exploring imaging techniques with greater freedom. My presence encouraged him to integrate creative and aesthetic considerations into his scientific activities, fostering a unique and personalised scientific sensibility. Our non-empirical SRM experiments revealed unexpected outcomes, leading Markus to appreciate the beauty and wonder inherent in his findings. This collaboration emphasised what can arise from interdisciplinary knowledge-sharing; for example, Markus educated me in SRM and CM protocols, revealing how he approached problems. He conveyed concepts that transcended theoretical conventions so that the blending of artistic and scientific methodologies could lead to breakthroughs that neither field could achieve independently.

By building trust and initiating open discussions about personal and institutional perspectives. I encouraged Markus to share candid thoughts about the human aspects of scientific research. This enabled him to communicate his work in ways that extended beyond the constraints of scientific research and the pressure to publish results. As his exploratory approach extended, he informed my own, inspiring me to integrate scientific rigour into my artistic practice. Concepts such as the quantification of light intensities, pixelation, mathematical coding, fluorescence and the systematic recording of evidence shaped my methods, linking artistic creativity with his scientific discipline.

This exchange demonstrated how interdisciplinary collaboration fosters innovation, pushing the boundaries of both fields. My play-based interventions catalysed creative exploration in science, highlighting the transformative potential of the “magic circle” (Huizinga, 2016: 20) within the lab. By not following traditional scientific methods, we revealed learning opportunities, illustrating the profound value of integrating diverse perspectives to generate richer insights.

The scientific computer lab, once a site of strictly technical analysis, became a vital space for experimental data processing. I prioritised a less rule-based approach to experimentation, embracing software testing as a form of creative play, iterating and reprocessing datasets in spontaneous and incremental ways to extend data processing methods. The flexibility of approach proved crucial to my practice and extended my creative outputs.

This approach was unfamiliar to my collaborators, who typically relied on fixed protocols and conservative outputs. Critically, they had not systematically tested the limits of their graphical software tools. Through using diverse combinations of software tools, I revealed new possibilities in data representation that reflected the material modifications observed during imaging procedures. This process ultimately reframed our interdisciplinary understanding, underscoring new possibilities for integrating artistic and scientific methodologies and revealing the untapped potential of software as both a creative and analytical tool. Notably, this shift altered my perspective on what a finished artwork could be; it could be conceived as raw data or as data reworked through playful engagement with software. These results underscored how data could be understood as a form of creative material, not just evidence.

Through my presence, my scientific collaborators adopted artistic methods to visualise image data, demonstrating the transformative impact of integrating artistic approaches into scientific workflows. Former COMPARE Director Stephen Hill acknowledged this impact, affirming the value of artistic contributions in prompting public inquiry and supporting the lab's outreach, stating "Our job is not only to do clever science but also to communicate with the public on what we do and why we do it. Your input has provided an artist's perspective on the imaging work we do, and your displays prompt the public to ask what they are showing and what is the science behind it. Which has to be a good place to be". Hill further emphasised the value of my contribution, affirming, "Yes, we would have artists in the lab again – no question" (see Appendix Five). Our collaboration underscored the profound potential of blending art with science to foster innovation, to enhance public engagement and reshape traditional research practices.

My long-term collaborator, Self, reflected on the impact of my work, stating,

> *My time in the lab was valuable in that it opened up new ways of thinking for myself and the SLIM team to think more creatively (within the bounds of scientific process). Your work has led to promoting our images not just as purely scientific but also as works of art in themselves. We now run annual SLIM art image competitions for the user base of the facility (over 300). We also apply the artistic methodology and approach to our outreach*

activities at under-represented schools and through the national technicians' networks. (see Appendix Five)

This serves as a powerful example of how I constructively challenged conventional scientific imaging practices, fostering meaningful advancements in both art and science. By extending traditional drawing and image-making methodologies through embracing scientific techniques, I demonstrated the transformative potential of blending artistic exploration with scientific inquiry to uncover new insights, extend boundaries and bring lasting benefits to the department.

My digital drawing practice, particularly during cycle two, illuminated how artistic methods could extract nuanced meaning from scientific data. These drawings became both analytical and imaginative tools, exploring pixel granularity to visualise cellular structures captured beyond visible perception. Drawing served as a distinctive form of mimicry – a process that illuminated the intricate interplay between industriousness and play. It was simultaneously analytical, yet it afforded me the freedom to be imaginative. It allowed for an interpretation of a scientifically fabricated reality of cardiomyocyte images and molecular interactions of impervious structures, dynamic shapes and unpredictable interactions. Creative breakthroughs – ones likely to have been overlooked through a more controlled, mechanically objective method of visualising data – came to light through developing an idiosyncratic surface-based analysis of data, captured beyond visible perception and rendered as a computer graphic. It led to a method of visualising cellular structures that transcended the limitations of a purely scientific lens. It revealed the impervious structure, dynamic shape, size, depth and intensity of cells, representing their complexity in ways that traditional scientific methods often overlook. These works underscored the potential for drawing to challenge and enrich scientific representation. Drawing revealed key attributes of authorship, universality, economy of means and expressive intensity. This approach disrupted the conventional boundaries between the technical and the creative, offering a space where structured scientific inquiry could coexist with the fluidity of artistic expression.

Applying Gadamer's (1998) notion of the artwork as *gebilde* – a self-contained creation – I embraced experimentation through low-tech craftsmanship, repurposing scientific data into data-montages and soundless experimental films. These served as vehicles for achieving a state of creative 'playfulness' in the reconstruction of cellular activity. Employing cinematic qualities, they effectively structured time and linked data through compositional structuring, computational colour, juxtaposition and layering of datasets to create a dynamic body of work that expanded the spectrum of experimental production methods and art practice outcomes. Consequently, this illuminated other ways to convey complex biological phenomena, by blending the analytical with the creative, highlighting the visual potential of pharmacological data.

As the only non-scientific researcher in cycle three, I exhibited my art-practice research at the Centre of Membrane Proteins and Receptors (COMPARE) Conferences at Nottingham University in 2017 and 2018. This contribution to pharmacology and advanced imaging dissemination expanded scientists' perceptions of how and what scientific data can represent. My work showed the inherent differences in how artists and scientists engage with imagery. This prompted both my collaborators and the scientific audience to reconsider their findings, encouraging a more interdisciplinary approach to scientific inquiry and fostering reflection on the potential of visualisation methods.

At the COMPARE Conferences at Nottingham University in 2017 and 2018, my role as an exhibitor facilitated cross-disciplinary exchange, enabling me to draw critical insights into the contrasts and overlaps between artistic and scientific views on imaging and aesthetics. Feedback from scientific collaborators and audiences confirmed that art could provoke meaningful dialogue, encouraging scientists to consider new visual approaches. This fostered broader engagement and a deeper understanding of cell signalling image data. Dissemination demonstrated how art can enrich the interpretation of complex data and bridge the gap between disciplines.

By the end of this first project, Tim Self introduced me to his colleague Dr Alex Ball who worked at the Science Infrastructure Platforms Imaging and Analysis Centre (IAC) at the Natural History Museum (NHM), London who was a specialist in EM. This led to art project two.

Chapter Four: Art project two

The first cycle of art practice: At the Science Infrastructure Platforms Imaging and Analysis Centre at the Natural History Museum (NHM), London.

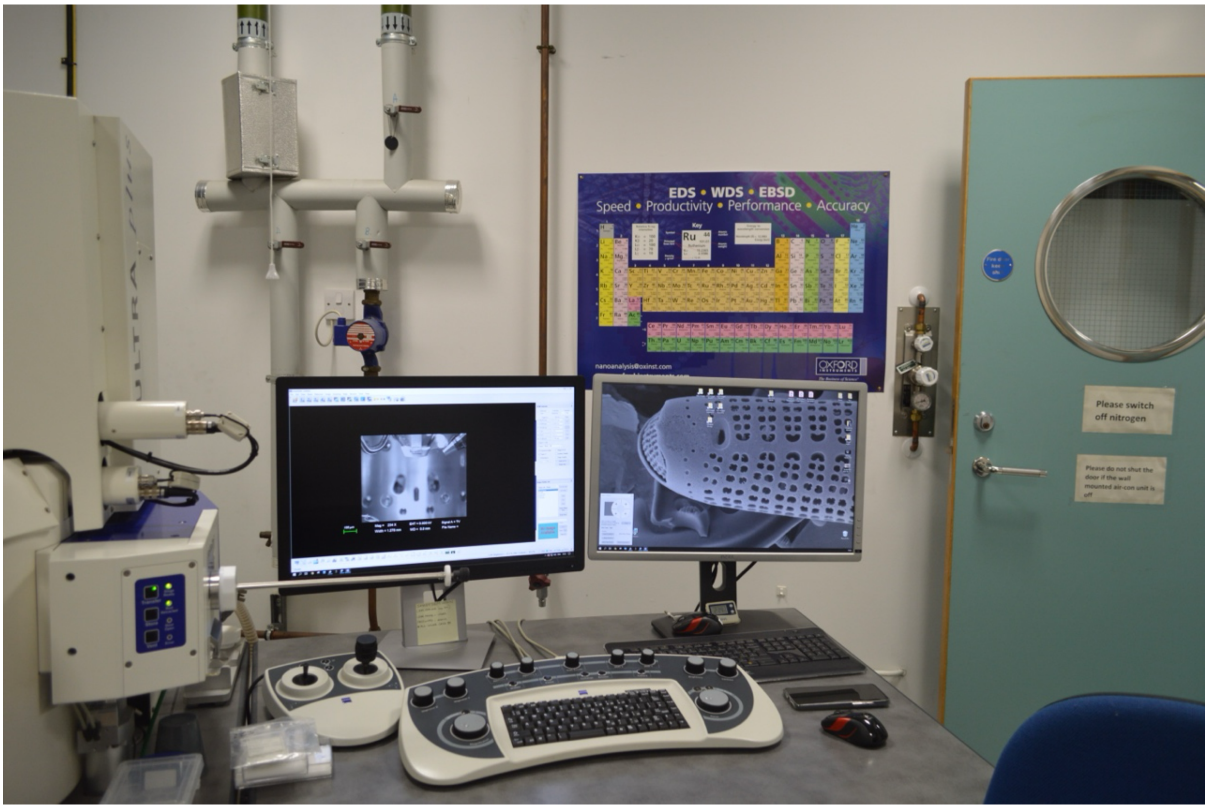


Figure 41. Berry-Frith, J. (2024) Zeiss Gemini SEM set up with computer monitors and keyboards. © Jo Berry-Frith.

Building on insights from earlier collaborations, this chapter charts the next stage of my engagement with scientific imaging, moving from initial exposure of transmission electron microscopy (TEM) to deeper, practice-based collaborations within a new laboratory setting. Following a referral from Self (a long-term collaborator), I initiated a partnership with Dr. Alex Ball, Head of Division at the Imaging and Analysis Centre (IAC) at the Natural History Museum, London. This chapter examines how my creative interventions – rooted in artistic inquiry – challenged conventional lab protocols, expanded aesthetic possibilities and tested the boundaries of visualising scientific data. One key objective was to draw critical insights into the contrasts and overlaps between artistic and scientific approaches to imaging and aesthetics, using new imaging technologies to build on the significant shift identified in Chapter Three.

In 2015, I spent several days working at NHM's IAC, a world-renowned museum and multidisciplinary research facility. Here, expert team members produce, evaluate and examine biological, geological and synthetic materials, and assist scientific visitors and consultants. Yet activity between artist and scientist is limited; for example, when I returned to conduct further research in 2024, only five artists (including myself) were conducting research in this lab.

I embedded myself in this modest, functional laboratory setting, located in the museum's basement, concealed from public sight. It was a stark contrast to the opulent exhibition halls above. I was delighted to discover a 3D visualisation laboratory, as well as light microscopy (LM), confocal microscopes (CM) and electron microscopes (EM). Understanding technological visualisation was the source of our mutual curiosity.

My goal in 2015 was to learn how and why scientists utilise EM to generate visual data at 100,000x magnification. Figure 41 demonstrates the Zeiss Ultra Plus Scanning Electron Microscopy (SEM) and the space-age machinery used to view specimens, housed in an imaging room (1. Zeiss Gemini electron optical column, 2. specimen chamber, 3. semi-automatic load lock, 4. dual joystick, 5. control monitor, 6. control panel keyboard, 7. mouse). In 2015 and 2024, I saw SEM technology and tools as an opportunity to test visualisation parameter setting.

In 2015, I toured the NHM's lab and exhibition displays, exploring potential exhibition opportunities that inspired me to think about how I could incorporate my study to complement their collections. While there wasn't an opportunity to display practice outcomes at the NHM during the initial phase, I considered how to present my findings in line with the NHM's display policy. Returning in 2024, I had productive discussions about developing a project focused on investigating the preservation of carbon on the ocean bottom and I intend to collaborate in the future with Ball (Head of Division, IAC), Isabel Davies (Research Leader in Collections and Culture), and micropalaeontology curator Dr. Giles Miller. I envision integrating artistic and scientific materials to enhance comparative analysis in public displays, building on the research undertaken in 2015 and 2024.

Drawing on Bourriaud's (Ross, 2006: 167–181) concept of relational aesthetics and referencing the work of Mark Dion, I wanted to explore how institutions shape our understanding of knowledge and the natural world. My long-term goal was to collaborate with scientific specialists to exhibit my findings alongside NHM collections. These were related to the samples I studied, to uncover unexpected connections between complex natural systems, technology and science, while highlighting the imaginative aspects of scientific inquiry. My objective in this art project was to communicate effectively these outcomes and engage audiences in exploring science through an artistic lens.

Drawing and its link to technological innovation

Conversations with Ball (2015) were enhanced by our shared passion for drawing. His capacity to contribute to this PhD was assisted by his long-term co-operation with artist Johanna Love (2024). Love's research at IAC also involves working with SEM (she examines samples of dust collected from her family's home in the centre of Hamburg, Germany). On my return (2024), long-term co-operation seemed more prescient, as I had already completed a number of drawings based on NHM collections. I was interested in expanding my practice outcomes through conducting a more focused approach, by gaining more data that captured structural complexity. In 2024, Miller prepared samples and identified several marine plankton species for me to investigate.

I was interested in the fact that Ball – and scientists such as Self – have witnessed a rapid transformation in bioimaging. Yet, as older scientists, they had been taught to draw and use traditional photography techniques. Ball regarded drawing as an important analytical tool for observing, mapping and communicating essential information for artist and scientist. Ball and I discussed the fact that scientists today rarely make observational drawings, relying instead on imaging technology and analytical graphs. Yet we both recognised the attributes of drawing, which are linked to eye, hand and brain coordination. I reflected on Ball's PhD drawings depicting the ontogeny of the foregut of Neo-gastropod molluscs (Ball, et. al., 1997). These pen and pencil on paper drawings were made before advanced imaging was available (see Figure 42). Ball mapped information using a pointillist approach, similar to the pixelated grid of a computer screen when viewed through a stereoscopic microscope, as seen in art project one (see Glossary). Both Ball and I saw drawing as a mechanism. While Ball used it to map information, I used it to re-map complex data and experiment, as discussed later.

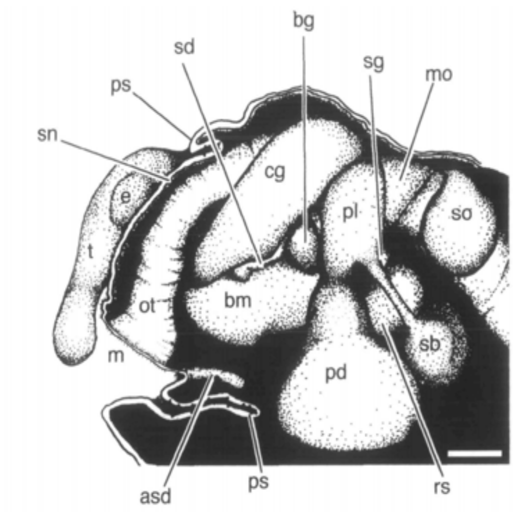


Figure 42. Ball, A. (1997) Reconstruction of the foregut of a contracted stage 7 embryo, viewed from the left of proboscis development in nucelli. Scale bar-25um. 21 x 29.7 cm. © Alex Ball.

I witnessed a shift in generational attitudes around drawing while working with scientists in this lab. Like me, Ball perceived that drawing necessitated slowing down to examine scientific material visually. I encountered diverse traditions between scientists regarding drawing, which depended on how they were educated and trained. For instance, in 2015, I met Dr. Dimitrios Panagiotopoulos during a Medical Dissection Class in Nottingham, where he was researching the lack of systematic use of drawing in anatomy education and the limited study of its assessment potential in UK medical schools. His PhD thesis, *Drawing in Anatomy Education: Exploring Its Roles in Teaching and Assessment* (Panagiotopoulos, 2018), examined the use of visual representations, particularly drawing, in anatomy teaching and assessment. His work provided valuable insights into how scientific educators utilise drawing, illuminating their perspectives on its educational role, contributing to current analysis methods in the field. I recalled talks I had with other scientists, such as Self, Associate Professor Sally Wheatley and Associate Professor Peter Wigmore, during art project one. We discussed the changing function of drawing and the growth of technology. All underlined the decline of drawing as a critical disciplinary tool for understanding in their scientific domains. Ball noted the lack of observational drawing at IAC, which led me to invest in drawing as a way to highlight the artist's agency in extending scientific visualisation processes. This approach allowed me to analyse science through an artistic lens, broadening my digital drawing explorations, by incorporating SEM technology and studying monochromatic, highly detailed data.

The findings published by the Biotechnology and Biological Sciences Research Council (BBSRC) (2019; Errington, 2022) suggested that traditional visualisation techniques (such as traditional drawing) have been fully superseded by digital technology in the realm of advanced imaging and microscopy. This indicated that we had reached a tipping point. The conversations that I had with Panagiotopoulos, Self, Wheatley and Wigmore, together with the evidence collected in Chapter One regarding artists who draw in labs (Anderson-Tempini, 2017; Casey and Davies, 2020; Lyons, 2009), supported the idea that this change is the outcome of shifting observational practices among scientists. I concluded that drawing may serve as a counterpoint to a solely computational visual examination of events.

Studying the work of artists like Lucy Lyons (2009) was instrumental, as her PhD research revealed that students studying histology were still required to draw. Lyons argued that sketching tissue through a microscope demanded more intensive examination than simply observing photomicrographs, offering a deeper engagement with the specimen. She described the process of drawing histology samples using a camera lucida as challenging and time-consuming, but also enlightening, providing insights into the specimen's structure, despite the co-ordination difficulties between the microscope and drawing tool. For Lyons (2009), this process extended her drawing practice, enabling continuous visual contact with the specimen, much like Anderson-Tempini's approach to museum collections at NHM. Anderson-Tempini's work relied on tacit knowledge – touch, texture, form and colour (Anderson, 2017: 21) – and, through collaboration with four zoologists, she adopted a flexible, dependable and test-based approach to knowledge, rather than seeking certainty (Anderson, 2017: 46, 32). Anderson-Tempini also noted that clinicians found drawing with microscopes taxing yet rewarding, requiring practice, co-ordination, analysis and improvisation.

Anderson-Tempini (2017) observed that scientists are increasingly relying on taxonomic representations created using photo-editing software and other time-saving technology, rather than visual observation. However, she also acknowledged that there is still a tradition of classification based on visual observation (Anderson, 2017: 32). According to Professor Emeritus Howard Riley, and Head of Knowledge Transfer at Cambridge Centre for Social Innovation, Michelle Louise Fava Darlington (Riley and Darlington, 2022), drawing has been shown to improve learning in subjects other than the arts (Winner and Hetland 2000; Winner et al. [2006], 2020; Simmons 2021). Their emphasis on "visualcy", an earlier and more graphic mode of communication that prioritises simplicity, is similar to Ball's graphical sketching technique and how I sketched information in my lab notebook. Both Ball and I enhanced our learning through drawing, a process I explore in cycle two.

Initially, Ball suggested that I explore three-dimensional visualisation techniques such as photogrammetry, which creates 360-degree photographs of a specimen – a system of visualisation with which I was unfamiliar. A student volunteer demonstrated how the system worked and how to print 3D images. Ball provided me with photogrammetry datasets of a daphnia eye (617 still images) and butterfly head (108 still images) to use as I saw fit. I studied 360-degree views of organic samples. However, these big datasets were daunting, due to their sheer volume and complexity, making it challenging to identify meaningful patterns. This overwhelming information created uncertainty and hindered my engagement with the data, inspiring me to focus on capturing my own, more manageable data.

Training to operate SEM

In this cycle of practice, Ball taught me how to use the Zeiss Ultra Plus and the LEO 1455VP SEM, as it provided detailed information about the surface of the material (Lyman, 2019). In 2024, I re-trained on the Zeiss Ultra Plus, which equipped me with practical skills and a better understanding of this imaging process.

Ball's scientific method of visualising data relied on systematic observation, experimentation and evidence-based reasoning. As a result, I was able to abide by the protocol of the lab, following standard image-capture procedures in the process of selecting, observing, focusing then capturing images, as Ball trained me to do. Building from experience, as discussed in Chapters One and Three, to explore the imaginative and unconventional dimensions of this scientific lab, I performed the role of scientist. I wore a white lab coat and protective gear, and meticulously documented all laboratory activities in a lab notebook, exactly as I had been trained in empirical methods for capturing organic specimens. I also recorded events as they happened, using written notes, audio, sketches, film and photographic footage. By developing this model, I was able to employ a mixed-methods approach, allowing me to learn more about scientific methods and apply that knowledge to answer my research questions (see Introduction).

Learning about NHM preparation procedures improved my grasp of procedural routines. As a result, I was able to appreciate the physical fragility of the metal-stub samples (the size of a one-pound coin), and their classification and labelling (see Figure 43). Developing an all-encompassing strategy enhanced my expertise, allowing me to consider the complexities of scientific labelling and preparation procedures, while simultaneously expanding my understanding of another scientific approach to data visualisation.

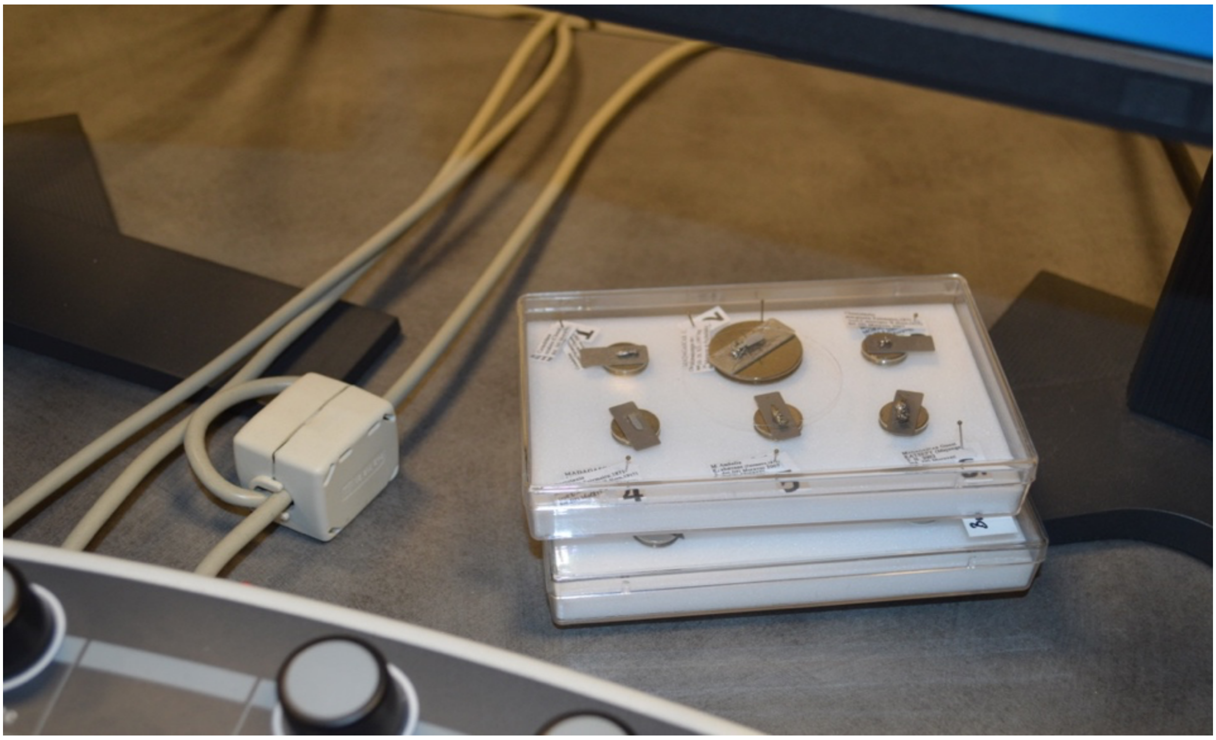


Figure 43. Berry-Frith, J. (2015) Sample stubs. 14.8 x 10.5 cm. © Jo Berry-Frith.

Discourse and interaction via observation and training enabled me to learn about SEM methods and the demanding set of protocols required for optimal data capture. A form of synchronous process-driven activity evolved that demanded complete focus and deliberate, unhurried actions to set up SEM to conduct imaging experiments. For example, I utilised forceps to carefully move six samples onto a metal plate while wearing large, cumbersome gloves, then meticulously placed them onto the composition stage within the hermetically sealed specimen exchange chamber. Placing a sample inside a machine before imaging commenced required me to stand up, twist open the chamber lid (which was attached to a long metal rod) and gently place the samples onto the stage before inserting them into the chamber. I noted how performative activity evolved through the physical (hands-on) mediation of technology as I was shown how to prepare samples ready for imaging. Developing a synchronous process-driven performative model meant that my tacit, haptic, experiential knowledge increased. I began to notice how subtle, playful elements were embedded in every action I took, which influenced how I played. This made me more calculated and in tune with what I was doing.

I was interested in understanding how my practice would be impacted by a) collaborating with Ball, b) interacting with SEM technology, and c) following empirical scientific procedure. Ball was insistently precise when obtaining image data. As we worked together, a process of two-way instructional play developed. Initially, I operated as a passive observer, asking Ball to capture images of specimen samples I selected. However, as the collaboration progressed, I became more assertive, instructing Ball to take images from various angles. At the same time, Ball began suggesting images he wanted to record – ones that were not scientifically correct, but more experimental in nature. This shift marked a more dynamic and collaborative exchange in our approach to imaging.

Selecting and taking images was a slow and tentative process, but it led to us breaking down boundaries. Figures 44–47 are examples of how we tested moving the stage at oblique angles to capture bizarre details of a variety of plankton specimens. Ball would not have taken these photographs if I had not been present. Figures 44–45 are unusual, in that sections of the stub are out of focus, discordant and lacking detail, yet we agreed both were interesting. It is one of numerous instances of how debating, testing and exchanging ideas, while conducting SEM imaging experiments, expanded our knowledge and enhanced our thinking. Collaboration enabled us to participate in deep discussions about scientific picture acquisition and, from this, our differing perspectives on empirical and non-empirical representations came to light. This type of discussion could be regarded as an example of how visual communication can be strengthened by inquiry and instructive engagement (Bourriaud, 2002). Experiential knowledge enabled me to identify how our mediation of technology expanded our serious, calculated and improvisational play tactics (Verbeek 2011: 13).

By developing an inquisitive and pedagogical model, we approached image generation from a fresh perspective, emphasising observation, analysis and trust-building – core elements of collaboration. This approach allowed us to explore intriguing specimens, follow tangents and accumulate knowledge through dialogue and action. We focused on creating novel datasets by combining our expertise, examining maximum and minimum magnification at various angles, focal points and resolutions. I noticed how two-way instructional play evolved as we integrated our specialised knowledge, broadening our experimental interventions. This enabled me to communicate alternative approaches directly to Ball while working alongside him. As a result, I confidently shifted from collaborative to solo play (discussed later), discovering that this flexible approach enhanced our learning.

By dedicating time and focus to understanding the operation of the machine, specifically the computer monitor's visualisation of the SEM chamber's interior, and the movement of the motorised stage, I was able to observe both the highly complex computer-generated images of organic subject matter and also the machine's internal attributes. I was fascinated by the engineered, shiny, metal internal chamber and the humming sound during its motion, as it was an aspect of microscopy I had not encountered before. I considered the requirements necessary to move the stage. Although it was uncomplicated, it required hand-eye coordination and a slow, sensitive touch to select one sample at a time. I observed the sample traverse the x, y and z Axis, while adjusting the x and y knobs until the image stopped moving. I continued to increase the magnification, focus the image and correct astigmatism, which resulted in distorted, blurred, or stretched images. By learning the requirements, I was able to conceptualise how to break from established conventions and push the bounds of the technology systems beyond scientific convention. However, breaking convention proved to be challenging. For instance, I faced difficulties when attempting to investigate the rotation and angling of the sample at various angles. I analysed parameters and variables quicker than both systems could process them, by zooming in and out and getting too close to the specimen's surface structure. I found that Ball's expertise was necessary to avoid damaging the SEM's lenses and optics, for example when viewing Bryozoa (see Figures 46–47).

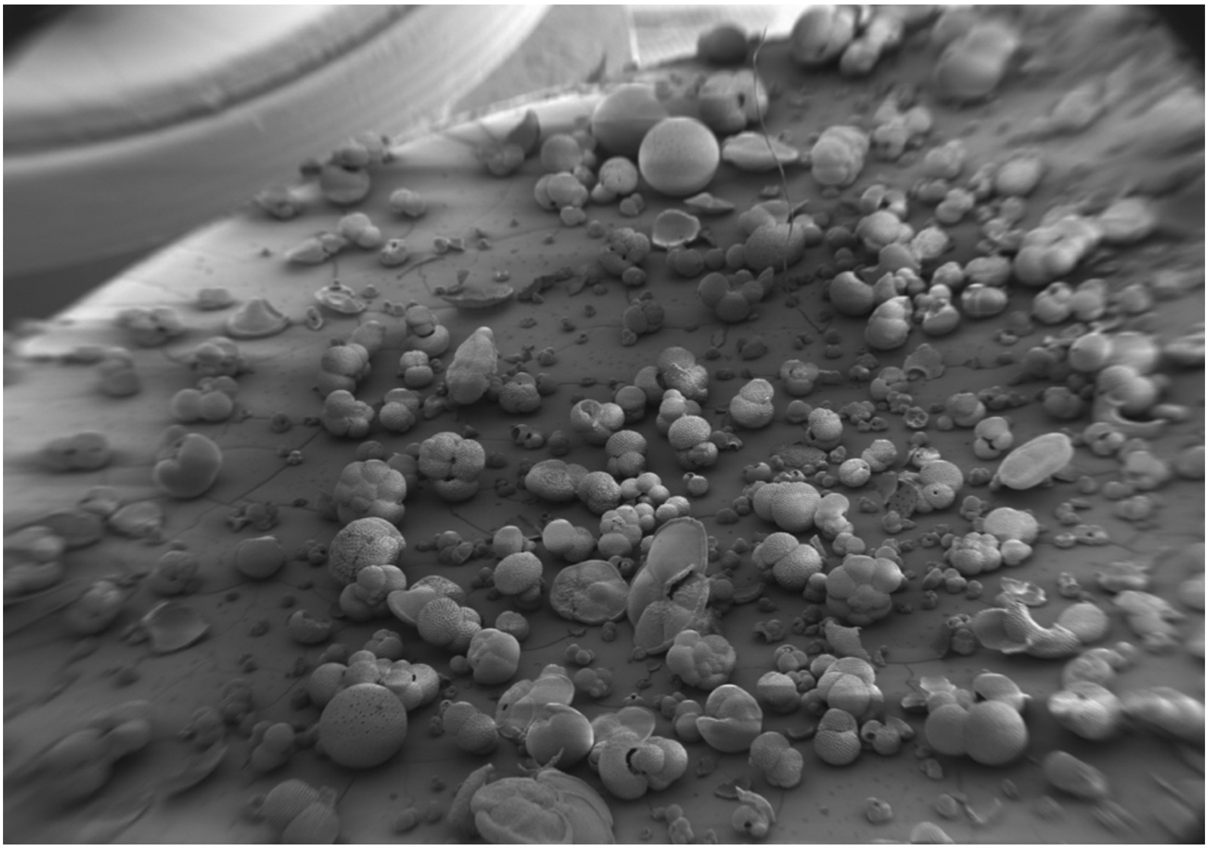


Figure 44. Ball, A., and Berry-Frith, J. (2024) Oblique Angled Stub 7_016.Tif. Taken On the Zeiss Ultra Plus. 72 x 54 cm. © Alex Ball and Jo Berry-Frith.

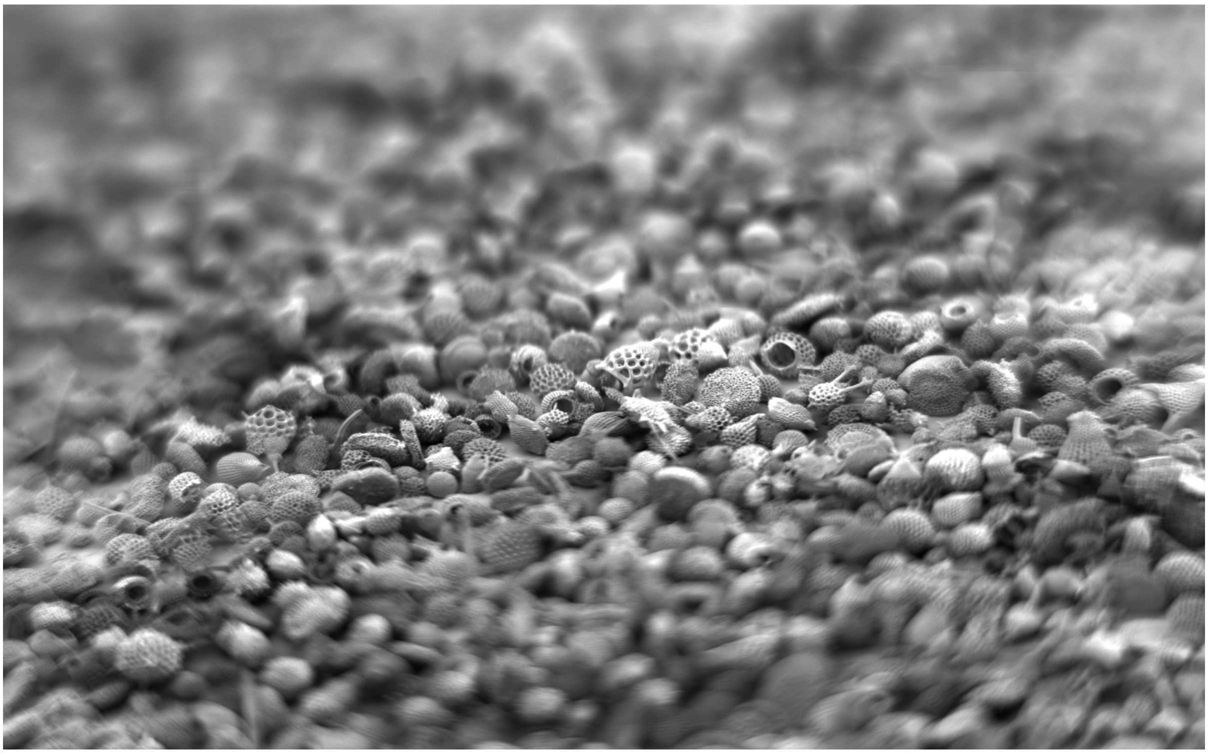


Figure 45. Ball, A., and Berry-Frith, J. (2024) Stub 9_063.Tif. Taken On the Zeiss Ultra Plus. 72 x 54 cm. © Alex Ball and Jo Berry-Frith.

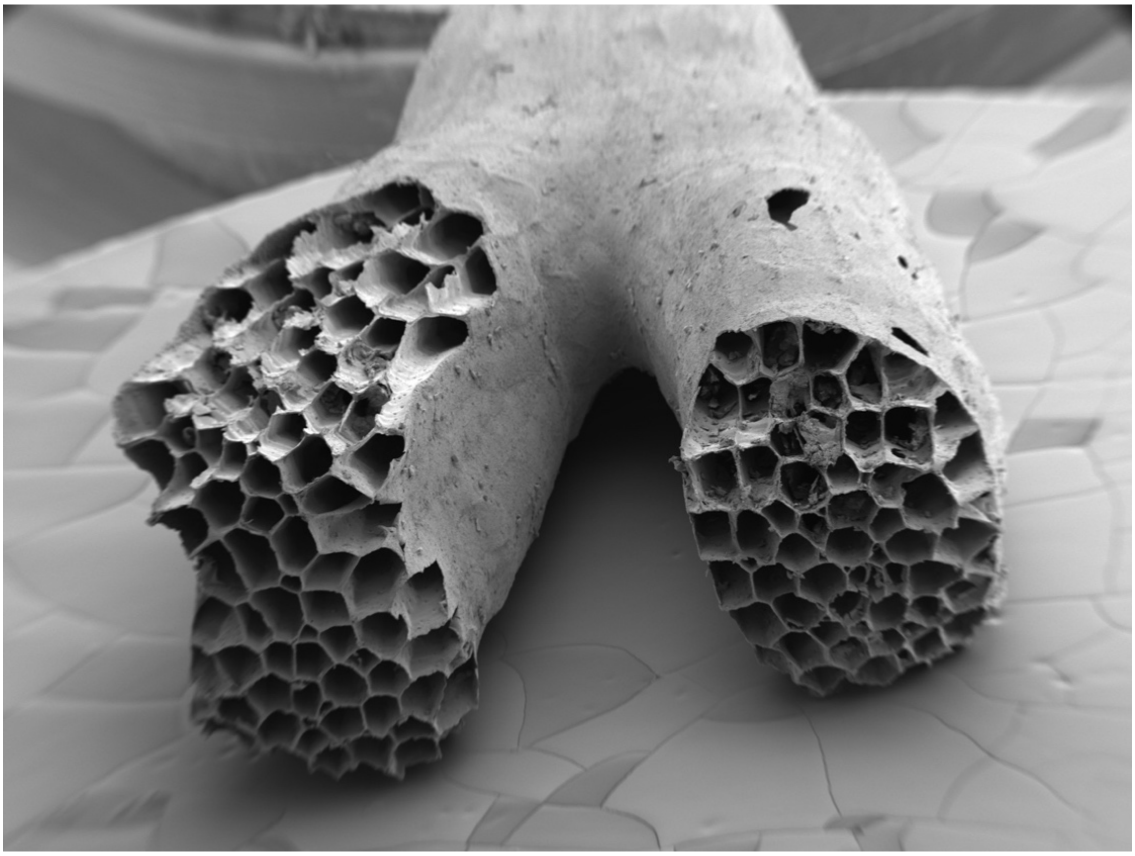


Figure 46. Ball, A., and Berry-Frith, J. (2024) Front_angle _Bryozoa _Stub 7_006.tif. Taken On the Zeiss Ultra Plus. 72 x 54 cm. © Alex Ball and Jo Berry-Frith.

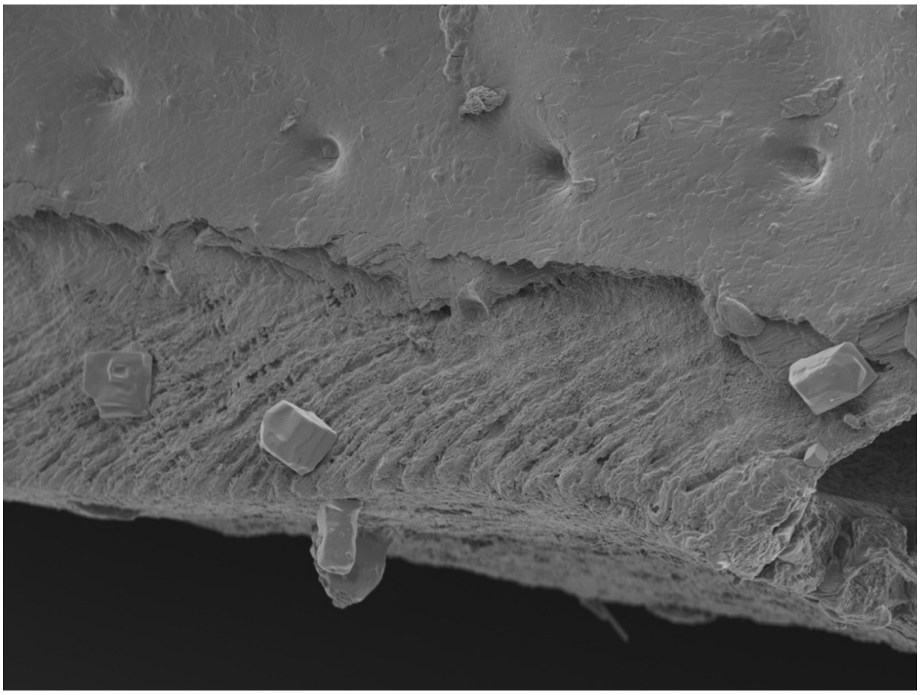


Figure 47. Ball, A., and Berry-Frith, J. (2024) Edge of a Bryozoa taken at a high magnification illustrating calciferous attachments _Stub 7_014.tif. Taken On the Zeiss Ultra Plus. 72 x 54 cm. © Alex Ball and Jo Berry-Frith.

Additionally, I had conversations with other scientists, technicians, post-doctoral researchers, research fellows, PhD students and volunteers working in the lab, whose knowledge spanned multi-disciplinary specialist skills (from astrophysics to zoology). These conversations raised my awareness of the breadth of the research conducted in the laboratory. Every scientist I encountered was eager to share their perspectives, including Chris Jones, the Head of Department at IAC, who described his work and was enthusiastic about me working in the lab to break down barriers. However, I noted that although scientists were well versed in communicating with other scientists, they struggled to explain clearly their research in lay terms. Conscious of the ambiguity between our disciplines, I identified reasons and justifications for advancing knowledge and educating scientists on how to connect with non-specialists to reduce this obscurity. To communicate findings to non-specialists, it seemed essential to use common language, disseminate research in a non-scientific manner and collaborate with artists to get new perspectives on NHM collections and the research.

Embedding myself in day-to-day routines, asking non-scientific questions and forming long-term partnerships with scientists such as Ball helped break down barriers. My attention on exploratory learning helped us feel more at ease and willing to take greater risks as we got to know each other. My perception of this field, its technology and the subject matter I studied, shifted because of addressing scientific conventions which would not have surfaced without being present in this lab. Consequently, I identified and gathered various forms of data. The development of this approach enabled me to effectively challenge standard scientific-image conventions, demonstrating my worth as a counterpoint to empirical norms.

Solo play: Working alone in the SEM lab

My comprehension of all procedures was strengthened by working independently with the two imaging systems. This was a unique opportunity for me to test my creative abilities and gather different forms of data to advance art practice. In over ten years of working with specialists, I was only able to operate an LM during art project one (Leica Microsystems, 2015). Occasionally, I had restricted access, but I was always supervised by a scientist. In this situation, I had the freedom to experiment and broaden my knowledge.

However, after training, I still relied on Ball's expertise, requesting that he identify biological samples with abundant structural data from NHM's archive. I was drawn to the unique structural geometry of several formations. Technology granted me access to highly detailed organic systems, and working in monochrome enhanced the visibility of these three-dimensional structures on the computer display, contrasting sharply with the vibrant colours of art project one. By leveraging Ball's knowledge, I conducted comparative research on specimens at different magnifications, focusing on formations like butterflies, Coccolithophores (Michaelson et. al., 2010), Radiolarian (Lazarus, 2007), microfossils (Gehrels, 2007), Foraminifera (Saraswati, 2021), and marine plankton (Falkowski, 2012). Figure 48 shows a close-up of a sea urchin spine, known for its role in mobility and predator defence, with a unique inner microstructure of single-crystal calcite. This striking geometric calcification inspired me to explore other unusual formations, extending my understanding of microscopic creatures' physical and chemical properties.

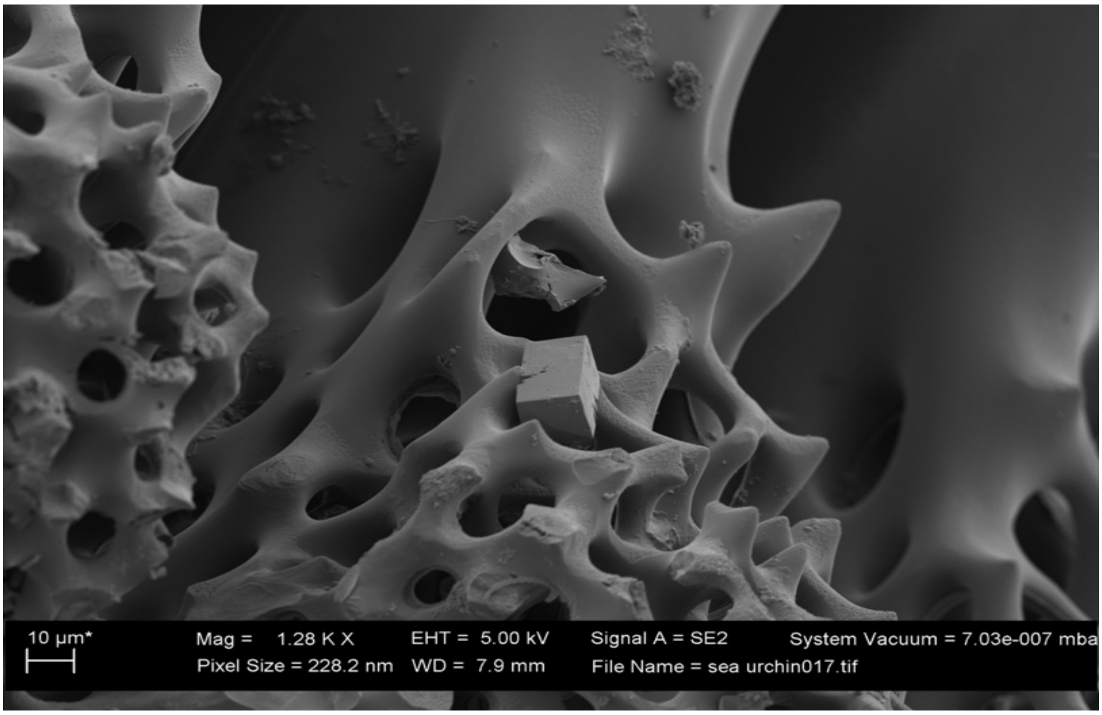


Figure 48. Berry-Frith, J. (2015) Sea Urchin Spine017. 72 x 54 cm. © Jo Berry-Frith.

In 2015 and 2024, I focused on taking SEM images of Radiolaria as they are exceptionally delicate and complicated (characteristics I was drawn to), despite the relative simplicity of the unicellular creatures in which they grow. According to Professor of Zoology D'arcy Wentworth Thompson (1860–1948), the group of microscopic creatures known as Radiolaria is extremely diversified in terms of species and form. In most situations, the skeleton of Radiolaria is made of silica (Thompson, 2014: 151–169). Figure 49 has a malformed Radiolarian attached to or sprouting from it. Again, this was a bizarre formation that piqued my curiosity. As I inspected Radiolaria, I saw that each of these biological items was unique, despite it being a unicellular organism. The fact that they were not identical reproductions reminded me that uniqueness is a quality I pursue when making art.

My creative process entails observation, taking images based on my subjective interpretation, which allows me to explore ideas freely and go off on tangents. This contrasts with the systematic techniques of scientists, whose research requires validation and precision. I pointed out this difference to Ball as we worked on imaging investigations together and separately. This contrast in our approaches was important, because it showed the value of integrating different methods. My approach provided flexibility and exploration, while Ball's focus on validation added structure. By combining creative exploration with scientific rigour, we enriched the investigation and gained a more comprehensive understanding, ultimately improving the quality and depth of our work.

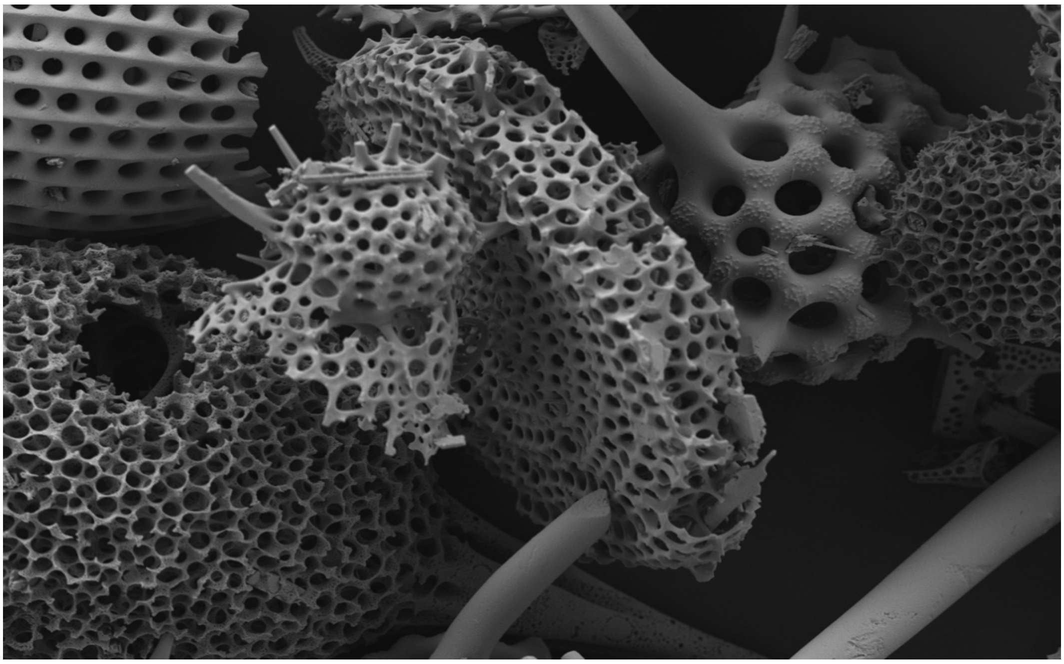


Figure 49. Berry-Frith, J. (2024) Stub 9_057.Tif. Taken On the Zeiss Ultra Plus. 72 x 54 cm. © Jo Berry-Frith.

In the lab, I worked alone, experimenting with the instruments and software enabled by SEM technology to expand my methods of visualising specimens, building on the knowledge gained from art project one. I captured images imaginatively, intentionally deviating from the precise rules set by Ball, who aimed for scientifically convincing images judged by clarity and empirical accuracy. Instead, I prioritised the collection of image data, which slowed my ability to employ playful strategies due to challenges in focusing, magnifying and positioning the sample on the stage. I took my time, adjusting the magnification and focus dials, realising that imaging required obsessive observation as the data formed on the screen.

I focused on creating sharp images, but also intentionally produced distorted, astigmatised ones, which occur when uneven focus in the electron probe distorts the image. Using the joystick and dials, I centred the image, adjusting brightness and contrast to create sharp results, then reversed the settings to generate blurred, stretched images. These techniques – divergence, offset and focusing – helped me push the limits of SEM imaging technology, transforming it from a scientific tool into a manipulable visual medium. This approach allowed me to expand the scope of the image capture 'games' I set for myself.

As I gained SEM skills, through solo play I implemented a semi-strategic yet digressive scanning and selecting system to extend my visual outcomes. Working with measurements beyond my grasp inside a range of five-to-ten picometres (Aqua-calc, 2024) of wavelengths of electrons, I captured data at different scales. The photographic artifacts are incorporated in this thesis because of the potential of the imaging technology used and the data obtained through my deviations. Figure 50 is an example of a double image captured on the Zeiss Ultra Plus as the stage moved. When Ball saw this image, he questioned why I took an out of focus photograph. Ball has worked at the NHM since 1997 and he explained that the method in which I deployed SEM technology had never been used for that purpose before, and that he had never seen a picture like Figure 50. However, despite being open to my approach for testing SEM, Ball was occupied with his responsibilities as the IAC Manager and had other demands on his time, which is why he had trained me to work autonomously. At this juncture, I executed the game in a manner that was self-directed and targeted at scrutinising my testing techniques, as I was keen to engage SEM as a creative tool, despite my concerns about damaging the optics. For this reason, I played with the tool's settings and parameters, twisting knobs and moving the joystick too rapidly, then doing the opposite and progressively changing the focus, position, viewpoint and angle. Visualising images required a delicate touch, and applying this simple technique allowed me to continue experimenting and extending my tacit knowledge of technology. Ball appeared intermittently to check on my progress, eager to see what I had produced.

Being left alone for extended periods expanded my perception of what an image could become. My research focused on testing the visual effects produced by SEM, experimenting with both imagined and unimagined possibilities of the technology. By ‘unimagined’, I mean the unforeseen outcomes and novel visual effects that arose through experimentation, which I had not initially conceived. This allowed me to build a collection of images that demonstrated the technology’s potential beyond its conventional uses. Through this process, I engaged in serious play, acknowledging – as the player – that it was still play within a world defined by its specific purpose (Gadamer, 1998: 23).

Solo play served as a springboard for further discussions with Ball about the outcomes when I deviated from his instructions, such as when I shifted the stage while images were being captured, while the electron charge was still loading. Figure 51 shows a species of planktonic foraminifera (Chaabane et al., 2023) – imperfect, circular-shaped calcareous shells, with pyramid-shaped protrusions – taken while the SEM was still charging on a tilted stage (at roughly 5 degrees). Defects like this are caused by negative charge accumulation on the surface of the samples, where an excess of signal is captured, resulting in visual aberrations like “glowing” bright spots that increase over time. Another negative effect of overcharging is beam drift, a phenomenon where the image blurs and appears to move throughout the frame. These technological abnormalities stimulated my curiosity, prompting me to continue exploring and capturing non-standard images.

Figure 52 is an example of how I experimented with focus and magnification by framing three focal points of *Emiliania Huxleyi,* a type of coccolithophore, at three distinct magnification levels in one shot. The resultant image led me to conduct further tests on focus and magnification. I took a series of off-centre photographs, such as Figure 53. Ball criticised the image for being too dark, not centred and having superfluous details of other objects, which goes against scientific visual conventions. Again, Ball's critique highlights a departure from standard scientific imaging, which values clarity and precision. His feedback suggests the image didn't meet expectations for clear, focused representation. However, this critique also reflects the tension between scientific objectivity and artistic exploration, as my approach aimed to challenge these conventions and push the boundaries of what an image could represent.

By including labels with magnification, measurement, pixel size and specimen name, the image highlights both its technological roots and the judgements I made in re-envisioning the data. This approach combines scientific precision with creative interpretation, reflecting my non-conventional visual methods. The resulting images demonstrate how an artist can challenge scientific norms by breaking rules and using improvisation to capture non-standard representations of scientific data. This process shows that what scientists may regard as errors or irregularities can provide valuable insights, fostering exploratory learning. Through the unrestricted use of SEM technology, I sought to challenge established protocols and expand the possibilities of scientific imaging.

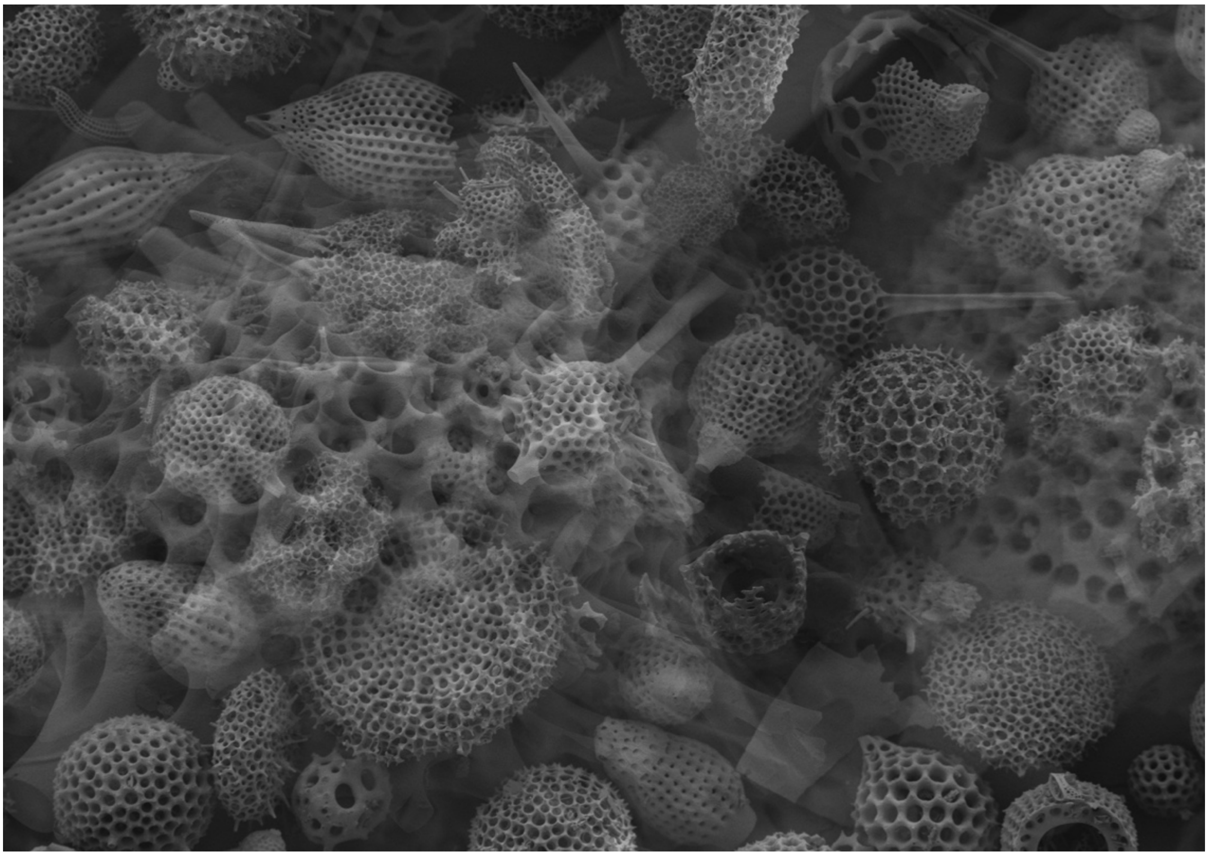


Figure 50. Berry-Frith, J. (2024) Stub 9_056.Tif. 72 x 54 cm. © Jo Berry-Frith.

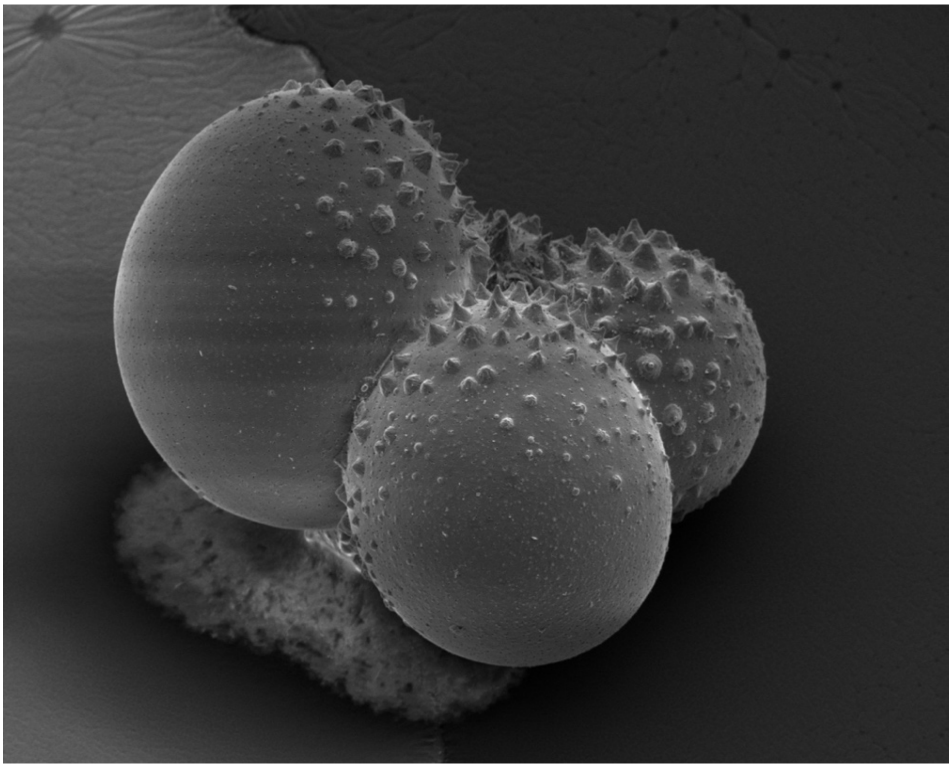


Figure 51. Berry-Frith, J. (2024) Stub 7_038.Tif. Image Still Charging. Taken On the Zeiss Ultra Plus. 72 x 54 cm. © Jo Berry-Frith.

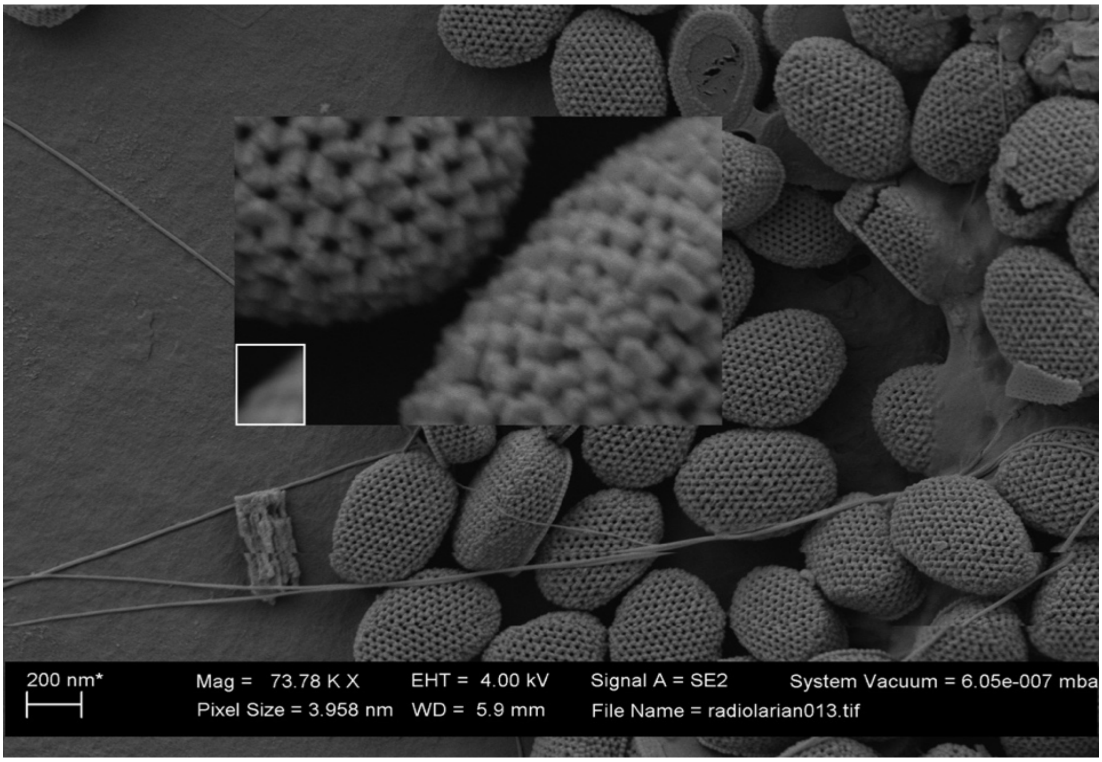


Figure 52. Berry-Frith, J. (2015) *Emiliania Huxleyi* a species of coccolithophores. In-focus and out-of-focus image captured at multiple perspectives. Taken on the Zeiss Ultra Plus. 72 x 54 cm. © Jo Berry-Frith.

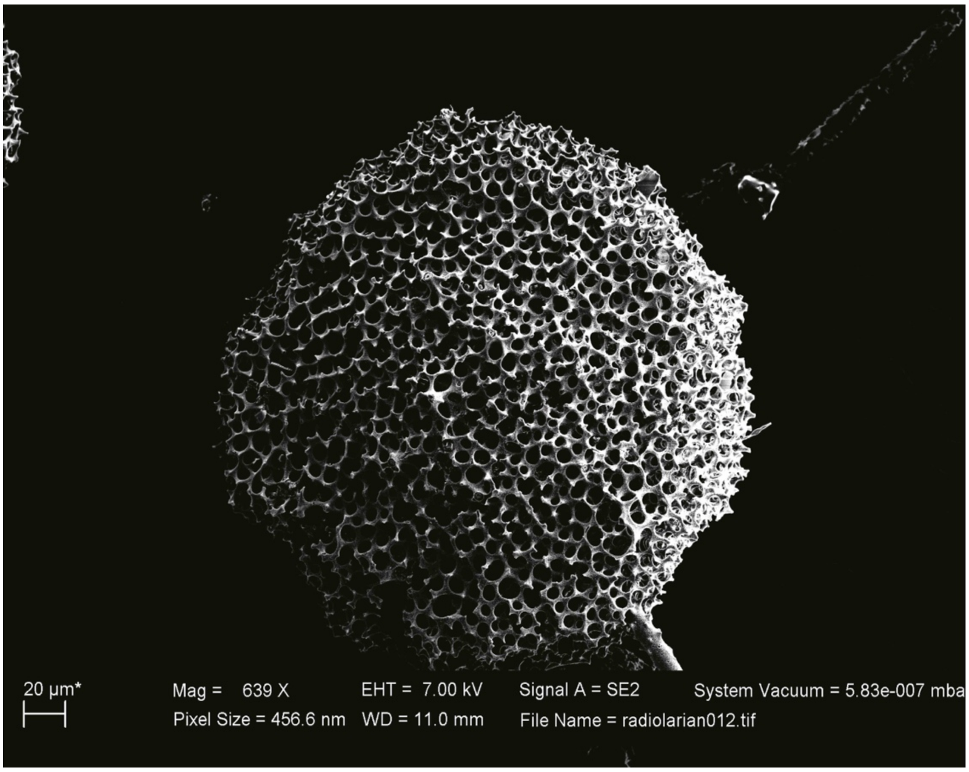


Figure 53. Berry-Frith, J. (2015) Radiolarian 012.jpg Taken on The Zeiss Ultra Plus. 72 x 54 cm. © Jo Berry-Frith.

Figure 54 depicts multiple misplaced mineral skeletons captured using the LEO 1455VP, producing data with a distinct tonal quality and colder grayscale hues. I drew a parallel between this work and Bernd and Hilla Becher's methodical documentation and topological classification of grayscale industrial structures, such as water towers (Rosenheim et al., 2022). The photographic artifacts I produced served not only as representations but also as part of an investigative experimental inquiry, blending scientific analysis with artistic exploration of grayscale image data. This was made possible through seriously playing with technology, testing distinct SEM machines attributes. In contrast to Robert Kesseler's richly coloured, multi-frame and highly staged microscopic images (Kesseler, 2010: 121–181), this work embraced a more direct approach.

Figure 54. Berry-Frith, J. (2015) Maim Section021.tif. 72 x 54 cm. © Jo Berry-Frith.

At the centre of this chapter lies a dynamic collaboration, though it was not consistently maintained. This allowed me greater freedom to experiment and play compared with art project one. By balancing collaborative and independent efforts, I developed a flexible working method that enhanced my efficiency as an investigator. Constructing specific variations through training and independent work underscored the importance of regularly sharing results with Ball, fostering a two-way approach to expand our image protocols. This collaboration ultimately led Ball to recognise the value of my artistic approach in reframing his established scientific imaging expectations, enhancing both our practices and fulfilling one of my objectives (see Introduction).

In line with Winnicott's (2005) perspective, play nurtured creativity and facilitated experiential learning. This dialogue between artistic play and scientific rigour opened new avenues for understanding and interpretation, aligning with Bateson's (2014) concept of building knowledge through diverse tools: stringent, factual and divergent. My reflections raised questions about representation in scientific imagery and how artistic intervention could shift perspectives, enriching both fields. I considered how this interplay would evolve in my future work, asserting that outputs didn't have to be traditional drawings; they could simply be grayscale photographs, or a sequence of photographic artifacts obtained directly from the microscope.

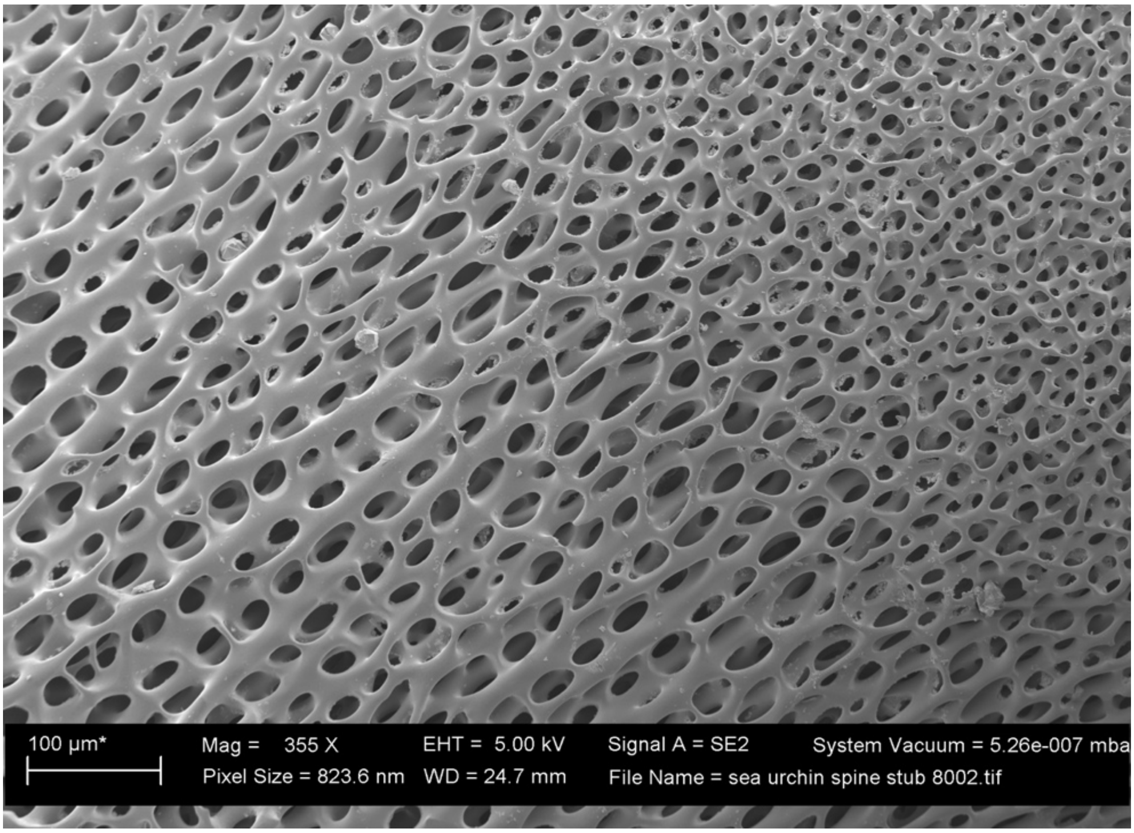


Figure 55. Berry-Frith, J. (2015) Sea Urchin Spine. Taken On the Zeiss Ultra Plus. 72 x 54 cm. © Jo Berry-Frith.

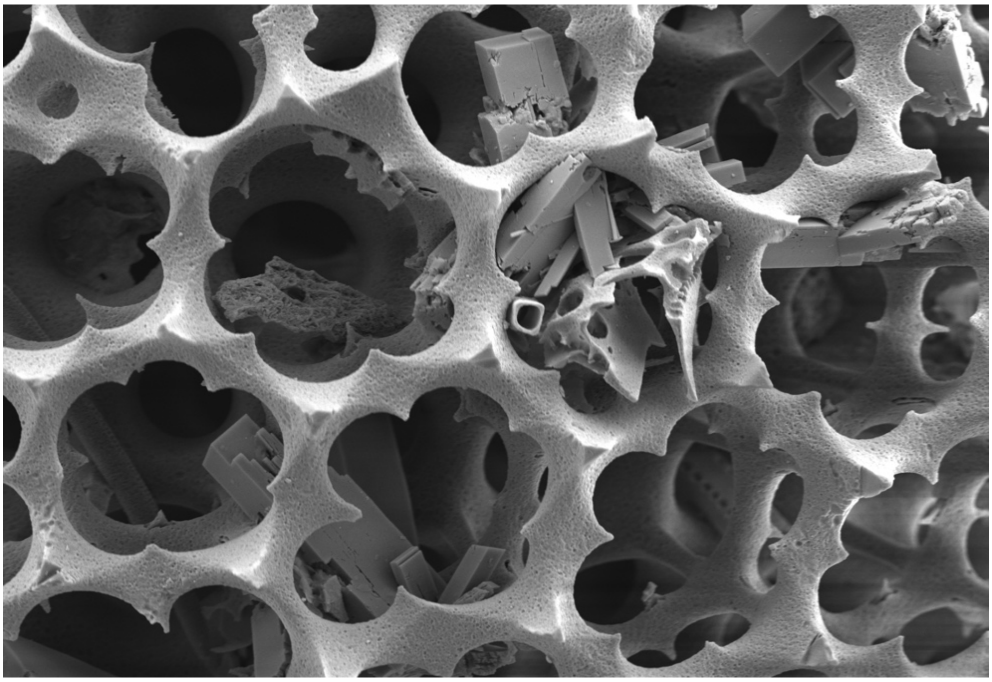


Figure 56. Berry-Frith, J. (2024) Stub 9_051.tif.Taken on The Zeiss Ultra Plus. 72 x 54 cm. © Jo Berry-Frith.

Latour maintains that scientific knowledge should not be perceived as "the truth" regarding "reality itself," but rather as a construct arising from the interplay between humans and non-humans within a network that encompasses definitions, problem-solving, experimentation and observation (Verbeek, 2011: 13). The photographs I took were the result of my interaction as an artist working in a scientific lab, engaging with various non-human entities, including organic systems, SEM technology (which includes components such as the electron source, lenses, apertures, scanning coils, detectors and the SEM chamber where samples are mounted), and the computer hardware and software that control the SEM via a graphical user interface. These tools and technologies aided me in addressing my research questions (see Introduction; Zeiss, 2022). My thinking aligned with Latour's (2010) constructivist Actor-Network Theory (ANT) approach (Verbeek, 2005: 102), which emphasises the critical role of both human and non-human entities in shaping knowledge and meaning within a network. Figures 55 and 56 visually represent this structural complexity – a theme I explored further through drawing, following these photographs taken in 2015 and 2024.

Figure 55 showcases an intricate luminescent structure of a sea urchin's spine, while Figure 56 depicts a species named Distephanus. I chose this particular organism because its inner shell contained several components formed in the grooves between clustered cells, belonging to the Silicoflagellata protozoan family, which exhibits a wide range of morphologies (Thompson, 2014: 166). As I studied these images, certain elements came into view – things that had been present all along but were previously invisible, yet necessary for the organism's sustenance (Latour, 2010). I began to perceive my study more deeply as an interconnected network of user engagement, highlighting subject matter, systems, processes, production and visualisation techniques. I comprehended my position within a multi-layered network of engagement and recognised the significance of interpretation in understanding the meaning behind all actions, activities and entities, both human and non-human. This insight illuminated the playful elements that drove my practice-based and process-driven investigation. Building strategies to challenge creatively scientific image conventions – by breaking rules, embracing improvisation and engaging in serious play with technology – was crucial for fostering innovation. This enabled me to explore and convey alternative methods for the scientific use of SEM, which was advantageous in expanding the scope of its application.

I observed a significant difference between how I, as an artist, gathered information and how my scientific counterparts collected data. As previously mentioned, Ball gathered extensive datasets, such as photogrammetry. By contrast, I was acquiring fragmented information and employing a semi-systematic approach to examining biological data. My actions felt disjointed and lacked consistency, but I didn't see this as a problem. It was an individualistic method of data collection that I sought to explore more deeply in the second cycle of my practice, as it aligned with the themes of complexity, serendipity and curiosity that became central to this study.

Examining Latour's (2010) critique of the network revolution and his analysis of data collection processes proved to be very useful for my research. He argues that an individualistic approach aligns with an inquiry method focused on identifying the essential unknowns for an entity's existence. Each newly revealed feature adds complexity, enabling a deeper understanding of the subject. Latour describes a network as a series of small jolts, allowing the inquirer to document the wide range of qualities surrounding any material. He also suggests that individuals can independently build complex systems without relying on a larger whole. He advocates for a social theory that resists reductionism, using all available information to understand individuals and systems, while avoiding sharp divisions (Latour, 2010: 16).

These ideas resonated with my process. The evidence I gathered through tests, audio, documentary film and data, gave me a strong sense of creative autonomy. By adopting this individualistic method of collecting data, I could approach complex systems with operational authenticity as an artist conducting visual research in the lab. This process added to my understanding. It also significantly enhanced my analytical and creative thinking, allowing me to bridge artistic and scientific perspectives in my work.

Latour explains that the sheer multiplication of digital data has made collective existence traceable in entirely new ways, largely due to the techniques used to collect such data. Navigating between individual profiles and aggregates has become easier than ever. However, the challenge lies in the fact that the less one can revert to the individual transaction, the more tempting it is to ascribe substantial reality to the aggregate. This creates discontinuities and disjunctions in traceability, complicating the process of tracking individual transactions.

As I reviewed my own transactions with digital images – whether on screen, as data files, part of a dataset, or through online transmission – I became increasingly aware of the intricate nature of traceability as it pertained to digital information. This reflection allowed me to grasp the value of capturing primary datasets; being able to trace their lineage granted me control over the source material. This control ultimately influenced how I approached the development of my practice in the second cycle.

Reflections on two-way collaborative and solo play

My artistic activities at IAC fostered communication and integration of alternative image-production processes rooted in the philosophical theories of play and technology. Being present in the lab allowed me to demonstrate to scientists how play as a methodological tool could expand their techniques for visualising data beyond their expectations.

Through my research, I recognised the value of both solo and collaborative play. Two-way instructional play enhanced my collaboration with Ball, while training on two SEM imaging systems deepened my understanding of imaging processes and optical visualisation as an artistic medium. This experience heightened my awareness of how subtle acts of play influenced my engagement with technology and performative preparation activities. By focusing on subjects aligned with our interests, such as optical visualisation, technical innovation and scientific-image representation, we extended shared learning opportunities.

Ball's expertise in capturing images quickly and accurately was crucial for selecting specimens. I enabled him to create images that surpassed his scientific expectations, infusing our process-driven experimentation with innovative outcomes and strategies for collaborative learning applicable in various contexts.

Solo play allowed me to achieve image results that a specialist like Ball had never seen before. Key aspects of playfulness emerged from exploratory testing, as I captured non-standard images that expanded the visual effects produced by SEM.

This approach underscored the value of exploratory learning, enabling me to mediate SEM technology without restrictions and to challenge scientific image protocols. Innovation arose from capturing images while the SEM was charging and focusing on image defects, such as visual aberrations and technological abnormalities. I also experimented with framing different focal points of a specimen within a single image, merging scientific labelling with non-scientifically accurate representations. These results sparked discussions with Ball about deviating from conventional instructions. I learned that contradictions and innovative shifts are essential for shifting the status quo, and that an improvisational approach leads to innovation.

My methods of documentation and data collection significantly differed from those of my scientific counterpart. To complement the complexity of the subject, data and technology, I employed a semi-systematic, fragmented method of data collection. This individualistic approach demonstrated the potential to build complex systems without relying on broader scientific expectations.

Working in the lab also revealed generational shifts in attitudes towards drawing, highlighting its value as a counterbalance to a solely computerised visual investigation. Unexpectedly, I became drawn to the monochromatic SEM visual language, which evolved into a significant extension of my practice outcomes (see Appendix One).

The second cycle of art project two: Art practice

The art studio

Richard Bright is the Founder and Director of The Interalia Centre (established in 1990) – an organisation that provides an international forum for the exchange of ideas between the arts and the sciences. In the book chapter *Uncertain Entanglements* (Ede, 2000: 120–121), Bright argues that both physics and art are simultaneously simple and complex. This is because both disciplines address fundamental questions about the nature of reality and explore how we perceive our place within it, whether as objective observers, or subjective participants. Within the "magic circle" of my studio (Huizinga, 2016: 20), I sought to view the entire picture – both objectively and subjectively – in order to gain a comprehensive understanding of ideas. This allowed me to perceive actions, events and concepts as interconnected, enabling a holistic exploration of the subject matter. I examined multiple data sets: raw data, documentary, film and photographic footage. However, the sheer volume of data generated became overwhelming, leaving me with an overload of choices. At this point, I had to consider how best to communicate the data back to the scientific community in a novel way, while also finding a way to shift into a state of experimentation in the studio. The vast amount of data and the process of selecting what to focus on were limiting my ability to embrace fully the creative freedom I was seeking. I identified the main characteristics of my approach up to this point – serious, complex, multi-faceted, experiential and optical. I evaluated my tactics, which involved acting as a conduit, conducting role-play, employing performative preparation techniques, and engaging in both two-way instructional collaborative play and improvisational solo play. I reflected once again on the human and non-human interactions I had observed and experienced in the lab, aiming to understand its purpose more deeply and to extract the data that emerged from this play.

At this stage, I engaged in independent creative play in my art studio, where I was in control and the decisions I made were mine. I recognised that my need to play as an adult stemmed from a desire to experience the pleasurable aspects of art, which evoke intuitive stimulation, even if it involves anxiety. This is because adult play is complex and unpredictable (Winnicott, 2005: 70). This meant that I shaped the creative game I set out to play to extend my investigation of the play-based framework I was developing, using it as a tool to explore and reflect on my art practice. Realising that play is a process that takes place in a liminal space, I operated as the player, accepting art's agency was tied to my ability to experiment and express ideas without restraint, even if its meaning was not immediately accessible to me. I connected my artistic behaviour to my play-drive, which was determined by the relevance of the experiences, data and ideas already generated in the lab (Gadamer, 1998: 124). I considered the impact of the computer (my art tool) as an alternate mediating device as it shaped my play (tactics and approach) and perceptions of how to visualise data (Verbeek, 2005). As I was responding to complex photographic artifacts, I decided not to engage in software play as I had done in art project one because the monochromatic images captured in the SEM lab were already sufficiently captivating and did not require additional adaptation.

Digital drawing

In my examination of art as play, my aim was to examine photographic artifacts captured as SEM data and explore their superior characteristics through drawing. I focused on the notion of versatile imaging as a three-dimensional sketch and was therefore able to use drawing as a means of identifying and conveying the qualities of these artifacts. Using this approach enabled me to focus on structural complexity. As discussed in art project one, I worked on the computer and used Adobe Illustrator software to construct drawings on an illuminated screen, and I recorded all stages of activity. By creating this model, I was able to investigate the act of creativity through being playful (Gadamer, 1998: 127).

The act of drawing triggered an "exciting interweave" between the photographic artifact (object-related) and its subjective conceptualisation, without pressure to produce a fixed hypothesis (Winnicott, 2005: 64). This meant that I was able to consider the "intermediate area" between lived experience and my imaginative perception, as I investigated the underlying features of the organic subjects. My aim was to bolster introspective exploration via calculated creative strategies, building on art project one. As a result, I focused on strategies that involved a thorough examination of my precise and detailed design decisions. This was underpinned by my understanding of drawing's evolution from a traditional medium to a broader, more expansive domain, and how it can be integrated into other disciplines to uncover hidden information about microstructures. Drawings' expressiveness and ability to reveal technique align with Petherbridge's concerns (1991: 7) about authorship and originality (see Chapter Three). I was influenced by *Drawing the Line* (1995), curated by Michael Craig-Martin, which explored Western and global drawing with a focus on linear qualities and cross-cultural connections. Nikolaus Gansterer's diagrammatic drawings (2017: 20) also inspired me, blending speculation and intuition to visualise complex associations. My practice centred on digital vector line drawings, devoid of tonal variation, emphasising precision and the expressiveness of linear forms.

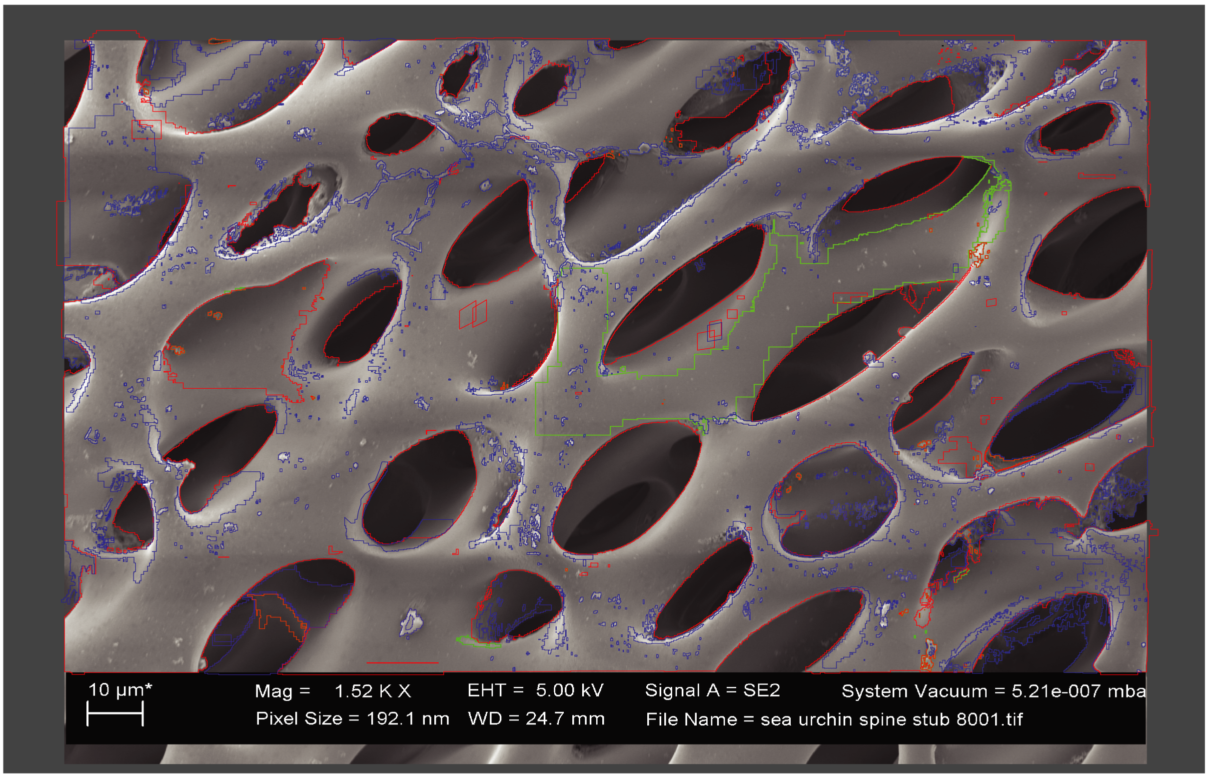


Figure 57. Berry-Frith, J. (2015) Sea urchin spine closeup 11thnov2015v1v3.ai. 72 x 54 cm. © Jo Berry-Frith.

Figure 57 is my first drawing of a zoomed-in section of a sea urchin's spine. However, I realised the selected image did not convey the notion of versatile imaging as a three-dimensional sketch – something Ball was keen that I conveyed. I rethought how I might use Ball's three-dimensional sketch concept to extend my calculated digital drawing tactics. I realised my relationship with Ball had evolved into a responsive method of inquiry, with my creative focus changing as a result of embracing Ball's scientific paradigm. Adapting his scientific strategy, I converted pixelated photographic picture data into two-dimensional representations of three-dimensional objects. Extending this model further, I created a series of iterative digitally drawn responses in which I traced and remapped pixel data to discover how each organic specimen was constructed. Like Anderson-Tempini (2017), the drawings I created were part of a surface-based interaction – a mode of play that I took seriously. In line with Latour's theory that scientific knowledge is a construct created by the interaction of humans and non-humans within a network of definitions, finding solutions and observation, drawing was crucial to my ability to articulate my ideas and comprehend the subject matter (Verbeek, 2011: 13).

Specimens were selected because I perceived them to be ideal structures for iterative learning. I made imperfect replications by employing digressive (discursive, inaccurate) drawing strategies to challenge scientific and technological uniformity. Creating large-scale digital design drawings (up to 1m tall or wide), I investigated complex irregular structures to demonstrate the incomprehensible nature of these artifacts.

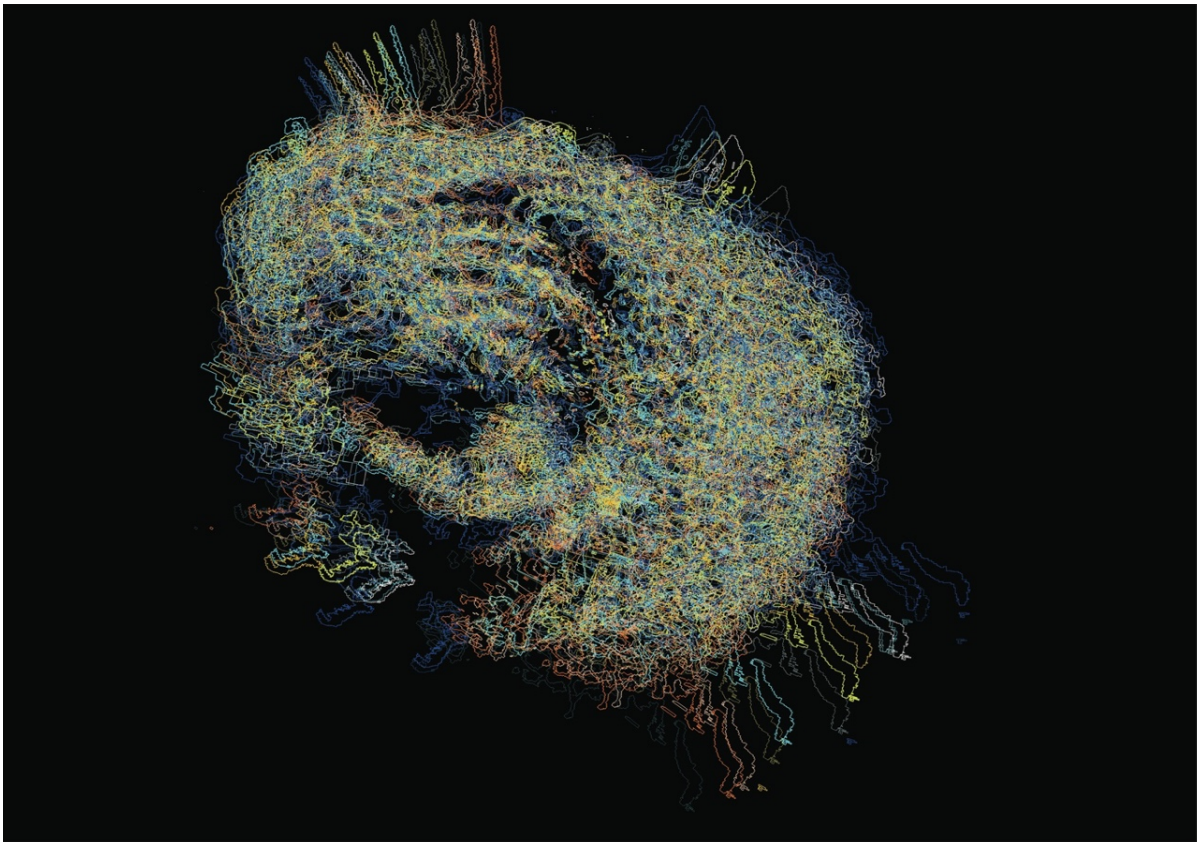


Figure 58. Berry-Frith, J. (2019) Radiolarian_004_ with_ five_degree_rotation_print.ai. 84 x 55 cm. © Jo Berry-Frith.

Figure 58 is an example of the dynamic form of a whole Radiolarian. It is made of fifteen layers of information. The drawing's formal constraints (pictorial frame, construction, composition and line weight) were abandoned in favour of offsetting the central axis and altering the focus through rotation and repetition. As a result, the final image resembles an intricate web of drawn information, an animated snapshot, floating in a darkened space without shadow or texture. The original photographic SEM image was deleted after the drawing was completed. Fourteen separate, iridescent-coloured linear drawings were copied, rotated, offset and layered on top of each other at approximately five degrees, directing the eye to areas of intensity. Rotation and repetition gave the impression of a three-dimensional sketch and linked the drawing back to photogrammetry. My desire for a thorough comprehension of the subject matter motivated me to choose a labour-intensive approach. The obsessive tracing method I adopted (i.e., tracing pixel detail) correlates to the Radiolarian's exceptionally delicate and distinctive characteristics, which I attempted to emphasise by depicting its skeletal structure. This creative play of production was inextricably linked to seriousness; I as the player was absorbed in obsessive and repetitive play, tracing an underlying network made through the act of mediating technology (Gadamer, 1994: 102).

Rosalind Krauss (1998), a critic and art historian, explores how humans perceive the world via the lenses of physiological optics and late nineteenth-century optical theory. Topographical modernism evolved in the late nineteenth century, influenced by artists who used new imagery, materials and methods to depict contemporary culture. According to Krauss (1998), Mondrian began with divisionism. This was the technical foundation for Neo-Impressionism (discussed in art cycle one), with the positivist idea of making the picture a mosaic of colour sensations, with each dot representing a point of light reflected off the field of objects, so that the painting became an imitation of the eye's surface. Mondrian's access to modernism occurred at a time when painting was being rationalised around colour theory and physiological optics. The reconstruction of the surface began with optical theory, which clarified composition and pictorial harmony through science. It was anchored on a series of abstract theorems from influential physiologists and physicists, such as Gustav Fechner (1801–1887), Hermann von Helmholtz (1821–1894), Thomas Young (1773–829) and Ewald Hering (1834–1918), establishing a unique platform for Mondrian's strategy.

Mondrian's envisioning of optical laws as though they were subjected to a code provides a historical backdrop consistent with my approach to reframing raw data through the construction of digital drawings. Mondrian conceived of the two planes – the retinal field and the picture plane – as analogous in form and relation to one another, with the rules of the first generating both the logic and the harmony of the order of the second. Both of these fields – the retinal and the pictorial – were clearly understood to be flat. This concept was particularly relevant to my own work, as I was intrigued by the complexity created by an image on the flat, illuminated digital screen, and my two-dimensional digital drawing of a three-dimensional artifact.

The contrast between the image's smooth linearity at 100 percent view and its fragmented appearance when zoomed in to, say, 2000 percent, allowed me to observe the granular pixel detail. I zoomed in to draw and I evaluated my progress by zooming out, making continuous optical adjustments as I re-conceptualised the subject matter that was invisible to the naked eye. This process involved a form of optical trickery, in which I saw and experienced the specimen as it truly is at 100% view, while mapping its pixel detail (at 2000%), using a limited set of tools (such as vector shapes and stroke) on an illuminated computer screen. Through this process, I gained further understanding of the mediating role of technology in my practice – specifically, how the photographic artifact, the computer and the software mediated my activity.

As photographer, curator and academic Monika Takvam (2010: 321–330) articulates, this process of seeing to understand phenomena transcends mere observation; it involves gathering, sorting, interpreting and arranging information through our senses. In my work, I focused on re-mapping SEM data to reduce complexity and enhance the functionality of scientific data, going beyond pure empirical effect. However, I ultimately found that my efforts led to the recreation of complexity rather than its simplification. This experience reinforced my understanding of drawing as a practical method for untangling (to re-configure) information, allowing me to engage with the data in a more meaningful way. It highlighted the intricate relationship between art and science, where attempts to clarify can reveal deeper layers of complexity.

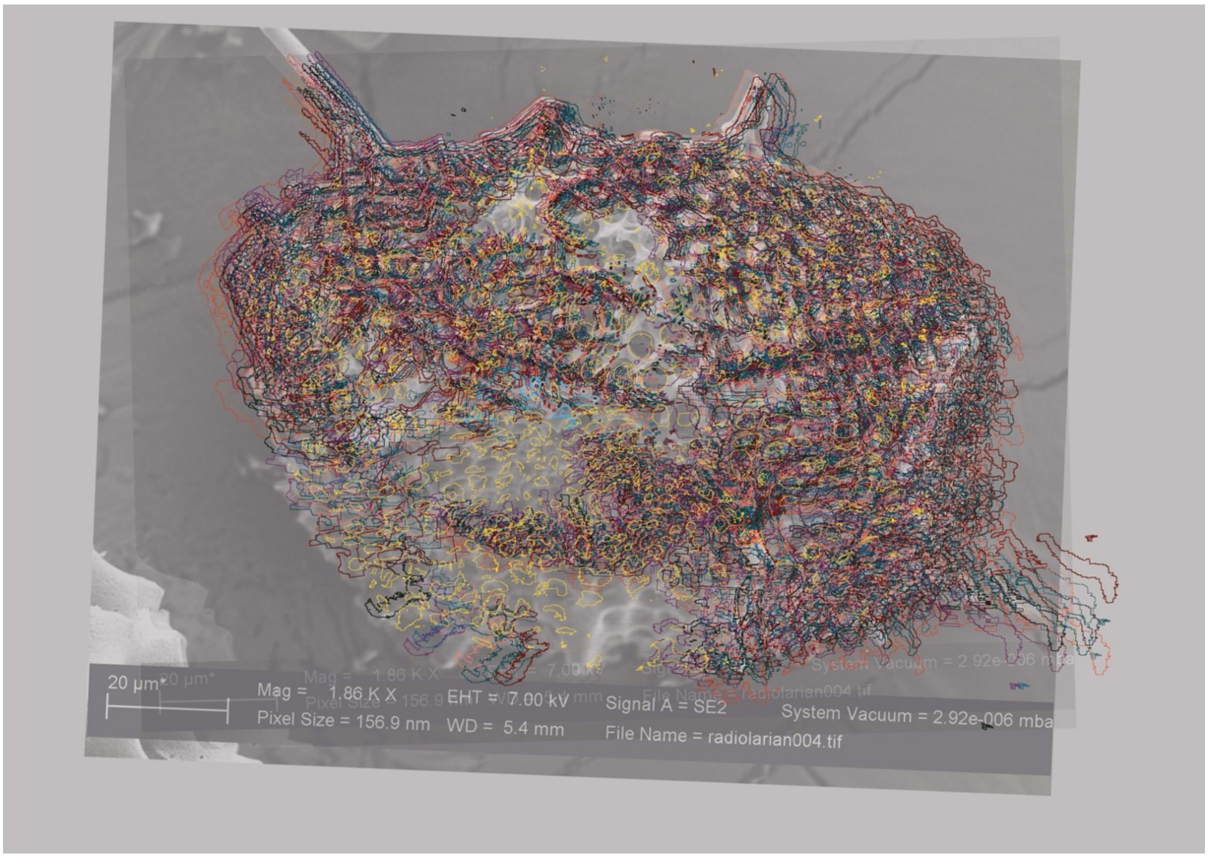


Figure 59. Berry-Frith, J. (2019) Radiolarian004.ai. 85 x 58 cm. © Jo Berry-Frith.

In creating Figure 59, I employed a range of graphical techniques, including copying, layering, opacity, rotation, offset and repetition. The drawing consists of sixteen layers, starting with a matte light-grey background. On top of this, I placed two copies of a Radiolarian photograph, angled and offset, with a transparency set to 20 percent. I then drew over this image, copying and pasting the drawing twelve times. The top layer features a linear yellow illustration that highlights the spatial gaps (negative space) between the solid structure of the Radiolaria. My aim through layering was to integrate these distinct digital-drawn elements into a cohesive visual. This integration emphasises the intricate relationship between the shape and its exterior structure.

To convey that the work is not a flawless artifact, I included an incomplete light-blue drawing on top. This choice reflects my idiosyncratic, hand-drawn approach, revealing that some sections remain unfinished. My intention was for the computer-generated image to reflect my active engagement as an artist, showcasing the process of re-mapping complexity through drawing, without the pressure to create something wholly complete. I recognised that some complexities can never be fully resolved.

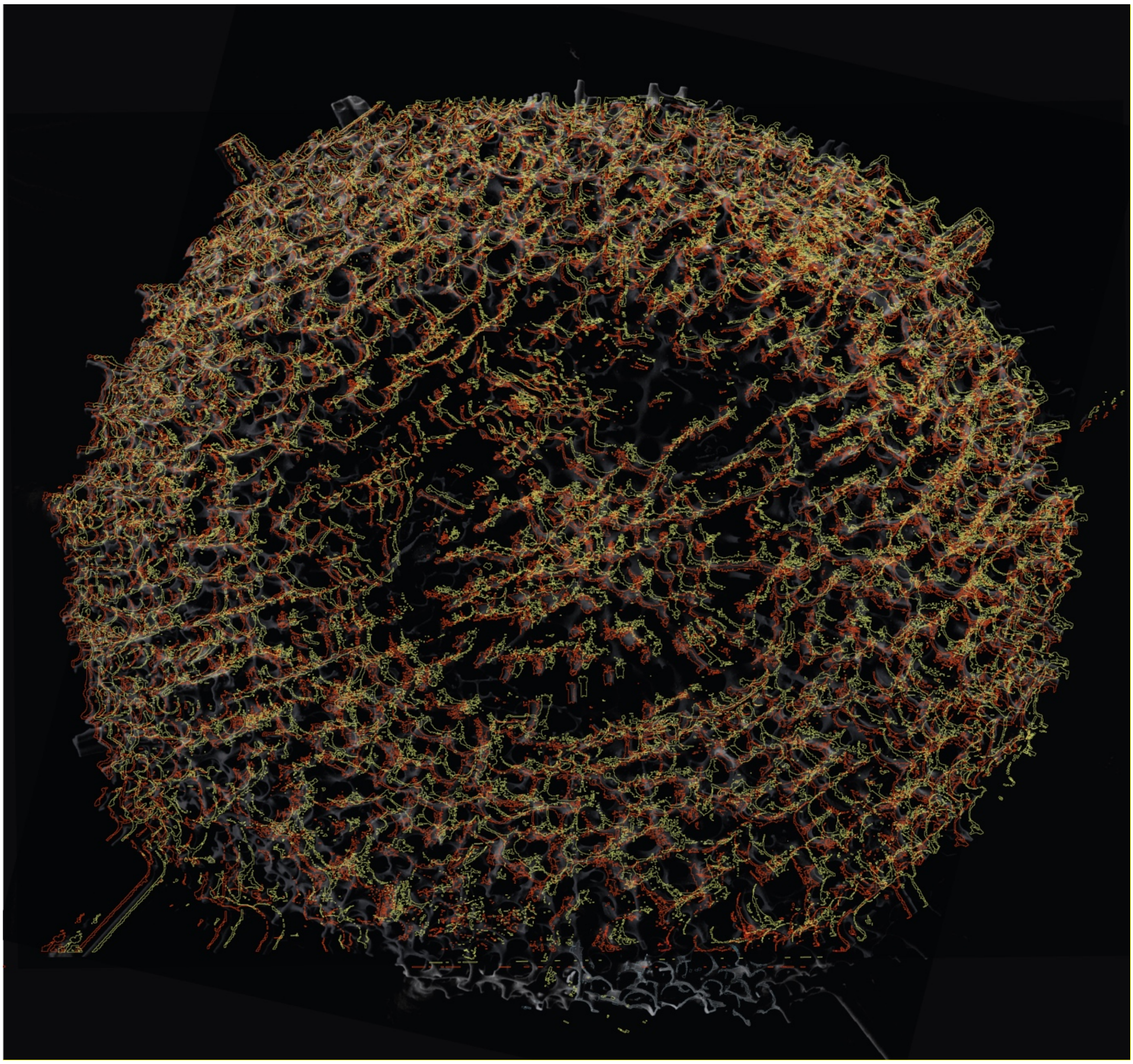


Figure 60. Berry-Frith, J. (2023). Radiolarian drawing offset and rotated twice.ai .84 x 55 cm. © Jo Berry-Frith.

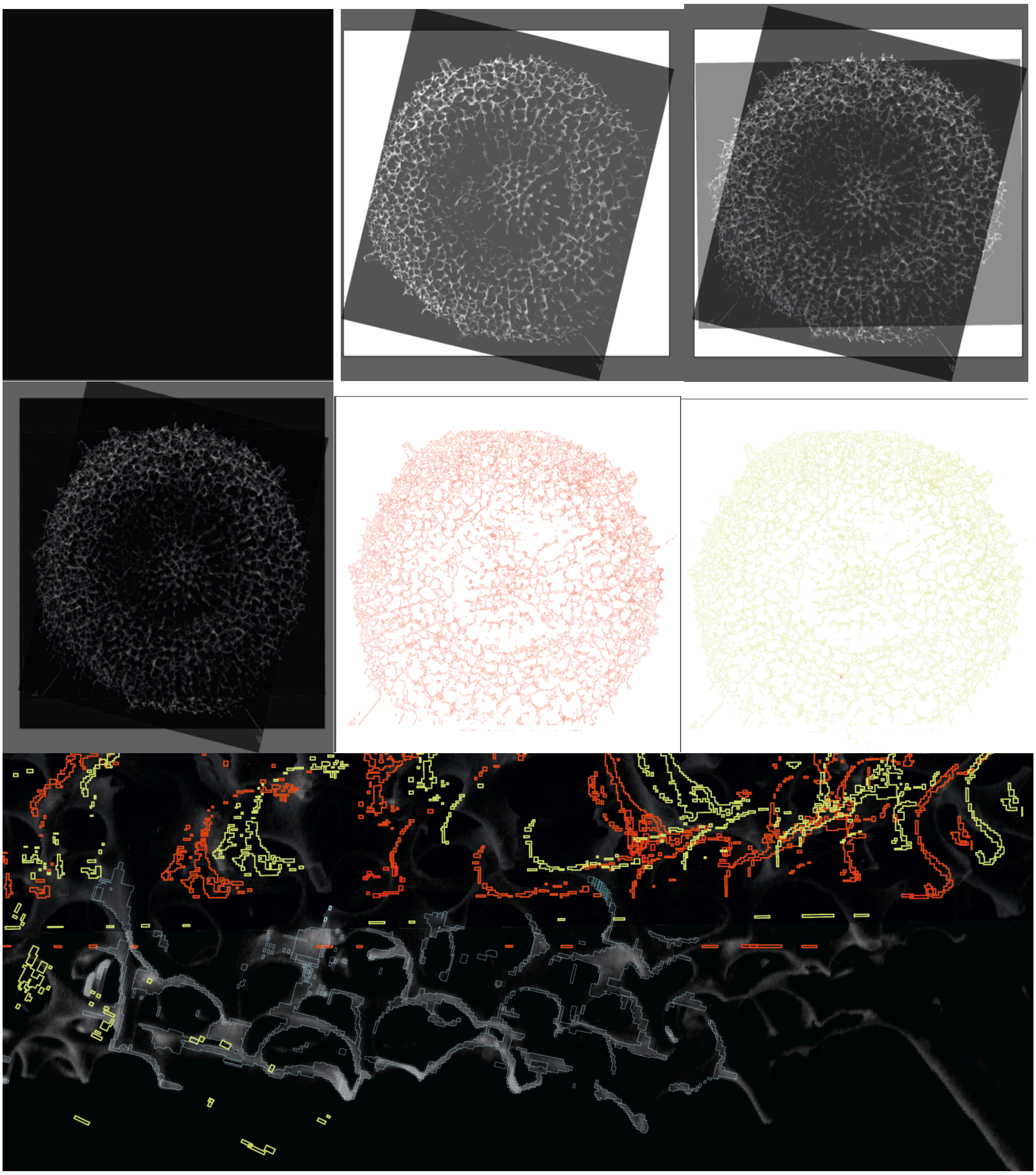


Figure 61. Berry-Frith, J. (2023) Screen shots of Radiolarian drawing offset and rotated twice.ai .84 x 55 cm. © Jo Berry-Frith.

Figures 60 and 61 present the final Radiolarian in this series, where I meticulously engaged in mapping pixel data at a magnification of 2000 percent. Over two years, I dedicated myself to capturing the pixel data in bright, dark and mid tones. This reflective process, examining micro- and macro-perspectives on the computer screen, initially overwhelmed me with information (a common feature of every digital drawing I made). However, as I progressed, my strategy crystallised, guiding my decisions about what to map and what to omit. The Radiolarian is centred yet slightly offset, rendered out of focus, and fits snugly within the pictorial frame. It comprises six layers: a solid black background, a photograph of the Radiolarian at 68 percent transparency angled at 257.4 degrees, another centred photograph at 45 percent transparency, a traced pixel drawing in orange (0.75 pt stroke weight), a slightly offset and rotated yellow drawing (0.75 pt stroke weight) and, finally, an incomplete light-blue drawing (0.25 pt stroke weight). This layering plays with visual perception, creating a subtle divergence akin to a holographic stereo image crafted by hand rather than by software, reflecting my engagement with the complexity of representation.

In my own practice, I have found that creating digital drawings served as a significant outlet for playfulness, which in turn enhanced my creativity. In 'Play, Playfulness, Creativity, and Innovation' (a reprint) published in *Animal Behaviour and Cognition* in 2014, Bateson notes that the study of play was once considered a non-subject. Play was viewed as the polar opposite of labour and, as such, it was incorrectly dismissed as a non-serious research issue in the 1970s. However, in recent years, interest in this type of behaviour has grown dramatically (Bateson, 2014).

For me, the process of drawing became an exploration – an opportunity to engage with ideas and forms without the constraints of conventional expectations. I created my own rules and conditions for play, which made the drawings I produced distinct. My creative acts of play – shaped by the computer, data and software – existed in a world defined by the seriousness of their own purpose (Gadamer, 1998: 124). As an artist, I was motivated by meticulous observation, investigation and evidence-based reasoning to communicate innovative methods in re-fabricating complex three-dimensional structural forms of biological specimens. I considered drawing to be an advantageous means of expression because it was exploratory in nature and created “flow” (Csikszentmihalyi, 2008: 116–117). Drawing was an intuitive activity, which absorbed me as the player. Drawing taught me that seriousness was not merely something that prevented us from playing; rather, seriousness in play was essential to making the game truly playable (Gadamer, 1994: 102). According to Arnett (2018: 20), in his article ‘Gadamer: Ethics and the Dialogic Character of Play’, play allows for the exploration of unknown possibilities, similar to jazz thinking. To hear or see something that others cannot, one must be familiar with the musical or visual norms. Only when the interpretive effort is led by logic and serious abilities may ‘playing’ lead to enlightened discoveries. That is why I took the act of drawing so seriously. I made surprising discoveries. For example, I found the process to be thoroughly absorbing in ways that I had not expected, and it opened up unplanned experimentations. This led to a profound understanding of movement, rotation and composition, prompting me to experiment with varying line weights and techniques such as cutting and pasting. By adopting playful strategies to reinterpret images, I uncovered optical tricks that challenged conventional ways of seeing. This dynamic interplay between intention and spontaneity enriched my artistic practice and deepened my appreciation for drawing as a medium for discovery and innovation.

Findings from digital drawing

Re-mapping three-dimensional, structural complexity allowed for an experiential exploration of phenomena that lie on the edge of visibility (Casey and Davies, 2020: 208–209). The act of drawing became an end in itself, as digital drawing was a key method for exploration. This process was characterised by a serious engagement with data, where each action was rooted in creative ideas that showcased the expressive potential of digital drawing, revealing both skill and authorship. Throughout my practice, I repeated individual actions, often leaving drawings incomplete or intentionally exaggerated, while also experimenting with optical tricks such as offset and repetition. I approached my work instinctively and adaptively, staying attuned to the surrounding circumstances (Bateson, 2014).

The third cycle of art project two: Dissemination

The NHM lacked exhibition and presentation opportunities. Consequently, the third cycle of practice faltered, since the scientists and the wider field of scientists at the NHM could not witness the artwork I made for them to feed back on. Hence, I did not complete the game I set out to play with Ball and members of IAC. I took a pragmatic approach; even if no-one observed my creative achievements at the NHM, they were nonetheless important to me as an artist–researcher and to other audiences. Several other outputs were presented and exhibited at alternative conference events and through publications, including Cumulus Conference (2016), Open Design for Everything Hong Kong; A Chapter in *Big Data in the Arts and Humanities: Theory and Practice* (2018), (see Appendix Seven); *Varoom Lab Journal* Issue 4 –Visionaries (2016), The Varoom Lab, a solo exhibition titled: *Art–science interplay,* The Coningsby Gallery, London, 17 July – 29 July 2023, and several other events (see Appendix One).

Findings

According to Professor of Economics Jonathan Levin (2002), incomplete games are models with information gaps, where participants lack a shared understanding of the rules. This concept is crucial for capturing data in situations where many aspects are unknown or unclear. In my research, I did not complete the ‘game’ (dissemination in cycle three) I initially set out to play with Ball. However, this openness to uncertainty broadened the scope of the project, allowing for a more expansive approach to the data and its implications. Unlike the first study, where dissemination occurred away from the IAC lab, I recognised that completing the game could have brought additional feedback and uncovered new networking opportunities. In the next project (see Chapter Five), I took the initiative to communicate my intention to share the research with the scientific community by presenting it at conferences, ensuring that the broader implications of our collaboration were fully recognised.

The fourth cycle of art project two: Reflection

As in art project one, I reflected on data from cycles one to three to evaluate how play-based activities shaped my adaptive framework. This process of reflection revealed how play and technology can reshape relationships across disciplines.

Cycle one: I could now see that adopting Ball's scientific framework influenced my creative direction as an artist working with new technology and subject matter, while Ball's engagement and feedback regarding my artistic methods (PAR, disrupting SEM imaging protocols, documenting data) broadened his own frames of reference. I am more convinced that alternating between solo and collaborative two-way instructive play extended our examination and understanding of micro-structures and SEM. Additionally, I recognised that further vigorous testing with Ball and other scientists was required.

Reflecting on my process, I found that using a semi-systematic approach to documenting and analysing data helped me understand better complexity by mapping the networks and connections involved. Moving forward, I aim to develop this method further to enhance the experimental (reflexive) aspect of my work.

Cycle two: I am now convinced that Ball's concept of versatile imaging as a three-dimensional sketch has significantly deepened my understanding of structural complexity.

This was especially evident in organisms like Radiolaria, where my ability to interpret complex data was improved.

Cycle Three: I realised that the limited presentation opportunities at the NHM encouraged me to develop a more flexible dissemination strategy and seek feedback through external platforms. In retrospect, I realised that this was beneficial – sharing my work beyond the IAC lab broadened its interpretation and impact. Informal feedback from the public, artists, designers, academics and scientists reinforced the value of my interdisciplinary approach.

Going forward, I intend to plan for feedback and dissemination from the beginning, while staying open to unexpected opportunities – engaging curators, specialists and evaluators to embed critical reflection more deeply throughout the process.

Cycle four: This phase of the project marked a pivotal shift in my investigation of the intersections between art, science, play and technology. By integrating qualitative and quantitative methodologies with serious play, I was able to engage more critically with diverse modes of knowledge production. This hybrid approach extended the inquiry beyond the boundaries of what either artistic or scientific methods could achieve independently. In retrospect, the work undertaken during this cycle represents a more deliberate and methodologically rigorous application of concepts that had previously emerged intuitively in Art Project One.

Looking ahead, I intend to establish longer-term, collaborative engagements with the NHM to more effectively trace and understand the evolving processes, relationships and epistemologies that underpin such interdisciplinary work. Theories of play deepened my appreciation for the significance of this research, especially for lab-based scientists and artists seeking collaborative models and opportunities for wider dissemination. Play induced contemplation, which was a vital element of creativity and an approach that enhanced the developmental outcomes of my research – particularly in refining my visualisation techniques. This was exemplified by my drawing and use of SEM to visualise subject matter in ways that extended beyond its original scope, revealing effects that exceeded expectations. This process reinforced the value for long-term collaborations between artists and scientists, demonstrating how such partnerships can uncover new dimensions in both fields.

Conducting research at the NHM confirmed the importance of training artists to work within scientific laboratories, without expecting them to replicate the same results as scientists. It also illustrated how artists and scientists can coexist and contribute equally to knowledge production when given appropriate structure and support.

Points of Learning: Mastering SEM imaging methods was time consuming, and I would have liked more time to examine defects and visual aberrations to investigate fully each sample's structure. I did not inform scientists that my approach was a 'game' – a detail I kept hidden, wondering how they would perceive it. In retrospect, I might have been more transparent. Since my findings were not directly presented to NHM scientists, I hope to do so in future collaborations, especially around topics such as carbon sink properties.

Art Project Two's significance

I was one of only five artists to have conducted research at the Imaging and Analysis Centre (IAC) at the NHM (2015 and 2024) — a strikingly low number given the scale and resources of the institution. This rarity highlights the limited access artists have to scientific environments, raising critical questions about how such spaces are structured, who they are for, and what forms of knowledge are privileged. My work at the IAC aimed to interrogate these boundaries and advocate for more porous, interdisciplinary approaches to research.

I used scanning electron microscopy (SEM) as my primary imaging tool. In a two-way, instructive collaboration with Ball where we focused on capturing microstructures, I challenged traditional scientific protocols, blending artistic creativity with scientific rigour. By embracing experimentation and serendipity, Ball and I created visualisations that were beyond standard imaging protocols, driving cross-disciplinary innovation and new approaches to interpreting microstructures.

This “rule-breaking” mindset and our shared willingness to ask, “what if we try that?” led to a transformative collaboration that transcended disciplinary boundaries. Pushing the limits of Ball’s training, we produced visualisations that extended his insight into conventional scientific practice.

My creative strategies challenged a reliance on systematic observation and evidence-based reasoning. SEM training served as a catalyst for interdisciplinary learning, fostering new techniques that disrupted traditional scientific frameworks. The resulting images – unfocused or unconventional – questioned assumptions and revealed the value of cross-disciplinary collaboration in generating new insights. Open discussion and joint experimentation enabled us to challenge norms, while cultivating a space for creativity that moved beyond disciplinary silos.

Our collaboration enriched our individual practices. The fusion of artistic and scientific perspectives led to novel ways to understanding complex microstructures. The captivating monochromatic primary datasets we captured extended my understanding of what an artwork could be – be it a single SEM image or an entire series. Our exchange sparked an ongoing dialogue with Ball and Dr. Giles Miller, and we continue to collaborate to deepen scientific understanding through the lens of artistic inquiry.

Through independent experimentation, I pushed SEM to its optical limits, challenging imaging conventions to explore complex microstructures. Techniques I developed included:
(a) *Visual Aberrations* – capturing bright glowing spots that added unexpected depth;
(b) *Dynamic Imaging* – moving the stage during active electron charging, creating beam drift and double exposures;
(c) *Multi-Focal Framing* – composing images with three focal points; and
(d) *Unique Formations* – capturing malformed structures, calcareous attachments, and other anomalies.

A shared interest in drawing also became a key part of our collaboration. While both of us valued scientific observation and technological innovation, we questioned the diminishing role of drawing in the age of advanced microscopy. We recognised drawing's continued power to facilitate shared understanding.

Building on this, I reinterpreted the scientific concept of "versatile imaging" as a three-dimensional sketch using Adobe Illustrator. I developed a series of digital drawings that represented Radiolaria microstructures, serving as counterpoints to purely computational SEM imagery. Through drawing, I explored how digital tools could represent depth and complexity within a two-dimensional format. This approach enabled me to explore the dynamic interplay between depth and flatness, manipulating the retinal and pictorial fields within the confines of a two-dimensional computer space.

The innovation in my work lies in its approach to recreating complexity rather than simplifying it. Using photographic artifacts and digital tools, I reshaped how complexity could be interpreted through visual art. These experiments disrupted conventional imaging practices and deepened viewer engagement with microstructures.

My drawings also resonated with Bruno Latour's Actor-Network Theory (ANT) (2010), illustrating how knowledge is shaped through networks of human and non-human interactions. This theoretical lens supported the idea that my art practice not only challenged imaging norms but also opened new avenues for unravelling art and scientific connections.

Cycle Three's focus on dissemination enabled critical feedback through non-scientific exhibitions, presentations and publications (see Appendix One). This broadened public and institutional engagement with NHM's microstructure collections. The digital drawings and SEM artifacts expanded the visual vocabulary of scientific resources. This dissemination helped audiences understand better interdisciplinary collaboration and enriched knowledge exchange.

A major achievement was my ability to act as a mediator between scientific processes and diverse audiences. By challenging singular viewpoints, this part of the framework furthered collaboration and reframed scientific processes as creative acts. This conceptual shift contributed directly to addressing the research questions laid out in Chapter One.

My goal in the next art project was to complete a comparative visual survey across all four cycles of activity. This synthesis was to bring the "game" to completion and to serve as a foundation for generating new collaborative platforms and multidisciplinary perspectives.

Chapter Five: Art project three

The first cycle of art project three: In the core imaging lab

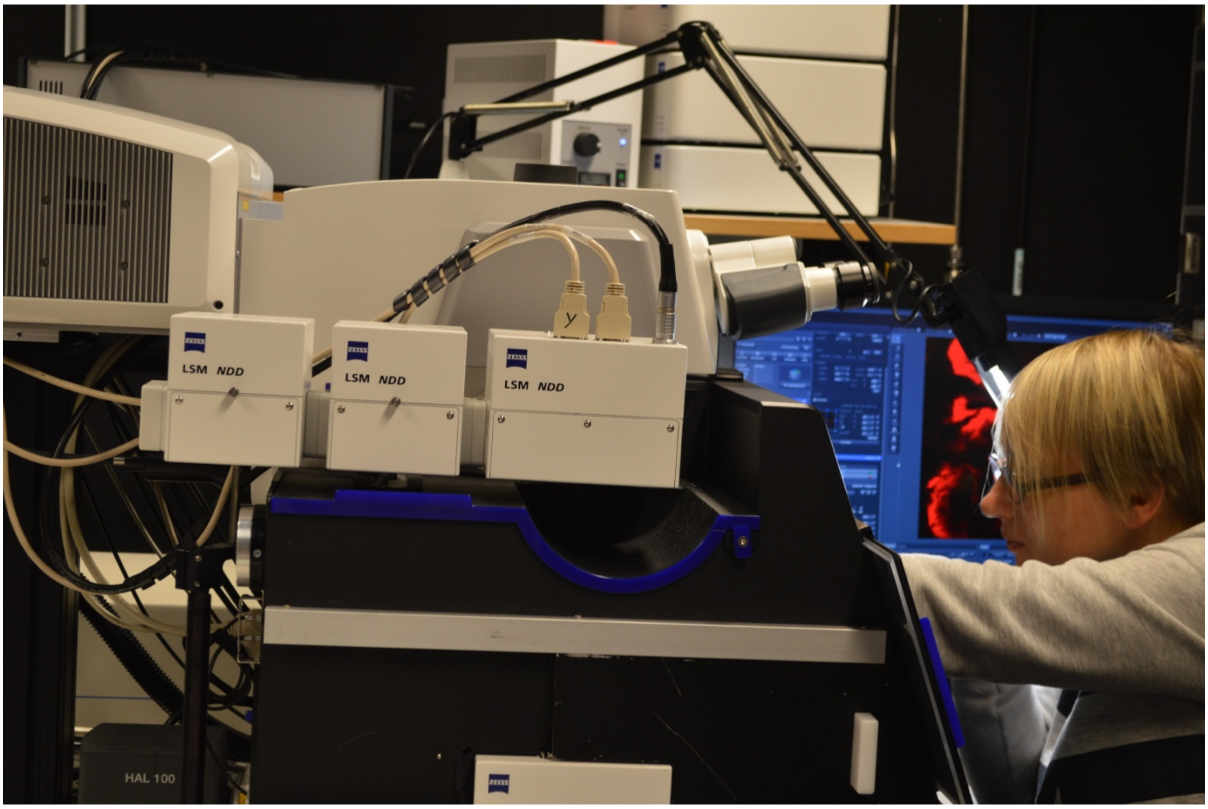


Figure 62. Berry-Frith, J. (2016) Jankunec working on the Multiphoton Microscope. 14.8 x 10.5 cm. © Jo Berry-Frith.

This chapter begins with the premise that completing the “game” does not signify an end, but rather consolidates a new methodological and conceptual terrain. By concluding the four-stage integrated model – designed to blend art with scientific research and foregrounding play as both a methodological tool and a way to challenge disciplinary boundaries – this final project becomes a pivot point for future exploration. The focus here shifts toward synthesis: integrating insights from the previous two projects and reflecting on the evolving priorities across four practice cycles. Rather than serving as a summation, this project is a culmination, that is, a point of convergence from which new forms of cross-disciplinary collaboration, inclusive perspectives and interpretive frameworks may emerge. Through the lens of play, creativity and innovation are fostered, roles and expectations are reframed, and new ways of thinking are encouraged.

As with art projects one and two, each cycle contributed distinctively to this integrated body of knowledge. In this third art project, cycle one centred on face-to-face participatory research with four scientists, again with the intention to explore the role of play within laboratory environments, deepen my understanding of advanced imaging modalities and foster creative teamwork. This phase combined technological, ethnographic, dialogic and practice-based data to map the contours of artistic engagement in a new scientific setting.

Building on this foundation, cycle two focused on expanding creative outputs and developing more robust practice-based methodologies. In cycle three, I worked to solidify my identity as an artist–researcher in the field of bio-imaging by presenting findings at two international scientific conferences in Sweden. As discussed in Chapters Three and Four, dissemination and feedback were instrumental in refining and articulating alternative approaches to science. These iterative efforts culminated in the fourth and final cycle of this study.

As the chapter unfolds, it examines how drawing functioned not merely as representation, but as an epistemic method, capable of expressing the complexity, ambiguity and nuance inherent in interdisciplinary research. Through the dynamic interplay of solo experimentation and collaborative inquiry, a hybrid and adaptive model of artistic–scientific exploration emerged – one grounded in dialogue and reciprocal learning.

This final project builds not only on the knowledge produced in earlier cycles but also on the relational and conceptual transformations made possible through sustained collaboration. It adopts a semi-systematic approach to data collection, rejecting the unifying logic of traditional science in favour of layered, responsive and situated modes of seeing. Within this framework, drawing and visual play are positioned as legitimate tools of inquiry, and I (as the artist) becomes a mediator, reframing laboratory practices as inherently creative acts.

Tim Self, Head of the School of Life Sciences Imaging Facility and Chief Experimental Officer at Nottingham University, was a key collaborator (see Introduction). In 2014, Self introduced me to Julia Fernandez-Rodriguez, the Centre for Cellular Imaging (CCI) manager, believing we would collaborate effectively. Fernandez-Rodriguez was familiar with the pilot research 'Hijacking Natural Systems' (2010–2011) and was eager to promote art–science collaborations in Sweden and the Nordic countries. I was first invited to present my research at the Nordic Imaging Conference in 2014. In 2016, Fernandez-Rodriguez initiated a multidisciplinary research project involving SkinResQU (Biomedical Photonics group at the University of Gothenburg), The Biofilms Research Centre for Bio-interfaces (BRCB) at Malmö University, Sweden, and industry partners. She invited me to participate, providing a significant opportunity to collaborate with bio-interface professionals on an international project and to be trained in multiphoton microscopy (MPM) for imaging deep skin samples. I collaborated with three researchers: Fernandez-Rodriguez, Principal Investigator (PI) Professor Johan Engblom, and Post-Doctoral Researcher Jeanne Jankunec. Professor Marcia Ericson, another PI, served as an adviser. None had previously worked with an artist–researcher, but they all granted permission to be recorded and, as the project progressed, they gave their permission to switch roles and document my actions (as detailed later). From the onset there was a mutual desire to engage in a meaningful collaboration. I had complete freedom to use empirical data as I thought fit.

In this study, my collaborators and I examined the effectiveness of skin treatments and the depth to which cream penetrates skin. We employed MPM, a laser-scanning confocal microscope that combines two or more photons to produce high-resolution, three-dimensional data of microscopic material (see Figure 62). Through this experience, I gained a comprehensive understanding of MPM technology, learning how it provides a nonlinear optical effect that allows for the creation of three-dimensional images. I was also introduced to Optical Diffraction Tomography (ODT) (Ayoub et al., 2022), a technique to image three-dimensional semi-transparent objects.

As a participatory action researcher (PAR) (Gray and Malins, 2004), I documented every activity and interaction throughout the week, conducting semi-structured interviews and engaging in various group events, including midday discussions and evening social gatherings. This immersive approach enabled me to test my hypothesis and explore my research questions within an international laboratory setting. As a result, I acquired in-depth knowledge of MPM's intrinsic features, as well as valuable insights into skin research.

Adopting an inquisitive approach aided interdisciplinary collaboration and deepened my understanding of the synergistic possibilities between art and science, particularly as I mediated the use of new tools and technology. I focused on the mechanisms, characteristics, attributes and emergence of play as a means of eliciting data. This approach allowed me to test and refine my play-based creative processes, while collaborating with scientists in the lab. Through this collaboration, I examined a network of interconnected relationships, as I discuss later.

As both instigator and investigator of play, I embraced serendipity by introducing role-play, mimicry and play-centric dialogue, informed by insights from art projects one and two. I focused on a key characteristic of play, its serious, even sacred quality, which I observed in formal settings like the core imaging lab (Gadamer, 1994: 102). To foster cultural awareness, I drew on my curiosity, adaptability and willingness to learn. I actively sought experiences beyond my core expertise and embraced opportunities to take risks. Johan Roos and Bart

Victor's (2018) work on LEGO Serious Play (LSP) and its emphasis on knowledge emerging from personal, history-dependent and context-driven research added to my understanding of how interactive, context-sensitive methods could be used to explore complex scientific questions. Given my limited biomedical knowledge and the unfamiliar research setting, I focused on addressing issues such as public perceptions of scientists and scientific freedom. I deliberately sought out playful elements already present in the lab, such as scientists' use of process-driven techniques, which I saw as creative and innovative. I studied the culture and traditions of the lab to develop effective strategies for understanding how play was integrated into the laboratory environment, as I looked for serious, calculated play activities. This allowed me to gather data efficiently, even within strict time constraints.

Drawing upon the findings from art projects one and two, I adopted a performative approach, immersing myself in the role of a scientist. I wore a white lab coat and learned to complete all skin preparation procedures, fully engaging in the scientific process. Simultaneously, I documented all activities through film, photography and notes in my lab book.

Jankunec and Engblom, the scientists visiting from Malmö University, were not familiar with CCI, which introduced an important dynamic to my research. As we all adapted to new roles and adjusted to the laboratory environment, I built on the methods I had previously employed. This allowed me to gather evidence on how play functioned within the context of a new laboratory setting, with scientists who were also less familiar with the lab's procedures and dynamics.

Figure 63. Berry-Frith, J. (2016) Jankunec preparing skin samples. 14.8 x 10.5 cm. © Jo Berry-Frith.

Figure 64. Berry-Frith, J. (2016) Skin-preparation tools and materials. The pre-prepared skin sample is inserted between two plastic circles and on top of a small water-filled glass bottle using tweezers. Rhodamine (fluorescent dye) is applied topically in a cream. Zero hours, six hours and 24 hours. Simultaneously, a drug-free control experiment is conducted. Three times per experiment. In each experiment, skin is immunostained with three solutions to determine viability. After 10 minutes in the water bath, the lotion is washed off. 14.8 x 10.5 cm. © Jo Berry-Frith.

Figure 65. Berry-Frith, J. (2016) Before analysing skin components without lotion, non-fibrous tissue is ethanol-washed and utilised. After which, a skin sample is applied to a glass plate with white sticky paper; a brown paper frame binds it; blue varnish protects it; and the slides are labelled for imaging. 14.8 x 10.5 cm. © Jo Berry-Frith.

Figure 66. Berry-Frith, J. (2016) Documentary photograph of Jankunec's hands. 10.5 x 14.8cm. © Jo Berry-Frith.

One advancement in my exploration of play in this study was my examination of mimicry as a key element of role-play. For instance, I mimicked Jankunec's behaviour during training to prepare skin for imaging, aiming to gain insight into her process-driven practices, such as her body language and the timing of experiments. By replicating her actions, I sought to align myself with her professional expertise and create the impression of being a competent scientist. This strategy allowed me to immerse myself more fully in the scientific environment, while highlighting the performative nature of scientific and artistic practices (see Figures 63–66).

This approach was deliberately performative, as both my collaborators and I were aware that I wasn't a scientist. In fact, this very awareness of my non-scientific status was one of the reasons I was included in the lab setting. Nevertheless, my goal was to assimilate and adopt the role of a scientist. Drawing from my experience in other scientific labs, I was determined to be perceived as competent by those unfamiliar with my background. I recognised that mimicry – specifically the ability to adopt the behaviours and attitudes of a scientist – became a strategic tool to navigate the lab environment more effectively. It allowed me to bridge the gap between artist and scientist, fostering better understanding and communication.

This experience reinforced the importance of understanding the meaning behind all actions. As I learned new protocols, customs and strategies relevant to my study, I recognised how crucial it was to adapt and integrate these practices to function effectively in the scientific setting. By intentionally employing play, I navigated this unfamiliar space with greater ease, demonstrating the potential of play as both a tool for learning and a means of connecting across disciplinary boundaries.

Jankunec was a postdoctoral researcher and biophysical technologist with expertise in atomic force microscopy (AFM) (Ekelund et al.,1999), artificial membranes, drug delivery, liquid crystalline phases (Tadros, 2013; 2017), and skin membranes (Singh, 2024). At the beginning of our collaboration, she expressed her nervousness by saying, “Well, I’m trembling because this isn’t my typical work”, as I documented her preparing glass slides ready for imaging. I noted our interaction was cautious and exploratory in nature, necessitating the establishment and agreement on boundaries and norms (Caillois, 2001). Jankunec and I, as participants, mutually defined the parameters of our interaction, setting up the game of mimicry that I encouraged her to play. I established the boundaries for this play, ensuring respect by consistently checking if it was acceptable to copy her actions as I followed her instructions after observing her. I proceeded to meticulously mimic Jankunec’s actions, which changed her from being unable to engage in play to being playful. In turn, this helped her feel more at ease as we worked together. I noted her body language, her stance, and how she used tools (see Figure 64–66) to cut skin to the proper proportions (the size of a fingertip) to fit precisely onto the glass slides (sized 25 x 75 mm).

Importantly, as we became more familiar with each other, I asked Jankunec to perform a new role and photograph me doing science. She became a documentary photographer as I directed her to capture images of me imitating her actions while preparing skin specimens, following her instructions. From mimicking her actions, I was able to appreciate the labour-intensive practical methods required. I pondered on the creativity of human intervention, the dexterity of Jankunec’s hands and the scientific rigour required to prepare samples for imaging during these regular chores. From mirroring Jankunec’s activities, I began to focus on capturing crucial components of the scientific process that I found intriguing, such as hand gestures and tools. She had to take on the unexpected role of educator and demonstrator. Despite her reticence, this simple act of instructional role-play overcame our initial awkwardness and built trust, which made for a truly collaborative experience.

Accurately mimicking Jankunec's actions was an integral part of my learning process. According to Caillois (2001: 20), there is a similarity between insects and humans in their tendency to engage in mimicry and play roles. He draws analogies from the insect world, particularly mimetism, which refers to the mimicry exhibited by certain species. For instance, the praying mantis disguises itself as an emerald blade of grass. Krauss (1998: 155) refers to this phenomenon as "protective coloration", where the organism mimics its surroundings to evade predators. Similar examples of mimicry can be found in philosopher David Rothenberg's (2013: 6–9) examination of the biology and science behind the actions of bowerbirds. These birds are known for their tendency to create art, despite each species producing drastically different forms. This diversity in their creations intrigued me.

For example, the satin bowerbird builds a simple avenue and decorates it with blue objects, while the Vogelkop bowerbird constructs a teepee-like mound around a pole, surrounding it with small piles of flowers, seeds, and feathers from birds of paradise. These contrasting approaches can be compared with the differing responses I had with Jankunec in this scientific investigation project. While we both collected data from the same process, we responded and disseminated it in distinct ways.

Jankunec, as a scientist, was responsible for conducting experiments in an efficient and precise manner, systematically addressing the research question. She provided the results to the PIs, her university research group, sponsors and industry partners, all of whom sought to publish the findings in an academic paper. In this context, she was one component of a larger organisational framework. On the other hand, I, much like another species of bowerbird, eclectically documented the visual aspects of the laboratory that caught my attention, such as the fluorescent pink cream and sky-blue glue, or the textures of materials like tin foil, rubber mallets, glass slides, metal spatulas and sticky-back plastic. I collected data that I found visually captivating, seeking to generate a different interpretation of science, as discussed in the second cycle of this research.

I focused on the practical applications of science to highlight the importance of the various practice models used by scientists, specifically exploring how the objects we used shaped our work (Verbeek, 2005). This approach enabled me to examine both the remarkable and bizarre, yet practical aspects of the scientific process. Throughout, I remained acutely aware that my level of competence with the scientific equipment did not match the expertise demonstrated by Jankunec. This discrepancy deepened my appreciation for the customised processes and handcrafted tools Jankunec employed in preparing skin samples for imaging. Objects of interest included the scientific spatulas used for mixing, scraping and transferring materials, the metal skin cutter and heavy rubber mallet, as well as more domestic items like plastic chopping boards, cutting scissors, glue, nail varnish and sticky-back plastic. These everyday objects revealed how materials and tools are deeply integrated into the practice of science. There were also elements of tacit knowledge – the sensory experiences that were often difficult to articulate, such as the smell of ethanol, the steam from the water bath and the thickness of the (fluorescent pink) cream. As an artist, I found that photography and film became my primary means of capturing these sensations, allowing me to document aspects of the lab that might otherwise remain intangible.

Furthermore, while working at the scientific bench in this small basement laboratory, I recorded individual scientists and technicians as they conducted their daily experiments. This provided valuable insights into the lab's routines, which I could then incorporate into my artistic work. By constructing an emergent, responsive, and eclectic model for data collection – incorporating both the atypical and the mundane – I was able to explore and extract fundamental aspects of science that transcended empirical rationality.

Developing a sensitivity to these elements and capturing a broad spectrum of both human and non-human data enabled me to establish connections between the material world and human activity. I examined how human aspects (gestural, auditory, intellectual, etc.) and non-human elements (tools, materials, processes, sounds) were interwoven. This approach allowed me to understand how these components converge, affecting my appreciation of the relationships that shape scientific practice.

For instance, Jankunec frequently had to explain what objects were used for, and because English was not her native language and I could only speak English, at times this resulted in disjointed sentences that did not make logical sense, such as “it’s our plastic, our student prepared the holes” and “you have voter vapour, so voter will go up. Then I will put to the voter bath for ten minutes”. I noted her Eastern European accent, and how she pronounced phrases like water as ‘voter’, captured live as an audio recording. While she was speaking, and later when I listened to the recordings, I mentally imitated her comments and paid attention to the intonations of her accent. I found this to be one of several captivating linguistic details and sounds that I included in my practice. It prompted me to pay closer attention to how play-centred dialogue emerged as I examined the communications we used across our distant epistemic cultures (Birsel, et al., 2023).

Developing this play-centred, intuitive and responsive model – learning science by playing at being a scientist – allowed me to map fundamental aspects of reality that transcended logical thinking and rational feeling. It expanded my visual, performative, process-oriented, implicit, tactile and auditory knowledge. These diverse elements together embody a holistic approach to engagement, one that integrates multiple senses and modes of interaction. This approach not only deepened my understanding of empirical practices but also enriched the experiences generated through the inquiry and the emergent knowledge that resulted from it.

Expanding upon the ideas presented in art projects one and two, I invited every scientist to share their thoughts and engage in discourse about being a scientist, aiming to comprehend better our divergent viewpoints. As the research progressed, each gradually revealed more about what they were thinking and feeling. For example, I gained insight into Jankunec both as a scientist and as an individual, learning about her hobbies and opinions.

Jankunec believed that scientists always told the truth and assumed the public didn't understand the challenges scientists faced. Yet, she also thought that the public viewed scientists as performing miracles. I found her views puzzling, wondering if she was too immersed in empirical bias and not considering perspectives beyond the laboratory. I began to question whether Jankunec recognised the value of my research to her work. Upon reflection, I realised I had been making assumptions about how artists like myself are perceived. I often believed that the public and scientists overlooked the effort I invested in collaborating with experts who possess specialised skills and knowledge. At the same time, I recognised that my work could offer valuable contributions to my collaborators, even if they remained unacknowledged. Through reciprocal collaboration, I was able to challenge Jankunec's perceptions. By engaging in role-playing, imitating her actions and switching roles, we enhanced our understanding of each other's disciplinary processes and viewpoints.

While Jankunec's meticulous problem-solving methods, such as testing adhesive thickness, highlighted the intense focus on practical details essential for scientific innovation, Engblom, Head of the Department of Biomedical Science at Malmö University, emphasised the importance of networking and visibility for success. He provided a multifaceted view of scientific inquiry, stressing its intersections with broader societal, ethical and commercial considerations. Topics like skin-related ethics, medicinal benefits and the beauty industry's commercial interests revealed the overlap between science, economics and cultural practices.

For instance, discussions about anti-wrinkle creams and Moroccan essential oils connected scientific processes with consumer perceptions and market dynamics. Engblom's anecdote about his wife purchasing expensive products chemically similar to olive oil highlighted the tension between perceived and actual value in commercial goods – a theme that resonates in both science and art.

Ethical considerations in art–science collaborations highlighted the responsibilities of both scientists and artists in navigating disciplinary boundaries. This dialogue underscored how interdisciplinary practices can challenge traditional approaches and the need for thoughtful, ethical engagement in collaborative work.

As part of this reflection, I examined the work of artist Anna Dumitriu and Professor Bobbie Farsides on the ethical challenges faced by bioscience artists (Dumitriu and Farsides, 2015). They observed that as more artists turn to bioart for inspiration and as a medium, ethical concerns are becoming increasingly prominent. Recognising this, they developed a toolkit to address the complexities of multidisciplinary and transdisciplinary creative practices. Between 2011 and 2017, they also organised ethics events to raise awareness of the challenges artists face when engaging with ethics committees, fostering broader discussions around ethical frameworks.

Their insights proved valuable during my interactions with scientists. For example, discussions on the ethical use of pig skin in laboratory experiments revealed that ex-vivo pig skin is readily available from slaughterhouses, alleviating concerns about animal ethics (Uhm et al., 2023). This sparked further dialogue with Engblom, Jankunec, Fernandez-Rodriguez, and Ericson on the parallels and differences in testing theories, processing raw materials into data, and understanding ethical models. These discussions highlighted the importance of integrating ethical perspectives from multiple disciplines, enabling a more comprehensive approach to addressing ethical challenges in collaborative practices.

As noted by Dumitriu and Farsides (2015: 4), and supported by Fernandez-Rodriguez, Engblom and Briddon (as discussed in art project three), creative thinking – often exemplified by the "happy accident" – was once crucial to scientific innovation, but has become increasingly limited by funding constraints. Dumitriu and Farsides argued that incorporating an artist into a scientific institution could help reintroduce play as a catalyst for creativity. My collaborators recognised that the "happy accident" had been more common in the past and valued its contribution.

In my role as a practical thinker focused on process-driven techniques, I drew inspiration from Feynman's unconventional approach to research (Feynman et. al., 2011). I rejected rigid formalisms in favour of a deeply intuitive (serendipitous) methodology and treated the laboratory as a space for exploring innovative practices. This approach was particularly significant as the scientists I collaborated with had never worked with an artist before, making the concept of play as a meaningful tool entirely new to them.

I was increasingly convinced of the benefit of the framework using cycles of practice that I developed. This framework allowed me to analyse unexpected events, surreal moments and the distinctive sounds of multiple languages (Swedish, Spanish and Lithuanian) within the practice cycle. By adopting a hermeneutic approach, I critically examined the scientific method on my own terms, acknowledging my biases and interpreting the research context more imaginatively. This approach deepened my understanding of fundamental aspects of play, including its emergent qualities and impact on both individual and collective interactions.

Figure 67. Berry-Frith, J. (2016) Fernandez-Rodriguez setting up the multi-photon microscope [screen shot of film footage]. 14.8 x 10.5 cm. © Jo Berry-Frith.

One memorable example of how play emerged in the MPM lab occurred when I filmed Fernandez-Rodriguez setting up the equipment at the start of the week, before we had established familiarity. She suddenly exclaimed, "What is going on? Oh my God! Don't tell me the guy isn't working … let's see if there's any complaining. If we get red and we get mmmmmmmmmmmm". (See Figure 67). As she spoke, she mimicked the laser's movement, shifting her body at a 90-degree angle, extending her arm and turning her hand upwards as the objective lens moved onto the stage. She added, "On Mondays, when I switch off the guy for some reason, things are always bad". While all the collaborators crowded into the small lab, we observed this playful interaction as we patiently waited for her to set up the system. Suddenly, a loud noise broke the tension, and we all laughed at Fernandez-Rodriguez's interaction. This moment showcased how we, as a group, collectively reacted to an uncertain situation, leading to a comedic release that helped alleviate the tense atmosphere. Unforeseen events like this had a significant impact, as they created the precise and unpredictable conditions for play to emerge.

The acts of mimicry – both human-to-human and human-to-non-human – reminded me of Marcus Coates' *Dawn Chorus* installation (2015), where 19 singers used their voices and digital technology to imitate birdsong, exploring the parallels between human and animal behaviour through imitation and transformation. Similarly, I documented surreal moments in the lab through video and photography, understanding emergent play and capturing ideas that could not be reduced to or explained by scientific procedures (Verbeek, 2011).

This connects to earlier conversations I had with cultural producers and brokers on successful collaborations between science and the arts (see Chapter One and Appendix Two). Arnold (2018) emphasised that a successful collaboration involves "human beings with personal experiences" and the process of "bringing the subjective and objective together". Stanbury (2018) noted that such collaborations require "shared qualities across many different practices", as well as openness and a commitment to acting as "the bridge from the lab or from the research landscape to either public audiences or people who are significantly affected by that research". Glaser (2018) suggested that collaboration should involve tackling issues that cannot be understood from a single perspective and that he could see the value in developing an appropriate framework for interdisciplinary work.

Their insights reinforced that, as an artist working alongside scientists, I was not confined by traditional expectations. I intentionally sought out moments of play and creativity that might have otherwise gone unnoticed. My time in the lab helped me to understand play's significance in advancing both culture and society. I developed a more refined awareness of each collaborator's role, recognising the essential role of play in encouraging creativity and embracing risk. This research further solidified my conviction that play is a potent catalyst for cultural and societal progress, particularly when integrated directly into collaborative work with scientists.

For example, I was trained to operate and image deep samples using the MPM, a novel microscopy technique, to measure the bioavailability of two topical drugs on pig skin at a depth of 250 microns. Unlike in art project two, I was not allowed to operate the MPM independently; I was always supervised and had to follow strict scientific protocols. This experience expanded my understanding of optical imaging technologies. I focused on the group's research question (how far does cream penetrate the skin?) and observed the experimental methodologies used by the scientists. I then reflected on how the technology itself – the lived experience of this process – shaped my tacit understanding of visualisation (Verbeek, 2005). This highlighted the emancipatory nature of technology, as neither I nor my colleagues would have been able to complete the study without the mediation of human-to-human and human-to-non-human interactions with the MPM (Verbeek, 2005). I also witnessed visually engaging effects when the laser activated fluorophores (markers that light up when they penetrate the skin) in real time.

These moments revealed the unique nature of MPM image production, which fascinated me. My curiosity led me to explore other contemporary imaging devices and how image display influences perception. For example, Luci Eldridge's (2017) PhD research *on Mars, Invisible Vision, and the Virtual Landscape: Immersive Encounters with Modern Rover* examines how planetary imaging experts use optical visual effects to create scenes viewable only on a screen. Eldridge (2017) cites Michael Lynch, who argues that working with digital images creates an "externalised retina" for scientific perception – one that relies on controlled lab behaviour, where relationships and objects become tangible through technical skills and advanced tools (Eldridge, 2017: 24). Eldridge's insights reinforced the importance of the computer screen as a key visual tool, validating my belief that scientific visualisation is a dynamic, technological resource that can enhance my experiential learning and artistic practice.

I documented every MPM experiment to deepen my understanding of scientific practices. Extended face-to-face engagement with one, two, or three scientists in the MPM lab fostered integration and led to in-depth discussions during the image-making process. This allowed me, as an image maker, to share with scientists Fernandez-Rodriguez, Jankunec and Engblom what I found distinctive and captivating about their image-generation methods – beyond empirical explanation. For instance, I expressed my reaction to seeing the dynamic motion of biological matter come to life on screen, as the microscope moved through an active, complex organism to reveal the skin's structure (stratum corneum, epidermis, dermis, subcutis and fibrous collagen), its depth, scale and the cross-sectional structures of sweat glands and hair follicles. I also described the natural auto-fluorescence, radiant colours and surreal views of structural details.

Through conversations, my collaborators acknowledged that their theoretical analyses often overlooked the creative aspects of science, which were essential for advancing concepts beyond a purely empirical understanding. Having an artist on the team brought a fresh perspective, facilitating alternative, productive discussions. They realised they had become overly reliant on cultural references for representations, rather than producing their own illustrated conceptual insights (Ericson, 2016). They acknowledged how they had lost the capacity to advance their concepts beyond a purely empirical understanding. This realisation led them to understand that shifting their attention away from a strictly empirical approach could create new insights, improving the influence of scientific dissemination for the public. As a result, my presence as a British researcher working on a transdisciplinary Swedish project had a meaningful impact. An article based on this study received university-wide attention (see Figure 68).

In the next cycle of my art practice, I employed a variety of creatively driven, non-empirical techniques to refabricate and re-conceptualise skin data in ways the scientists had not previously considered.

Figure 68. Lundgren, E. (2016) Science and art in harmony. GU Journal at Gothenburg University. 25 x 33cm. © Gothenburg University.

Findings from cycle one of art practice

Focusing my investigation on play as a method for eliciting data expanded my understanding of scientific observation and image creation. Through face-to-face interactions, I gained insights into scientists empirical, professional and subjective perspectives. By immersing myself in the lab and documenting experiments, I built trust and familiarity, enabling valuable collaboration.

Exploring the deeper, non-rational aspects of science made the creative process more playful. Gathering the same materials for both artistic and scientific purposes highlighted the distinct yet complementary nature of our work. Role-play, mimicry and play-centred dialogue became key tools that allowed me to examine the interconnectedness between technology, tools, the scientific process and scientists. I found that my collaborators, particularly Fernandez-Rodriguez, were more imaginative, curious and creative than expected, especially when mediating technology and explaining complex topics. Describing what I found captivating about their image-generation methods led to a more nuanced understanding of our distinct disciplinary goals.

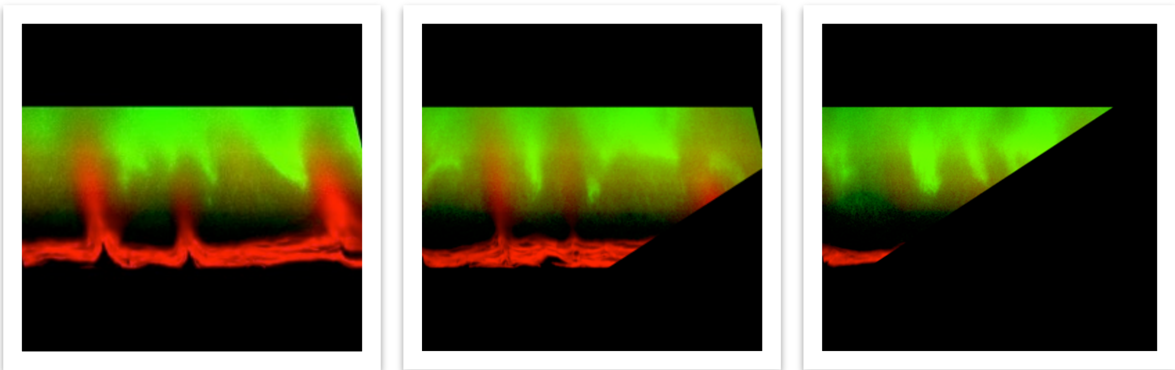
The second cycle of art project three

Collaborative two-way play in the scientific computer lab

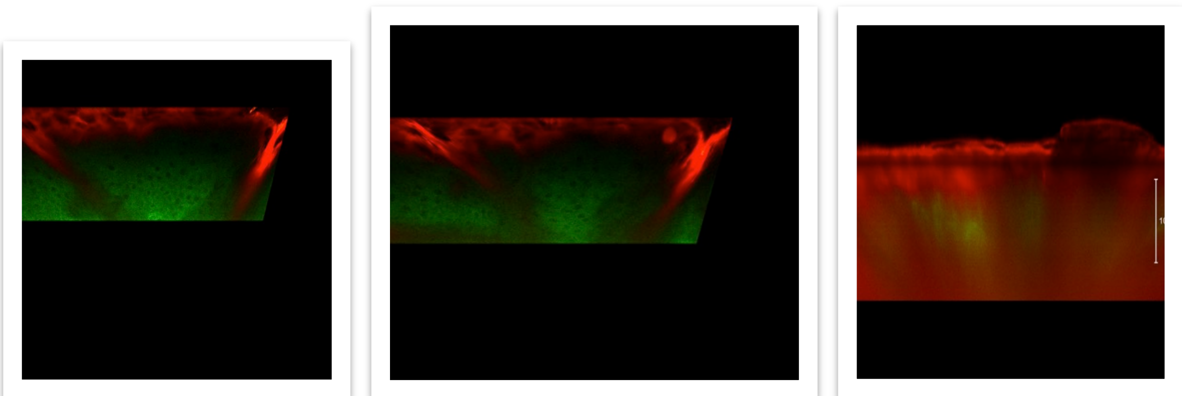
Technology played a central role in my decisions within the scientific computer lab at CCI, where I focused on expanding my knowledge by learning new software techniques (Verbeek, 2005). I collaborated closely with Fernandez-Rodriguez, a specialist in scientific visualisation. Together, we employed a speculative yet calculated approach to testing Zeiss software tools, aiming to explore the skin data obtained from the imaging lab in a more exploratory or non-traditional manner.

Initially, we were unsure how to combine our expertise, as visualising data beyond the constraints of scientific image protocols was not typical for Fernandez-Rodriguez, due to time limitations and the pressure to create conventional scientific representations. However, we adopted strategic and divergent methods to test software tools using the available parameters and variables, generating novel datasets through two-way instructional play. We tested how altering x, y and z Axis rotation and coordinates can alter form, as Thompson

(2014: 268–325) suggested in his description of the theory of transformation. We used the shear tool to adjust the pitch and yaw angles of skin cross-sections, testing how coordinates could become oblique by inclining the axes at varying degrees (see Figures 69–71). We recalculated angles to create alternative perspectives on the z axis. Additionally, we manipulated colour values to create different cross-section samples of skin (see Figures 72–74) and three-dimensional visualisations (see Figure 75), augmenting the data beyond traditional scientific depictions.



Figures 69–71. Berry-Frith, J. and Fernandez-Rodriguez, J. (2016) HG2_RBHE_image1pitchandyaw2_6315z_z000.jpg; 897z_z000.jpg; 1024z_z000.jpg. 36 x 36 cm © Jo Berry-Frith and Julia Fernandez-Rodriguez



Figures 72–74. Berry-Frith, J. and Fernandez Rodriguez. J. (2016) Ovixan_001_6h_image4_auto_Juliapitchandyaw2_z00.jpg; 18_z00.jpg.

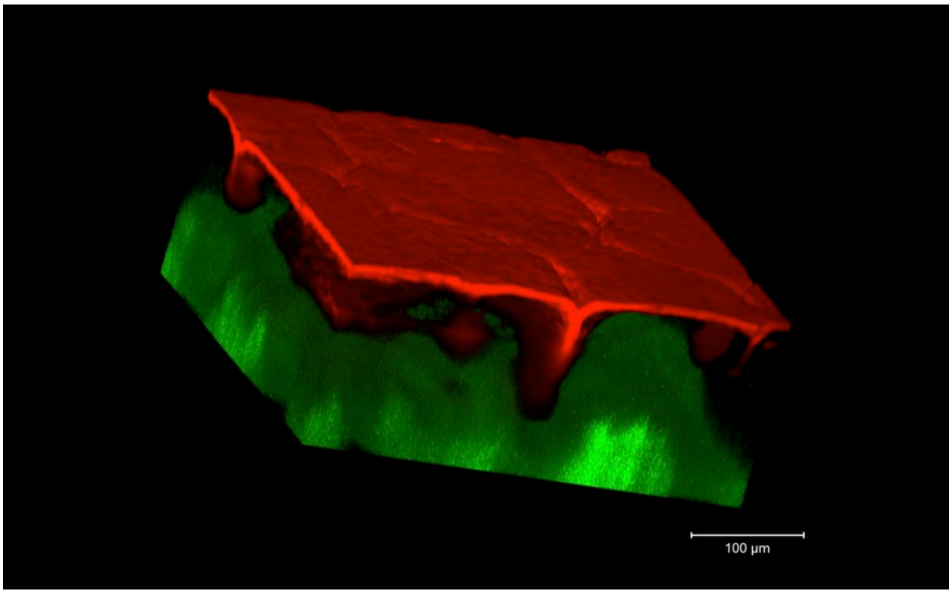


Figure 75. Berry-Frith, J. and Fernandez Rodriguez. J. (2016) RBHE_PG_pretreated_D1_image2_good_Render_Series.jpg. 36x 36 cm © Julia Fernandez Rodriguez.

Solo software play in the scientific computer lab at Nottingham University

Upon returning to the United Kingdom, I continued my solo investigative art practice within the "magic circle" (Huizinga, 2016: 20) of the scientific computer lab at Queen's Medical Centre, Nottingham University. To grasp further this process-driven research, I adjusted my visual strategies, allowing for a more flexible exploration of ideas and concepts. Taking the game of solo strategic software play seriously, I worked within specific parameters and variables to create visual outputs that scientists often overlooked. Using logic and a focused approach to creative play, I made discoveries through direct engagement with the computer's software and interface. As I tested the software, I explored both the physical components (screen, touchpad, monitor) and the digital landscape displayed. My approach evolved as my testing progressed (Manovich, 2001).

Building on insights from art project one and my fascination with optical effects, I employed speculative yet calculated methods to test Zeiss software tools that I had first encountered at CCI. My objective was to reimagine and refabricate skin data by generating numerous iterative visualisation outcomes. I approached the software tools step by step, adopting a divergent and innovative mindset to uncover new possibilities and outcomes.

Building on Crary's (1992) account of early nineteenth-century optical devices of the stereoscope, which emphasised radical abstraction and the reconstruction of optical experience over accurate visual effects, I actively manipulated timing by altering the pace of moving image files – experimenting deliberately with fast, slow, staggered and smooth transitions to assert greater creative control over the visual dynamics.

I developed three-dimensional topographic experiments that fundamentally transformed raw and fabricated data collected from various angles and viewpoints (see Figure 76). By converting two-dimensional images into dynamic three-dimensional topologies and creating stereo projections at varying speeds and rotations, I explored form, topology and trajectory on the x, y and z axes, resulting in the emergence of novel conceptual structures (see Figures 77–78). Additionally, I conducted stereoscopic projection experiments, presenting two images of the same subject taken from slightly different perspectives. However, rather than focusing on creating solidity and depth, I explored the perceptual effects of patchwork intensities in structural relief, achieved through offsetting, slowing down and stretching the frame (see Figures 79–80).

In my art studio, I initially tested optical effects using Image J – an open-source microscopic program – but found its oversaturated colours and pixelated noise unsatisfactory. Consequently, I redirected my focus to conducting advanced software experiments in the scientific computer lab. During this intensive period of speculative inquiry, I expanded my creative processes by employing innovative tactics to increase data outputs (indenting topologies, testing optical colour, focus, perspective, rotation). My deliberate manipulation of scientific-software imaging procedures intentionally disrupted conventional practices, broadening the scope of optical concepts at the intersection of art and science. This approach enhanced creativity and fostered alternative problem-solving strategies through responsive, exploratory testing.

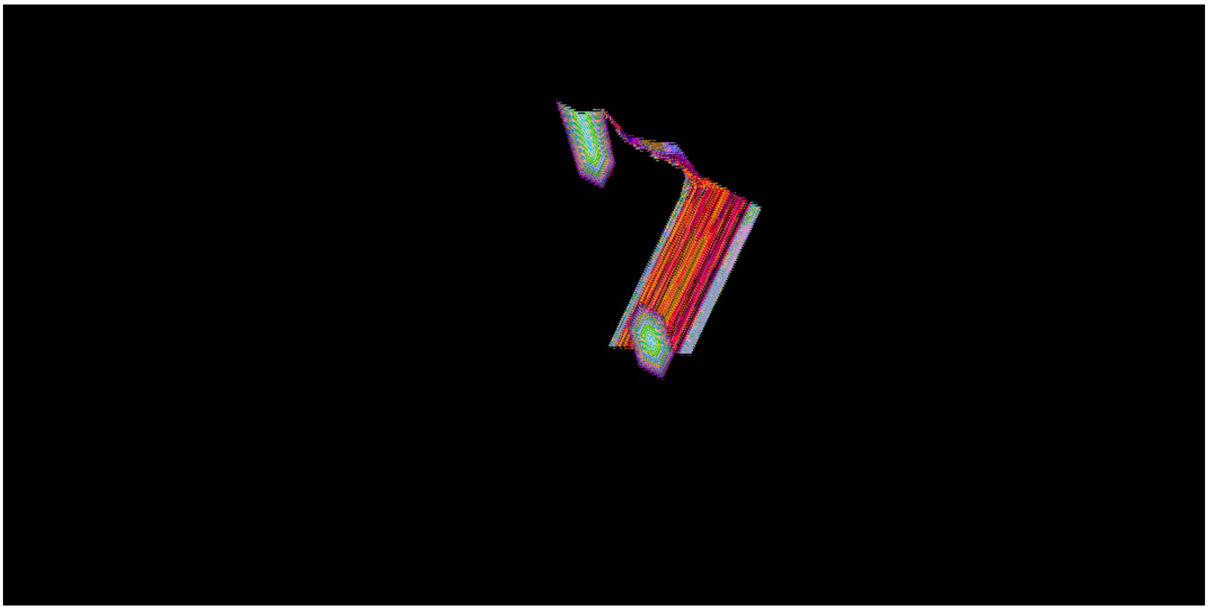
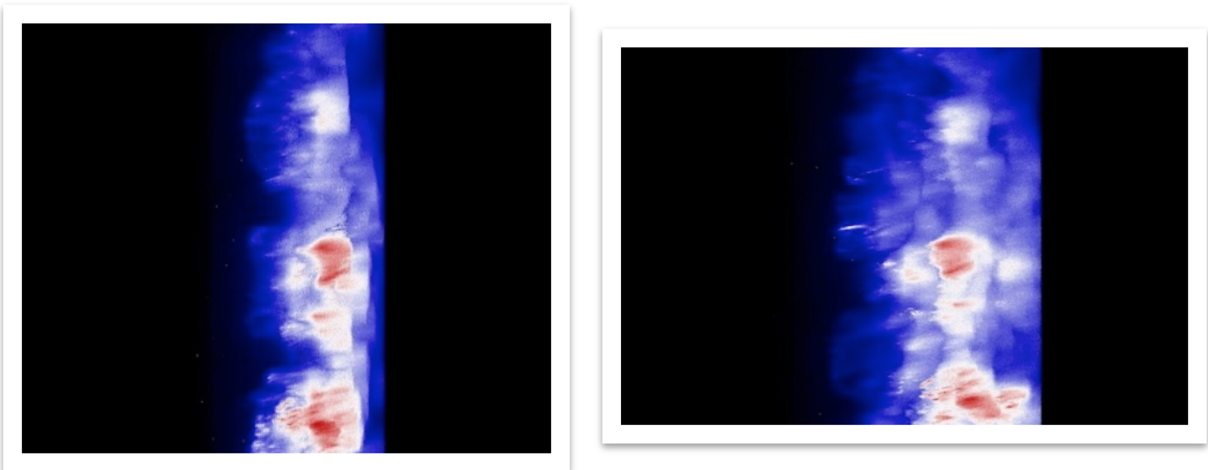
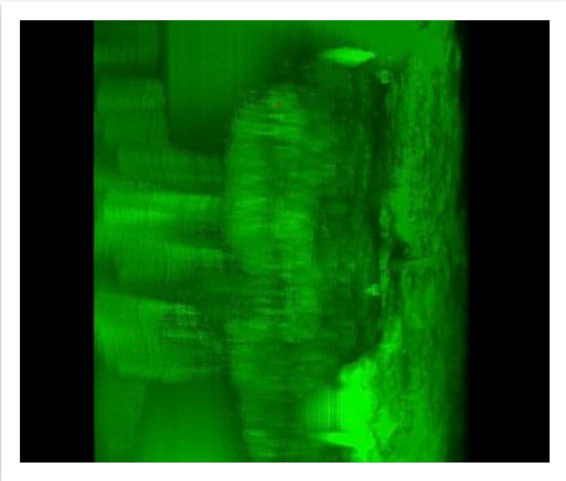
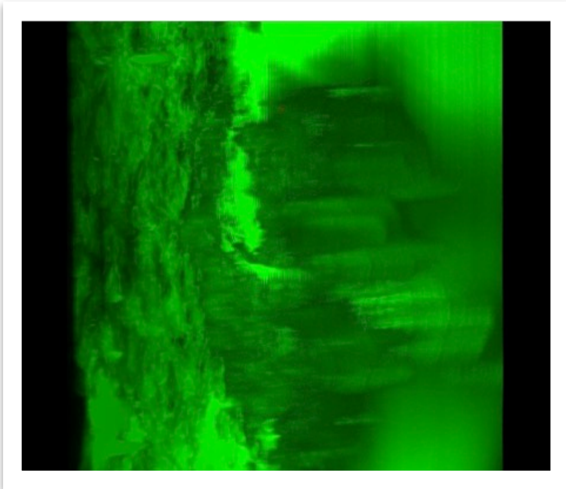


Figure 76. Berry-Frith, J. (2016) Rainbow-coloured indent topology still. tiff. 37 x 18cm. © Jo Berry-Frith.



Figures 77–78. Berry-Frith, J. (2018) Projection1v7; Projection1v2.tif. 25 x 17cm. © Jo Berry-Frith.

Figures 79–80. Berry-Frith, J. (2018) Projections of collagen captured as stills 2.v5.tif and 2.v12.tif. 8.47x 8.47cm. © Jo Berry-Frith.

Findings from software play

At CCI, face-to-face, two-way instructional software play broke down barriers, fostering trust, improvisation and risk-taking. It demonstrated the potential of calculated, collaborative play when artist and scientist test visualisation methods together. Fernandez-Rodriguez would not have explored data in this way or recognised the value of a creative, artistic approach to extending scientific data visualisation without my involvement. My non-empirical approach to testing scientific software was significant, producing outcomes neither I nor the scientists could have anticipated.

Experimenting with optical effects transformed my understanding of art by framing the refabrication of data as a crucial investigative process. Software play significantly impacted my view of authorship, as the original data were scientifically imaged, collaboratively created and then reinterpreted through the software interventions made by me and Fernandez-Rodriguez. This calculated play expanded my practice by emphasising the unique balance between seriousness and play (Gadamer, 1994: 102). It reshaped both my working methods and my concept of a finished artwork, which could range from raw data to data reimagined through software play.

In the art studio

In the "magic circle" (Huizinga, 2016: 20) of my art studio, where I worked alone, I reflected deeply on the entire experience. I assessed the impact of being an integral member of an international research team and how our collaboration advanced my understanding of scientific observation and image creation. Reviewing the body of work – documentary, film, photography, raw data and reprocessed visualisations – I focused on visual elements that connected my interest in biotechnology with my practice and our shared research. Building on insights from this collaboration and previous art projects, I concentrated on developing three graphically oriented digital methods: drawing, data montage and moving image. My aim was to complete the project and communicate these findings in a different way, not only to my collaborators, but also to the broader international scientific community at conferences.

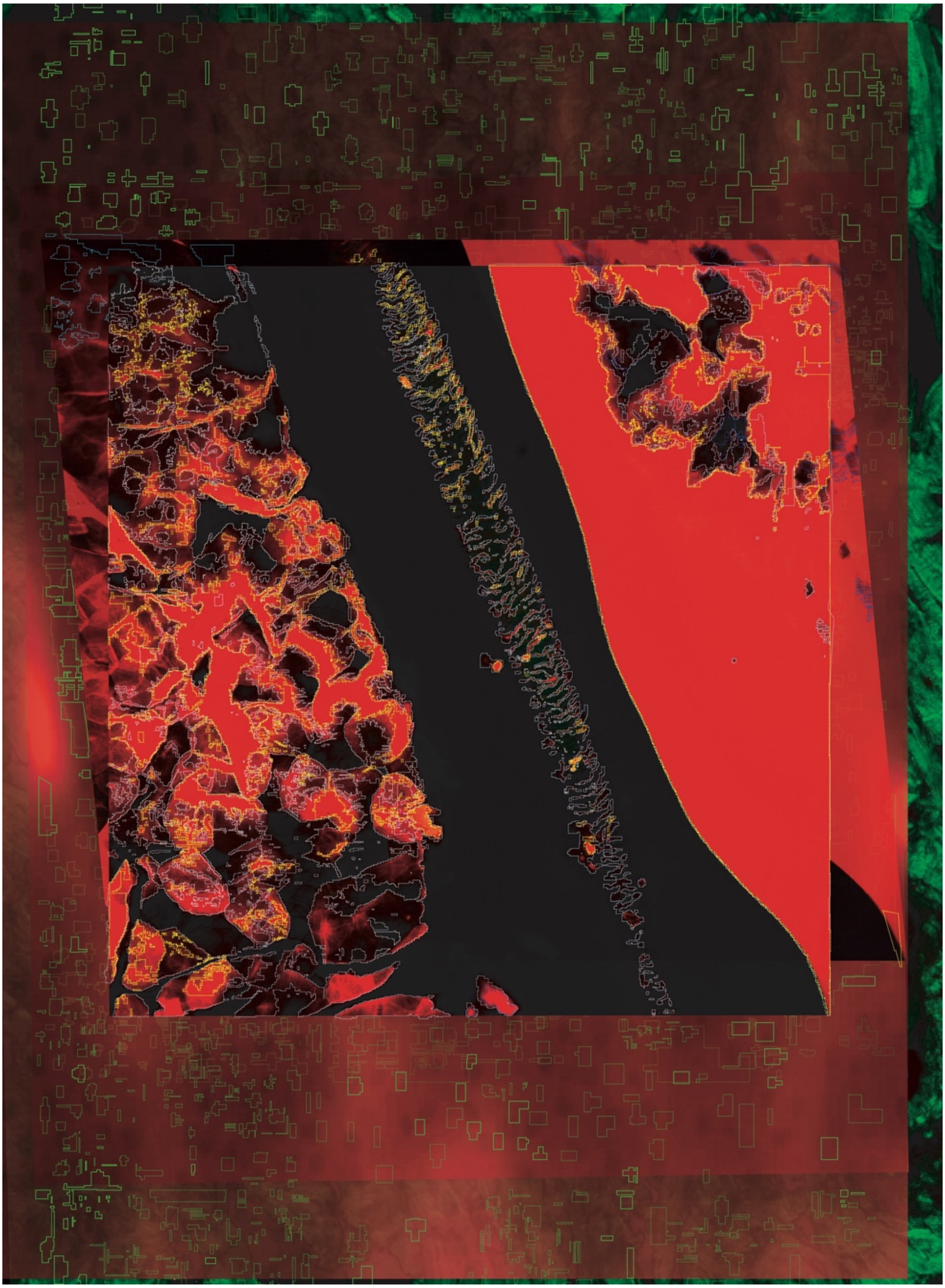


Figure 81. Berry-Frith, J. (2019) sweden1bitesize2v1.pdf. 95 x 125cm © Jo Berry-Frith.

To explore the complexities of visualising biomedical data, my digital drawing aligns with Krauss's concept of "misplay" (1998: 167) – the idea that representation can destabilise conventions while retaining structure. This reflects her view that true artistic innovation lies in balancing both adherence to, and transgression of, norms. For example, Figure 81 presents a cross-section of skin with a hair follicle, where I focused on reconstructing the surface by systematically remapping pixel data. The boundaries of the perceptual field were determined by the computer's ability to render the pixel grid, a two-dimensional projection of a three-dimensional scene. The Adobe Illustrator stroke weight tool (see Figure 82) allowed me to highlight the intricate layering of solid and dashed lines as I mapped pixel granularity. By toggling between micro- and macro-perspectives, I engaged with and pushed against the limitations of digital representation, reflecting on how these constraints shaped my understanding of complex biological systems. The composition, set at 95x125 cm, consisted of four frames and eleven layers, including depictions of collagen and the dermis. The deliberate visual tension, created by the off-set arrangement of the drawing and the use of 0.75pt to 3pt vector outline with no fill, encourages a deeper engagement with the subject matter. This technique underscores that biological entities like skin and hair follicles cannot be reduced to mere data points; instead, they represent a complex interplay of biological realities that my practice sought to capture and communicate.

Furthermore, the use of bright, contrasting CMYK vector lines in acid green, yellow, white, navy and Mediterranean blue, along with abstract forms, serves to draw viewers in, while simultaneously challenging their perceptions. This combination critiques the objectivity typically associated with scientific representation, suggesting that the reality of biological processes is inherently more complex and multifaceted. In summary, the work not only reflects a sophisticated understanding of the intersection between art and science, but also encourages a reconsideration of how we visualise and interpret complex biological realities.

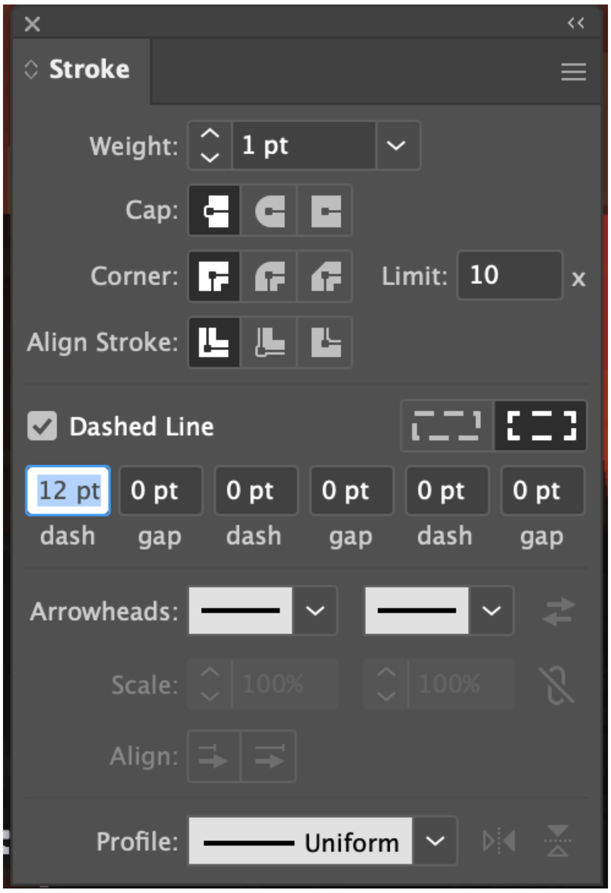


Figure 82. Berry-Frith, J. (2019) Stroke Weight and Dashed Line Tool.

In my practice, I drew inspiration from Wahida Khandker's (2023) study on mimicry in response to Anderson-Tempini's *Isomorphology* project, which compared the adaptive colour changes of cephalopods to Anderson-Tempini's colouring techniques. Fascinated by bioluminescent and fluorescent light, I explored colours beyond the visible spectrum, focusing on multiphoton light waves – a phenomenon in physics and microscopy where molecules absorb two or more photons simultaneously to reach a higher energy state. This technique's ability to penetrate deep tissue using infrared light, which can penetrate deeper into tissue than shorter wavelengths and confines excitation to precise volumes, enabled detailed imaging with reduced photodamage and enhanced clarity.

These drawings of richly coloured skin tissue (fluorescent red and green), embodied a process of analysis, abstraction and improvisation. Like cephalopods adapting to their surroundings, I transformed biological structures into new forms informed by scientific data. My work balances structure with creative fluidity, demonstrating the interconnectedness of science and art.

Similar to Anderson-Tempini (2023), my drawing practice integrates artistic, scientific and sensory knowledge from my scientific experiences, bridging abstract ideas with detailed representations. These drawings function as investigative tools, where each digital stroke captures the dynamic interplay of knowledge and creativity. The significance of this approach, discussed further in Chapter Six, highlights how art can expand and enrich scientific enquiry.

Returning to Latour's emphasis on the significance of practice models employed by scientists, he underscores how human actions are co-shaped by the artifacts they use, providing a framework for understanding the mediating role of technology through praxis (Latour 1992; 1994, cited in Verbeek, 2011). Latour argues that to transcend conventional understandings of science and facilitate knowledge transformation, scientific data must be disengaged from the material form and subsequently reconfigured. This process of re-making is essential for generating new insights, as I demonstrated in the construction of my drawings.

In alignment with Latour's views, the scientific data and observational subject matter I documented underwent material modifications. Figure 84 integrates raw collagen data, reprocessed as stereo projections and 3D topologies, alongside practical elements of scientific documentation from the CCI lab. These included laboratory equipment and depictions of Jankunec's hands – both natural and protected by blue surgical gloves. This juxtaposition highlights the interplay between craftsmanship and human endeavour. My intention was to illuminate the relationship between image data and the processes involved in data acquisition, reinforcing the notion that both scientific practice and artistic representation are intricately linked through their reliance on materiality and technology.

The two drawings framed within this work were constructed over stereo projection images of magnified collagen. The amorphous, abstract shapes oscillate in and out of focus, while vivid CMYK orange vector lines, which range from 0.75 to 3 points, trace essential details. The resulting digital line mimics a machine-made stitch, created after the drawing was made using the stroke, weight and dashed-line tools to apply a special effect (1 point solid, 2-point space – see Figure 83). Additionally, I layered a second drawing, a yellow 2-point vector line drawing, over the smaller-scale projection image, deliberately leaving it unfinished. This choice reflects my exploration of the concept of completion in my artistic practice (what to leave unfinished), while emphasising the dynamic relationship between visualisation and its inherently constructed nature.

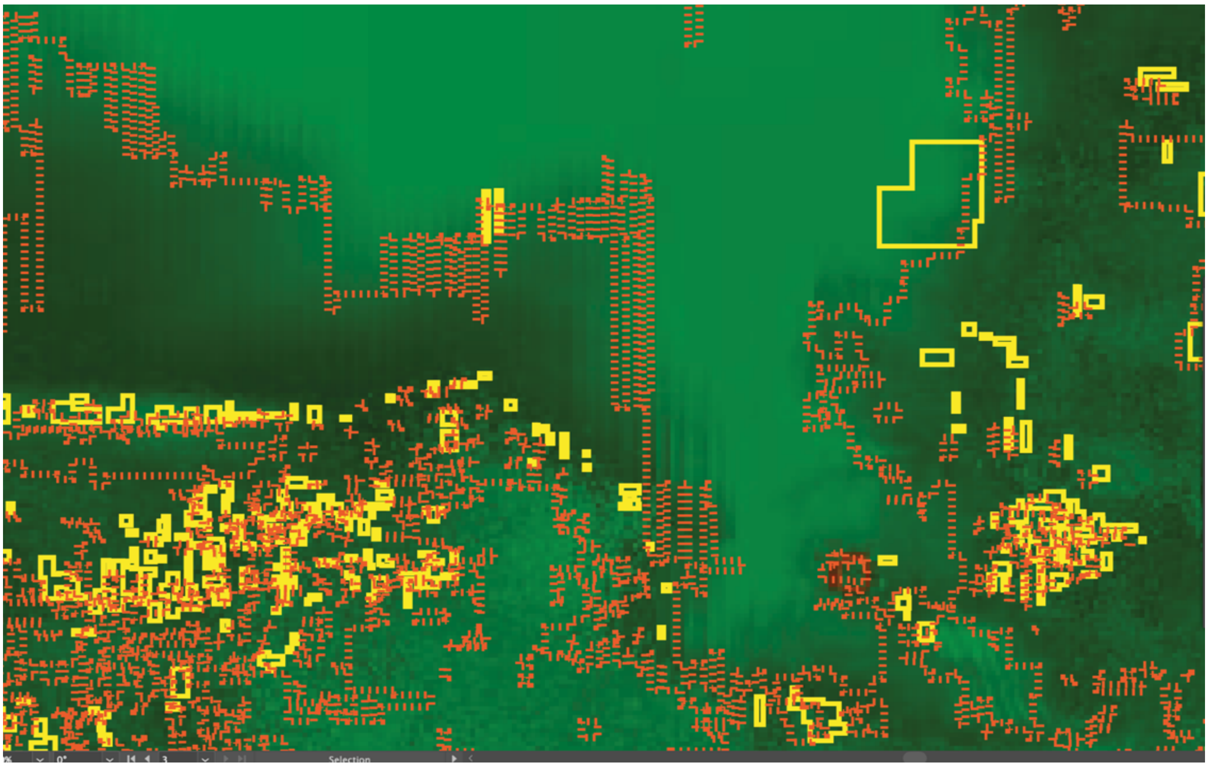


Figure 83. Berry-Frith, J. (2019) Detail – 021_5scrollprojectionrightscalewithframeincontinuingmay19.pdf detail. 95 x125cm. © Jo Berry-Frith.

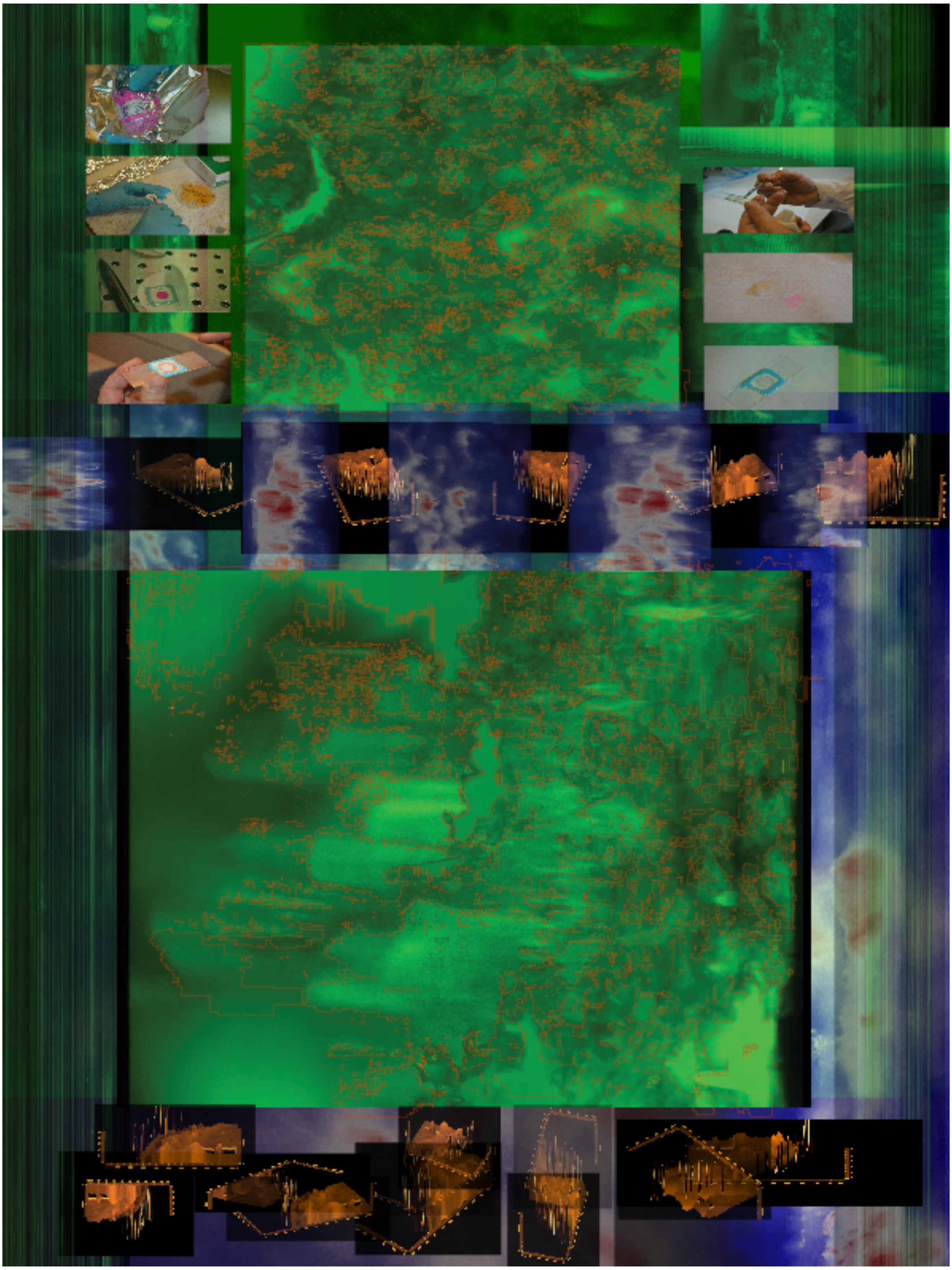


Figure 84. Berry-Frith, J. (2019) 021_5scrollprojectionrightscalewithframeincontinuingmay19.pdf. 95 x 125cm. © Jo Berry-Frith.

Findings from digital drawing

The relationship between re-mapping pixel data and drawing revealed a valuable intersection of artistic expression and scientific analysis, enhancing the creative process through a surface-based examination of skin data. Strategies like offsetting and copying countered empirical uniformity, while the drawings explored optical trickery and encouraged innovation. Embracing speculation, experimentation and incompleteness, this approach challenged scientific notions of control, deepening my understanding of drawing's core qualities, such as authorship, expressiveness and ability to reveal technique, as developed in art projects one and two.

The contrast of bright CMYK vector lines against a saturated MPM background demonstrated the impact of colour choices on visual storytelling. Latour's emphasis on practice in scientific inquiry resonated with my reconfiguration of scientific data and integration of documentary images from the acquisition process. This illustrated the dynamic interplay between representation, scientific activity and technology, contributing a novel perspective to my practice.

Through Krauss's (1998: 167) concept of "misplay", I explored how representation can be both structured and subversive, echoing her view that innovation arises from challenging boundaries.

In summary, my digital drawing practice embodies a critical dialogue between art and science, inviting deeper engagement with complex biological realities. Using innovative techniques and theoretical frameworks, I created a commentary on representation, urging a reconsideration of how biomedical research of skin is visualised and interpreted. Engaging with digital methods, particularly in Adobe Illustrator, highlighted how technology can enhance traditional drawing and inspire new forms of creativity. This drawing investigation advocates for a more nuanced understanding of biological processes and scientific representation.

Data montage

Gadamer (1998: 36) observes that the ancient Greeks classified creative activity into two primary forms: manual production, which involves creating tangible objects, and mimetic production, which represents ideas without physically constructing artifacts. The latter, particularly in the context of language, carries a significant interpretative dimension, where imitation plays a key role in meaning-making. This distinction is highly relevant to my work, as I reinterpreted data through a process of data montage (still and moving), aligning with mimetic production. In this process, I explored and represented the components of my research – writing, audio, conversation, photography, film and practice – using creative and interpretative methodologies.

The need for improvisation and experimental testing underscores the dynamic nature of this interpretative activity, demonstrating how meanings and insights can be reconstructed in the pursuit of knowledge. My approach aligns with Gadamer's (1998: 64) view that imitation and reinterpretation are not passive acts, but active engagements that drive the evolution of understanding. This perspective deepens understanding of how my interpretative practice facilitates the exploration of complex phenomena, such as those encountered in skin studies.

Figure 86 demonstrates my integration of both opaque and transparent elements from various datasets, creating a fluid representation of skin research. This figure includes raw data on skin and collagen from our collaborative experiments at CCI, where Fernandez-Rodriguez and I combined our expertise to create detailed cross-sections of skin. Additionally, the image incorporates photographs and video footage of our gloved hands – those of Jankunec and myself – preparing the skin samples for imaging. This multimedia approach not only enriches the visual complexity of the representation but also emphasises the tactile and procedural aspects of our research, highlighting the interplay between data, representation and the embodied experience of scientific inquiry. (See Figure 85 for further details.)

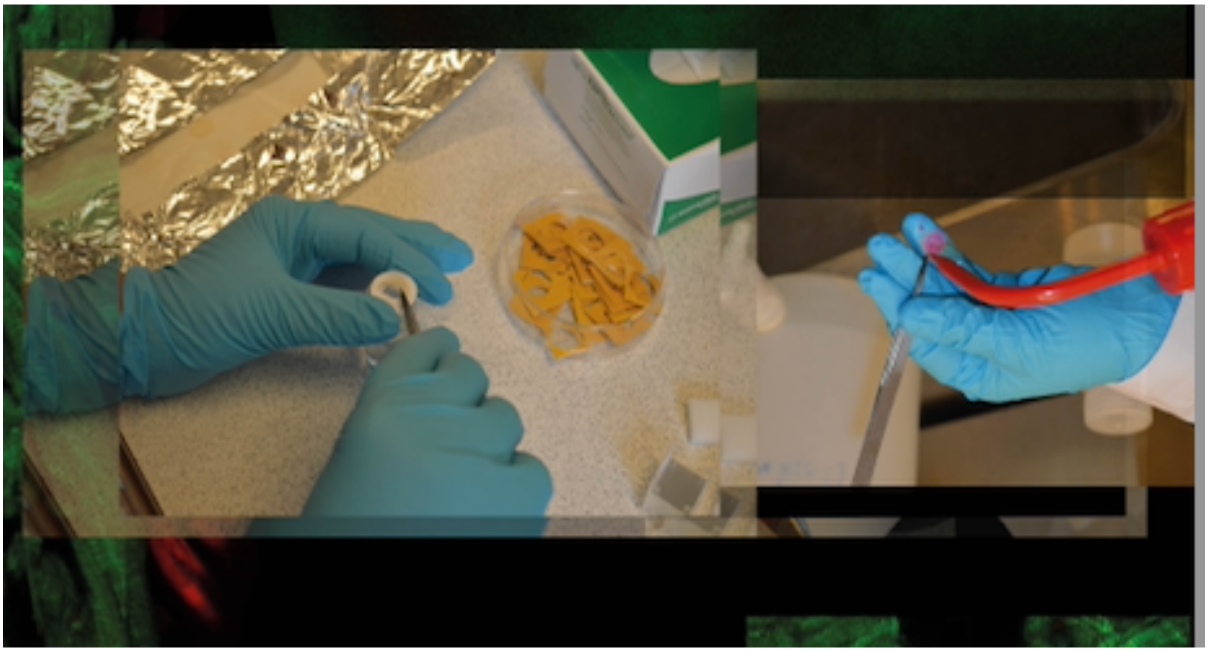


Figure 85. Berry-Frith, J. (2019) Detail of flattened skin May 2019 for screensv1.jpg. 95 x125 cm. © Jo Berry-Frith.

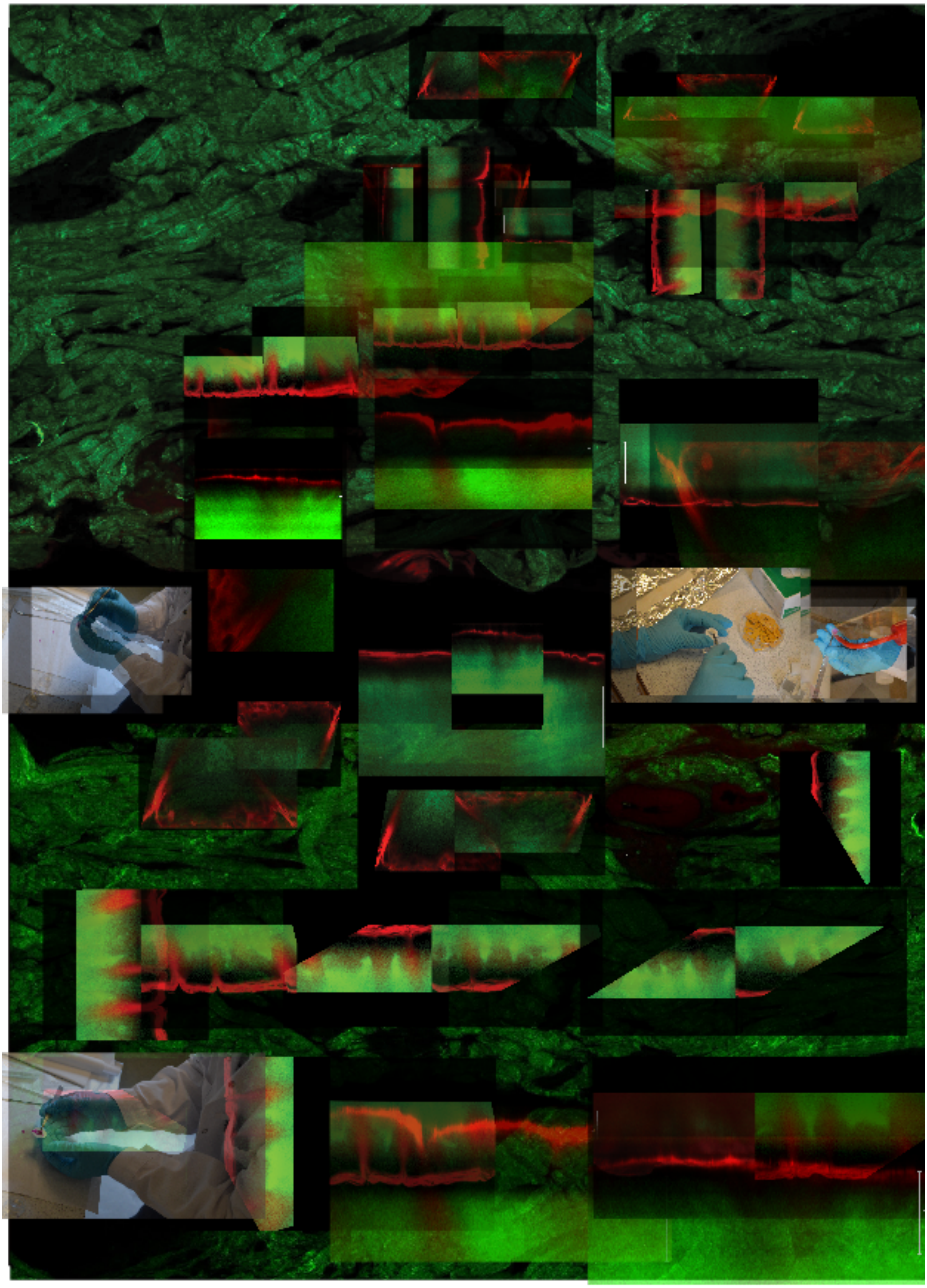


Figure 86. Berry-Frith, J. (2019) Flattened skin May 2019 for screensv1.jpg. 95 x125 cm.
© Jo Berry-Frith.

Figure 87. Berry-Frith, J. (2018) 7window1v_flattened.pdf. 950 x 125 cm. © Jo Berry-Frith.

Figure 87 presents a synthesis of vividly coloured, harmoniously toned datasets generated through experimental software play. This figure integrates practical experiences at CCI, where I employed strategies such as role-playing, mimicry and role swapping. These methods allowed me to explore various dimensions of representation, including perspective, composition, hierarchy and the layering of information. The deliberate interplay of these elements enriched the visual narrative, and also encouraged a deeper engagement with the underlying data. This approach facilitated a multifaceted exploration of the themes central to my research, while enhancing the interpretative possibilities of the datasets and fostering a more nuanced understanding of the complexities inherent in skin research.

Findings from data montage

By embracing the interpretative aspects of representation, I showed how the creative process of production is inextricably linked to seriousness (Gadamer, 1998: 64). Expanding on the data collages from art project one, I integrated human and non-human elements to add complexity and foster a deeper connection with the research. This creative appropriation and deconstruction of data, bridged artistic, scientific and technical domains, enhancing knowledge production. My focus on improvisation and experimentation through employing perspective (flattened) and composition (hierarchy) facilitated a multifaceted exploration of representation. Ultimately, this work invites viewers to engage meaningfully with the research, aligning with Gadamer's view that creative activities deepen understanding of complex phenomena.

Moving-image artwork

As discussed in Chapter One, I was drawn to artists who collaborate with and engage in philosophical discourse with scientists. For instance, *Illuminating the Self* (2020) was an exhibition that took place across two venues in Newcastle upon Tyne and included works made by Aldworth and Carnie in response to CANDO (Controlling Abnormal Network Dynamics using Optogenetics). The artworks addressed themes such as the lived experience of epilepsy as well as technological, ethical and legal concerns around optogenetics and neural technology. *Out of the Blue* is Aldworth's response to reading 100 testimonies of living with epilepsy, as well as the science that is discovering techniques to manage some focal epilepsies with a mix of brain implants and blue light. In *Blue Matter* (2020), Carnie visualised how brain patterns were altered during a seizure, and how gene therapy and the CANDO implant can help manage this interruption. Carnie integrated art and computer animation to produce a large-scale film, allowing the viewer to immerse themselves in the imagined world of the brain. The curator, Lucy Jenkins (2020) describes how walking through this largely monochrome movie was a captivating experience, as it was both calming and tranquil, yet hinted at uncertainty and danger. For instance, brain silhouettes appear elegant and powerful, but also enigmatic and intriguing. Tree-like patterns flow and morph in hypnotic ways, with jagged lines cutting across them like brain activity altered by a seizure.

The concept of disruption, interplay and improvisation served as a foundational framework for my exploration of the visual narrative of my skin research. I tested various visual effects, including rotation, mirroring, colour manipulation, shifting focus, viewpoint changes and timing. These visual tactics were employed to encourage a deeper connection with the work. I created a series of image sequences that integrated documentary elements, sound and scientific data. Embracing a holistic approach enriched my understanding of the subject, opening new avenues for visual storytelling.

Figure 88 is a 30-second film depicting a cross-section of skin. In the animation, a segment is deliberately removed from the cross-section and ascends out of the picture frame, creating a sense of dislocation. The slow, deliberate pace of the animation, combined with the minimalist approach, emphasises the ability of this animation to convey complex themes through simple visual strategies. This approach not only complements more elaborate works but also underscores the role of the surreal (strange, discordant) in exploring fundamental concepts of skin in an abstract and unconventional manner.

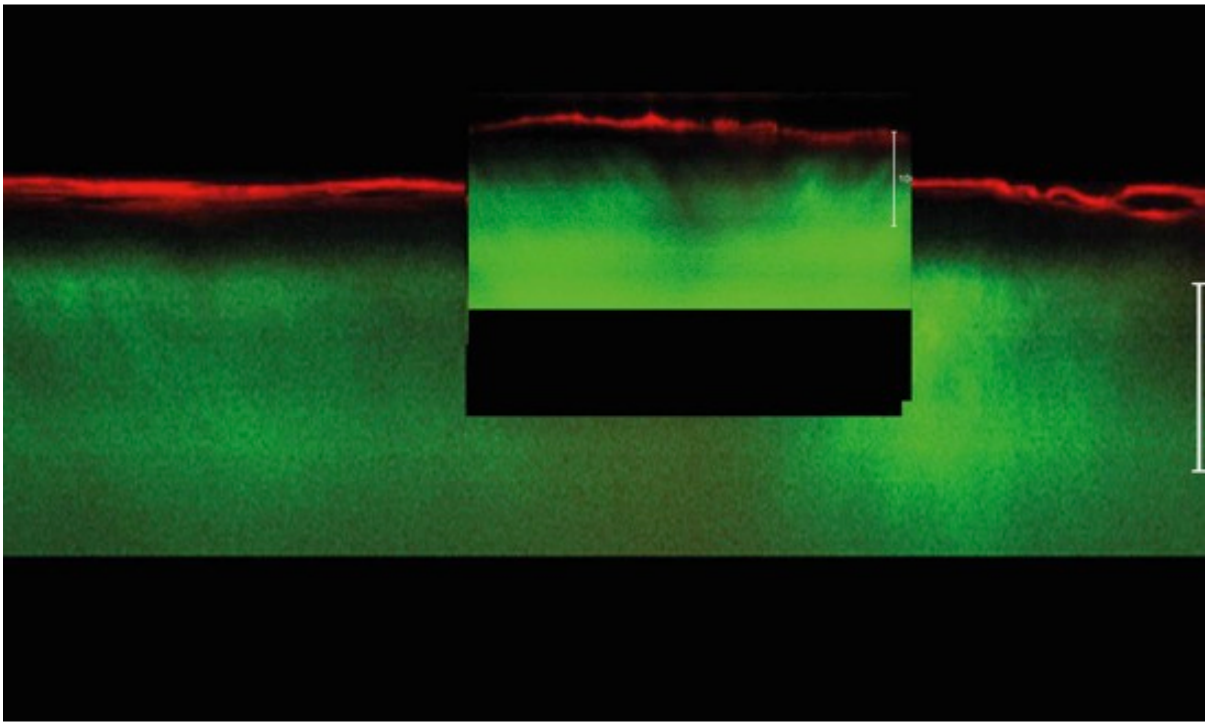


Figure 88. Berry-Frith, J. (2019) A still from an animated moving-image. © Jo Berry-Frith.

I also developed a series of experimental films that utilised raw data and software-generated datasets to create intricate sequences with multiple components. My practice focused on exploring themes of reconfiguration and mirroring, with an emphasis on elements like colour, focus, perspective, timing, rotation and the interplay between multiple-image sequences. This eclectic approach enabled me to craft longer films that moved beyond traditional linear narrative structures.

During the editing process, I collaborated with composer Edmund Hunt. After discussing my work in relation to CCI research, I shared several film examples with him. In response, Hunt composed original pieces for Northumbrian pipes, designed specifically to complement the visual elements and thematic discourse emerging from the films. These pieces, lasting 14:49 and 22:26 minutes, were electroacoustic compositions, marked by dissonance and an unsettling quality, which added a distinctive layer to my visual narratives.

The interplay between sound and image enriched the themes in my films – abstract, richly coloured visuals combined with fragmented, discordant imagery – and also prompted me to reconsider how viewers might emotionally engage with the work. By intentionally juxtaposing these elements, I sought to create a more immersive experience, encouraging audiences to explore their own emotional responses and interpretations. This process has been enlightening for me as an artist, revealing the profound impact sound can have on visual storytelling.

Reflecting on the founder of psychoanalysis Sigmund Freud's (1856–1939) insights, particularly his ideas about the layering of experience, I found resonance in his assertion that dreams and hallucinations often revert to visual experiences. The discordance in the soundtrack led me to explore Freud's concept of the uncanny, particularly the tendency to withdraw and replicate less developed aspects of the self, as explained by Krauss (1998: 171–178). Figure 89 captures *Skin/Kin* – a performance featuring Northumbrian pipes and live electronics, accompanied by a projection of the *Skin* film. Debuting at The Lab, Royal Birmingham Conservatoire, this work exemplifies how I layered multiple insights (documentary and software experimental footage) from skin research. The film was later showcased on TV monitors at the 14th Annual Workshop of Biofilms in 2018.

The dynamic interplay between personal experience and objective analysis in my CCI research aligned with Winnicott's (2005) concept of play, blending intuitive engagement with systematic analysis. This approach allowed me to explore the research as both a cognitive and emotional process. I embraced ambiguity and accepted uncertainty, treating abstract theoretical concepts with the same importance as concrete assumptions. This emphasised that the world is not passively perceived, and that imagination plays a crucial role in shaping our understanding (Winnicott, 2005). Winnicott's framework supported my research, enabling me to examine the data from a broad range of perspectives. This comprehensive methodology allowed me to weave diverse elements into abstract narratives, deepening my engagement with the themes of my films. By cultivating dissonance, I was able to articulate complex relationships between visual and auditory components, enriching the aesthetic experience and encouraging viewers to explore layers of meaning. Ultimately, this approach fostered a nuanced understanding of the interplay between documentary footage, scientific data, perception and artistic expression, underscoring the value of embracing ambiguity in creative practice.

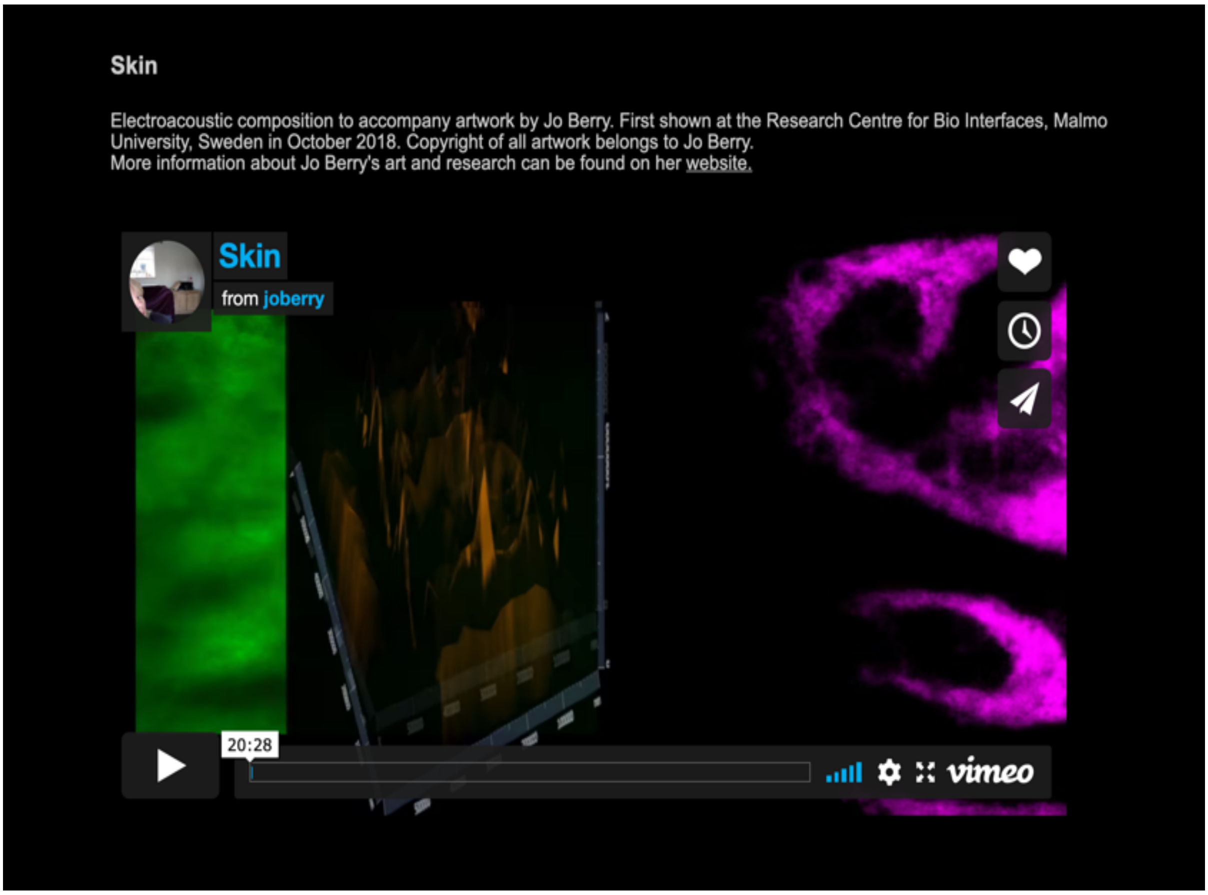


Figure 89. Berry-Frith, J., and Hunt, E. (2019) Skin/KIN and a new work for Northumbrian Pipes and live electronics, The Lab, Royal Birmingham Conservatoire. Integra Lab Showcase, 27th February, Royal Birmingham Conservatoire. © Jo Berry-Frith.

Figure 90 is an image from my *Skin-2* movie, where I explore how play manifests in the laboratory. It incorporates a series of abstract moving image data and captures moments such as when Fernandez-Rodriguez sets up the MPM, a scene that contributes to the visual narrative outlined in art cycle one.

The *Skin-3* movie is divided into three parts, further emphasising the surreal and discordant elements of science through carefully curated footage. It includes the laboratory preparation of skin, MPM imaging experiments and a series of software experiments. Additionally, I edited audio recordings of my collaborators discussing MPM modalities in various dialects, repeating and overlaying these to enhance the bizarre quality of the experience, alongside the loud hum of the MPM machine. This combination of visual and auditory elements invites viewers to engage with the complexities and incongruities inherent in my exploration of science.

Through this juxtaposition, I drew attention to the unexpected moments that emerge within scientific practice. I articulated the intricacies of the research process while fostering a deeper interaction with both the data and the creative expressions it inspires. Ultimately, my goal was to communicate the peculiar, strange and aesthetic qualities inherent in this scientific inquiry, promoting a more nuanced understanding of the interplay between art and science.

Figure 90. Berry-Frith, J. (2019) Stills from *Skin-2*.mov. © Jo Berry-Frith.

Findings from moving-image artwork

Working without a fixed hypothesis provided a space for experimentation (Winnicott, 2005: 64). The short animations complemented more complex works, highlighting unexpected and surreal aspects of skin data. The integration of dissonant audio, created through collaboration with composer Edmund Hunt, added a multi-sensory layer, deepening viewer engagement. The findings underscored the importance of embracing ambiguity in artistic practice, fostering a deeper exploration of meaning within scientific inquiry. By weaving together diverse elements, I articulated complex relationships between data and artistic expression, enriching the overall aesthetic experience.

The third cycle of art project three: Dissemination

I exhibited my practice findings at two temporary exhibitions to gather feedback. The first was the 14th Annual Workshop of Biofilms, Research Centre for Biointerfaces and Biomarkers in 2018, followed by the 70th Annual Meeting of SCANDEM, 2019. At the Biofilms workshop, I presented various artworks, including large digital prints (100 x 200 cm; 100 x 164 cm), silk creations (95 x 164 cm), scrolls (40 x 400 cm), a portfolio and the film *Skin*, alongside 23 scientific abstract poster presentations. This event attracted 91 attendees, including biomedical students, academics and secondary-school children. At SCANDEM 2019, where there were 300 attendees, I exhibited digital prints (1 x 95 x 164 cm and 9 x 95 x 125 cm) alongside 48 scientific abstract poster presentations and industry stands.

During both conferences, I focused on in-person interaction with scientists, exhibitors and academics. I engaged in activities such as poster presentations, seminars and conference dinners, which expanded my understanding of scientific topics and perspectives. I navigated multiple roles: artist–researcher, exhibitor, curator, presenter and documentary photographer. I engaged with colleagues, scientists and exhibitors, pointing out interesting aspects of their work, such as their visual representation of data. These face-to-face interactions helped break down barriers and encouraged valuable feedback.

Reflecting on Craig-Martin's (1995) argument that artists often face scepticism, while curators are more readily accepted as credible interpreters, I asserted my position as an artist engaging directly with scientists, standing alongside my work to communicate my research. This experience helped me understand the gap between my own perceptions of my work and those of scientists, by moving beyond the conventional boundaries of a traditional gallery settings. I also gained insights into scientists' willingness to hybridise imagery to test hypotheses (Wadasak, 2018) and their admissions of uncertainty regarding certain biomedical systems (Helmstaedter, 2019). Both events provided opportunities to discuss how artists and scientists adapt, think creatively and take risks. By asking unconventional questions and gathering diverse data from my interactions, I discovered a shared admiration among scientists for observing colour and shape under a microscope, along with a desire to design innovative experiments to test hypotheses. Participants recognised that having an artist–researcher in their laboratories could serve as an effective tool for reflection and public dissemination, offering a way to present their science in a less conventional and more engaging manner.

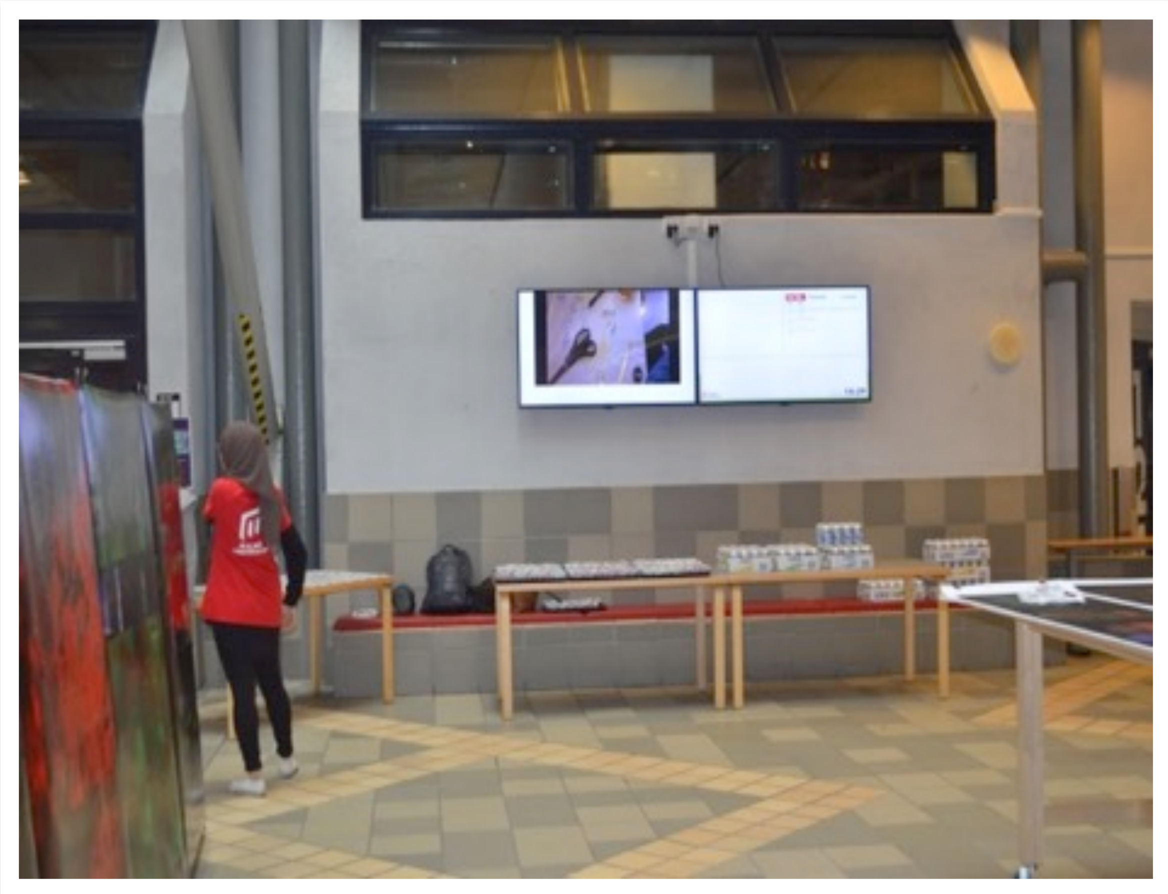
The exhibitions exposed the tensions and disparities I felt as the only artist to have exhibited at both events. Unlike other exhibitors adhering to strict empirical guidelines, I presented non-standard outcomes, providing a unique perspective on primary research. At the Biomarkers conference, I faced difficulties installing large-scale work without technical support. Inaccurate design specifications tested my adaptability, as I faced the challenge of attaching large digital prints and printed silk to spongy exposition panels and internal windows with double-sided Velcro and pins. I arrived the night before the event and set up my work, only to find that by the next morning, most of it had fallen, with some pieces damaged. I had to re-hang the artwork several times during the conference.

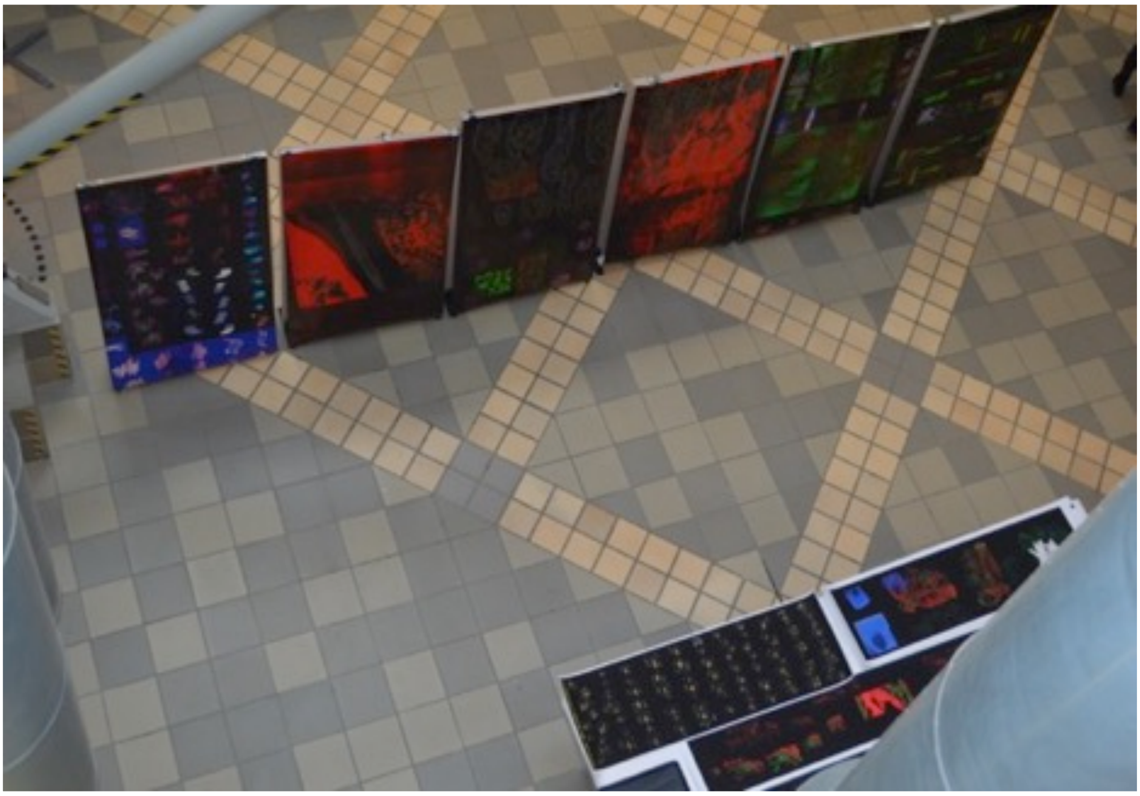
At SCANDEM, I encountered logistical issues such as the reassignment of my artwork to the exterior entrance wall of the main lecture theatre. I had to use white tack – an entirely inappropriate hanging device – to affix large prints (95 x 125 cm), and the *Skin* film, which was intended for HD monitors, was not shown. These experiences highlighted the complex relationship between exhibition value and user engagement, an area over which I had limited control as an artist–researcher at international scientific conferences.

I also faced other unexpected challenges, such as a woman sitting on her phone with her head touching my artwork, which was precariously fixed during SCANDEM. However, I embraced these challenges as opportunities for growth and creative problem-solving, refining my professional research skills to gather valuable feedback. Ultimately, these experiences strengthened my resolve to present my practice-based research as a legitimate form of scientific communication.

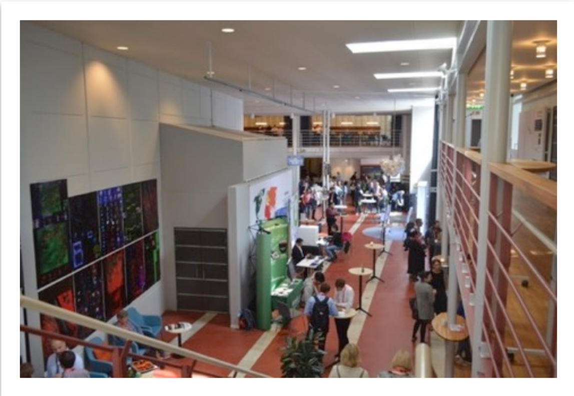
At the opening of the Biomarkers conference, I introduced myself as a researcher working at the intersection of art, science and communication. Attendees were intrigued by my role as a British artist–researcher collaborating with scientists in the Nordic countries on biomedical research. As a new voice in this context, I found that I could navigate conversations and engage with others, even without being a specialist in their fields. Scientists seemed eager to discuss aspects of their work related to imagery, strategies and concepts, and appreciated my contributions to these discussions.

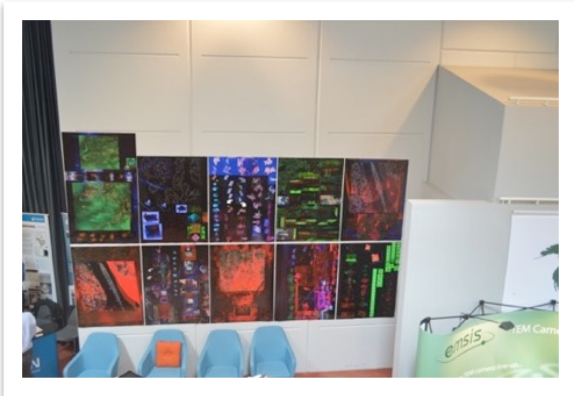
At SCANDEM, I was the only non-scientific expert to present a research talk, and the response was positive. Notably, Professor of Biomedical Science Andreas Holzenburg (2019) expressed that my perspective encouraged a novel and exciting creative exploration of scientific research, highlighting the potential of art to enhance scientific communication. This feedback reinforced the importance of interdisciplinary dialogue and my unique role in fostering innovative thinking and collaboration.

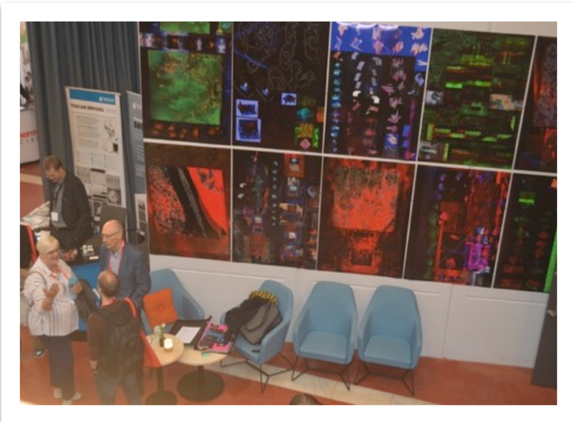


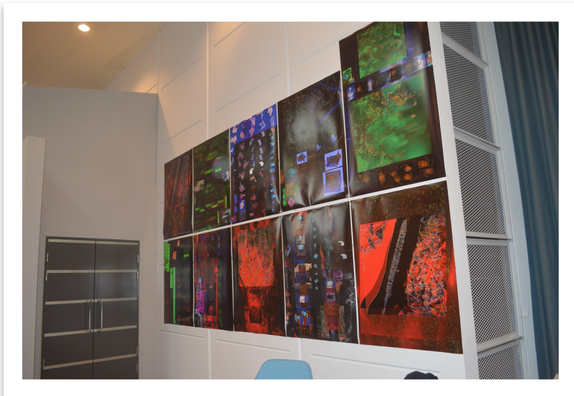


Figures 91–93. Berry-Frith, J. (2018) The 14th Annual Workshop of Biofilms, Research Centre for Bio interfaces and Biomarkers, 2018 Gäddan, Exhibition space, Faculty of Health and Society, Department of Social Work housing the University's innovation Centre, Malmö University. 14.8 x 10.5 cm. © Jo Berry-Frith.









Figures 94–98. Berry-Frith, J. (2019) SCANDEM exhibition and presentation, Chalmers-conference-centre, Gothenburg University. 14.8 x 10.5 cm. © Jo Berry-Frith.

Findings from art cycle three

My role as an artist–researcher fostered interdisciplinary dialogue and collaboration, bridging the gap between art and science. Through the interpretation and use of science and technology, I created new avenues for innovation and dissemination. My artworks and film offered unique insights into scientific discoveries from a non-empirical perspective, allowing collaborators and the broader scientific community to perceive science in new ways. However, I encountered logistical challenges while displaying my artwork, which revealed the complexities of engaging with scientific audiences within rigid conference guidelines. These obstacles emphasised the need for flexibility in interdisciplinary work and a better system for artists to exhibit research at scientific events. Overcoming exhibition challenges strengthened my resolve and professional development. The events highlighted the distinct aspirations of art and science exhibitions, underscoring the importance of adaptability in interdisciplinary environments.

Attendees expressed curiosity and appreciation for integrating art into scientific discussions, validating my contributions. I valued the opportunity to present to an international multidisciplinary audience, including industry partners and various scientists, receiving positive feedback throughout. Ultimately, these experiences confirmed the potential of art to enhance scientific understanding and the value of diverse perspectives in collaborative research, supporting my argument for integrating artists into scientific research teams.

The fourth cycle of practice: Reflection

In this final stage, the different data sets from all stages were analysed.

During **cycle one,** I collaborated with biotechnology and microscopy experts on a socially significant project in a foreign laboratory. This immersive experience enhanced my research skills and deepened my understanding of interdisciplinary work within an international team. As a non-specialist, I engaged in hands-on learning that exposed me to innovations in MPM, enhancing both my analytical and visual reasoning.

Referring back to Kester's (2013) concept of play-centred dialogue, I employed role-play as a methodological tool to investigate the role of play in laboratory practice. On reflection, I recognised that my approach illuminated the complex interplay between technological systems, scientific methods and the individuals operating within them. Kester's (2013: 68–69) advocacy for dialogic art further informed an analytical framework that positioned artistic inquiry as a means of approaching problems from an open, outsider perspective, facilitating unexpected connections and creative thinking.

Focusing on play as a mode of research had certainly aided my understanding of scientific observation and image-making. Two-way, face-to-face instructional play, whether at the bench, in the imaging lab, or during data analysis, broke down hierarchical barriers, fostered trust and encouraged experimentation. These collaborative exchanges revealed the human dimension of scientific work, blending empirical knowledge with personal insight. My integration into the research team affirmed the value of artistic engagement in scientific environments, where unplanned, serendipitous moments, or "happy accidents", often spark innovation.

During **cycle two**, I investigated the relationship between creativity and seriousness, drawing on Gadamer's (1994: 102) concept of their intrinsic connection. Engaging closely with biological data, I used analogies such as mimicry and refabrication to develop an experimental, inquisitive and multi-modal approach. This allowed me to merge data in unconventional ways, generating new insights into skin research while simultaneously evolving my artistic practice.

Collaboration with composer Edmund Hunt revealed productive tensions within my work, such as the incomprehensible, the non-linear and the contrasts between handmade and digital processes. These dissonances sharpened my awareness of how technology influences my creative decisions, particularly in how I use touch, cognition and software to interpret and represent biological information.

In the third cycle, as the sole, non-scientific researcher, I presented and exhibited work at two international conferences, which catalysed discussions and enhanced scientists' perception of art–science collaboration. These events highlighted the value of art–science partnerships, demonstrating how artistic perspectives can inform scientific methods and broaden research outcomes. At the end of the cycle, I could see the extent to which these contributions to bio-interfaces encouraged scientists to consider alternative ways of thinking and communicating, thus challenging disciplinary boundaries.

During the reflective stage of cycle four, I could see that a play-based framework created a dynamic feedback loop, advancing both practice-based research and methods of representation. This interdisciplinary approach broke down siloed thinking and offered replicable models for future collaborations (Groth et al., 2020: 16). The concluding chapter will synthesise the knowledge developed through all three art projects.

Art Project Three's significance

The collaboration with the Biofilms Research Centre at Malmö University and the Centre for Cellular Imaging at Gothenburg University (2016–2019) offered new insights through the analytical and reflective lens of artistic inquiry. A play-based approach allowed me to explore cognitive, tactile, auditory and visual dimensions, revealing the scientific aesthetic qualities of materials and processes. By 'scientific aesthetic qualities', I refer to the sensory characteristics of scientific phenomena as reframed through an artistic lens.

This shift in thinking enabled me to reinterpret MPM data of pig skin through a hermeneutic framework. Hands-on MPM training revealed often-overlooked subtleties, such as body language, hand movements, tool interaction and ambient elements like steam, thereby enriching my understanding of the research process and its material contexts. By mimicking scientific procedures, I gained a deeper understanding of biomedical design and its execution.

As part of my framework, I developed a reciprocal collaboration model that allowed for role-switching between artist and scientist, generating mutual understanding and trust. Scientist Jankunec stepped into roles such as educator, demonstrator and documentary photographer, while I brought a conceptual, exploratory approach. This role exchange disrupted traditional lab hierarchies and expanded our methods, resulting in a more holistic and enriching collaborative process.

While working with Fernandez-Rodriguez during data processing, we introduced two-way instructional play that enhanced our software skills and encouraged non-standard visualisation techniques. Our experiments with Zeiss software led to unconventional views of skin slices, challenging imaging conventions and revealing overlooked data. This demonstrated how a playful, artistic approach can lead to richer scientific communication and alternative forms of data interpretation.

Encouraging scientists to view their work through an artistic lens prompted them to reassess both their methodologies and the aesthetic qualities of their data. This shift enabled more open expression of thought and emotion, deepening their engagement with imaging practices and the results.

Reflecting on my time in the lab, I asked Fernandez-Rodriguez if she found my involvement valuable (see Appendix Five). She responded:

> *Having Joanne, an artist, conduct research in a core facility lab can profoundly influence scientific work by introducing a creative and exploratory mindset that challenges conventional approaches. Working with an artist encouraged me to rethink my methodologies, embracing experimentation and playfulness as part of the scientific process. Their ability to reimagine data visualization and interpret biological processes through innovative, artistic perspectives significantly enriched my approach to microscopy and imaging. This collaboration cultivated a sense of curiosity and adaptability, enabling me to view scientific challenges as opportunities for creative problem-solving. The focus on storytelling and visual communication also transformed how I present and share findings, making them more accessible and impactful to diverse audiences. Ultimately, this interdisciplinary exchange reinforced my belief in the value of integrating art and science, fostering a more dynamic research environment*.

In cycle two, I focused on haptic, auditory and experiential elements, creating narrative artworks that emphasised verbal and non-verbal communication. Edmund Hunt's dissonant electroacoustic compositions enhanced the audiovisual interplay in my moving images. I merged documentary footage, raw data and reprocessed outputs to reveal hidden relationships. This process cultivated a distinct scientific-aesthetic sensibility, born from my fascination with MPM imaging, and led to the creation of digital drawings, data montages and experimental films. These works illustrated complex interconnections between biological systems, software, technologies and human interaction, offering scientists new ways to interpret their data.

Dissemination occurred across multiple platforms, beginning with scientific conferences and extending to broader audiences (see Appendices One, Six and Seven). Key events included Skin/KIN, a live performance at The Lab, Royal Birmingham Conservatoire (2019), which publicly explored MPM and skin research. Exhibitions at the Biofilms Research Centre (2018) and SCANDEM (2019) further engaged (scientific and non-scientific) audiences and demonstrated the evolving role of the artist within scientific research.

These engagements revealed how alternative methods can enrich scientific discourse. Through artworks such as large-scale digital prints, silk pieces and the film *Skin*, I offered new visualisation techniques that went beyond conventional empirical outputs. Presenting to international, multidisciplinary audiences, including professionals from life and organic sciences and industry, underscored both the challenges and rewards of interdisciplinary communication. Feedback reaffirmed the value of artistic inquiry in reshaping scientific visualisation practices and encouraging reflective engagement.

Ultimately, this project contributed to both scientific and artistic knowledge and practice. It illustrated how artistic perspectives can deepen understanding, stimulate dialogue and prompt innovative approaches to interpreting complex phenomena. The resulting framework (see Figure 9, Chapter Two) serves as a guide for future art–science collaborations, with potential applications across diverse disciplines, including science, engineering and medicine.

Chapter Six: Conclusion

This practice-led research contributes to knowledge by demonstrating how incorporating a serious, purposeful and strategic play-based approach within interdisciplinary art–science collaborations fosters communication, innovation and knowledge production. By positioning play as a central and critical mode of inquiry, rather than as frivolous or peripheral, I have shown how it can unlock new possibilities for communication, experimentation and knowledge production across disciplines.

A key contribution of this PhD research is the development and implementation of a robust, four-stage framework for furthering art–science research. This framework integrates play into both scientific and artistic processes, and advances a novel, reflexive, art-practice led methodology rooted in Participatory Action Research (PAR) and influenced by Schön's (2013) model of reflective practice. It offers a flexible structure for iterative inquiry, allowing play to function as both a philosophical lens and a practical strategy.

I was drawn to the field of art–science collaboration because of its potential to create hybrid spaces where aesthetic, philosophical, scientific and technological modes of thinking could intersect. Rather than treating disciplines as fixed domains, I approached them as fluid networks of practices, materials and relationships, informed by ideas from Actor-Network Theory (Latour, 2010) and contemporary critical art theory. I wanted to create the opportunity to disrupt traditional disciplinary boundaries and to reimagine collaboration between the arts and sciences as a generative, reciprocal and critically reflective process. My aim was to examine how artistic inquiry – particularly through structured play – can lead to new forms of knowledge, challenge empirical norms and activate new dialogue within scientific spaces.

Play

The philosophy of serious play, drawing on the theories of Caillois (2001), Huizinga (2016), Winnicott (2005), and Gadamer (1994, 1998) is at the core of this framework. Play was taken into real-world collaborative settings, and in this context, became both method and metaphor, where play was used as a serious, generative force, capable of disrupting rigid structures, inviting experimentation and supporting embodied learning. Through play, participants (myself included) could adopt non-hierarchical, inquisitive and risk-tolerant approaches to shared problems and processes.

Play was enacted through immersive methods such as role-swapping, mimicking scientific procedures, software experimentation and responsive image-making. These engagements allowed me to work closely within the cultures and practices of pharmacology, natural history and biomedical science, uncovering new perspectives and insights in each field. In pharmacology, creative disruptions into rigid scientific workflows revealed overlooked phenomena, expanding modes of visualisation and fostered transformative interdisciplinary breakthroughs. At NHM, by pushing scanning electron microscopy beyond its conventional protocols, I demonstrated how artistic experimentation can reveal overlooked microstructural phenomena and generate new interdisciplinary methodologies. In biomedical science, adopting a playful, artistic lens revealed the aesthetic and experiential dimensions of skin research, disrupting hierarchies, enriching data interpretation and opening new possibilities for more engaging scientific communication.

The framework

Cycles one, two and three of the framework allowed me to generate diverse forms of data – technological, ethnographic, dialogic, practice-based and process-led – through the interpretive and critical dimensions of art as research (Macleod and Holdridge, 2005). Play enabled the emergence of unexpected connections and productive tensions between disciplines, materials, tools and ideas.

The framework developed through this research was actioned across three distinct art–science projects. Each project was explored over four iterative cycles of practice (see Chapters Three, Four, and Five; Figures 9 and 10). These projects contributed to the evolution of the framework itself, illustrating how the concept of play and the strategies employed (e.g., industrious, strategic, divergent), shifted in response to each context. This demonstrates that the research is not simply about applying play to various disciplinary environments, but about understanding how play itself is reshaped by context. In turn, this reflexive and adaptive approach allowed structured play to serve as a methodological tool for facilitating meaningful, situated collaboration within scientific environments.

This reciprocal collaboration model supports fluid role exchange between artist and scientist. By embracing non-rational and playful modes of engagement, the research challenged empirical rigidity and institutional hierarchies. These creative disruptions enabled new forms of interdisciplinary experimentation, in which collaborative roles could shift dynamically, enriching both the creative process and scientific understanding.

Drawing on Actor-Network Theory (Latour, 2010), the research also explored the human–non-human entanglements within scientific imaging practices. Through software-based play, I redefined the notion of the finished artwork, transforming raw data into reimagined visuals. The resulting works, which combined documentary footage, unprocessed data and processed outputs, took the form of digital drawings, data montages and experimental films, integrating haptic, auditory and experiential elements.

These outputs were disseminated through exhibitions, academic conferences, publications, and live performances. They engaged a range of audiences and repositioned the role of the artist within scientific research. Scientific collaborators, including Dr. Fernandez-Rodriguez, recognised the value of this approach for scientists, highlighting its contributions in terms of innovation, playfulness and creative storytelling in microscopy and visualisation.

The three art–science projects serve as exemplars of play-based collaboration in action. Each generated both scientific and artistic outcomes, including novel imaging techniques and experimental visual methodologies. These outcomes demonstrate that structured play is not only exploratory but also generative, capable of producing new knowledge, insights and methods that were recognised and validated within the scientific community. This validation came both through tangible outputs and testimonial evidence (e.g., Tim Self, Fernandez-Rodriguez) and provides reason to continue developing "serious play" as a strategy to rethink scientific research and communication.

Ultimately, I approached art–science collaboration not simply as a site of exchange, but as a laboratory for critical, creative transformation. Play functioned as a catalyst for new ways of seeing, thinking and working, across disciplinary divides.

Glossary of terms

Automated imaging and analysis in a plate reader format (AIPF) is a bioimaging microscope. A fluorescence plate reader measures the light signal emitted by a sample in Relative Fluorescent Units (RFU). Fluorescence plate readers are available as standalone devices (fluorometers), as part of larger systems, or as part of multi-mode microplate readers when combined with absorbance and/or luminescence detection.

Bio-interfaces are contact points between biomolecules, cells, biological tissues, or living organisms and biomaterials, emphasising biomolecular-surface interactions. This multidisciplinary field combines biology, biotechnology, diagnostics, and medicine, fostering collaboration between biochemists who synthesise biomolecules and scientists who develop tools for their precise positioning.

Bioluminescence is the chemical production of light that does not require laser or LED excitation, setting it apart from fluorescence. It is also not affected by phototoxicity or photobleaching.

Biomedical science is a broad field essential to modern medicine, used to assess blood needs for critically ill patients, identify infectious disease outbreaks, and track cancer biomarkers.

β (beta) -Adrenergic receptors (β-ARs) are G protein-coupled receptors (GPCRs) that mediate physiological responses to adrenaline and noradrenaline. Beta 2 (β2) Adrenoceptors spans the cell membrane and binds epinephrine (adrenaline), a hormone and neurotransmitter whose signalling mediates smooth-muscle relaxation and bronchodilation. Brian Kobilka and Robert Lefkowitz utilised the beta-2 adrenergic receptor as a model system to shed light on the inner workings of G-protein-coupled receptors. Beta Arrestin (β-Arrestins) are multifunctional intracellular proteins that can interact with a wide range of cellular partners, including G protein-coupled receptors

(GPCRs). They contribute to multiple aspects of GPCR signalling, trafficking, and downregulation.

Compounds are distinct substances formed by the chemical combination of two or more components in a specific weight ratio.

Confocal microscopy (CM) enhances resolution and contrast in fluorescence imaging by using a spatial pinhole to block out-of-focus light. It captures multiple 2-D images at different depths (ZED stacks) in a sample, enabling 3D object reconstruction (Wilhelm et al., Nd.).

Cultural producers operate behind the scenes in the art and culture sector, managing event schedules, finances, marketing communications, customer service, and providing administrative support to artists and technical participants.

Data management involves collecting facts and statistics for reference and analysis. These include quantities, characters, and figures generated from computer transactions, which are stored and transmitted using various software.

Electron Microscopy (EM) uses a beam of electrons to generate high-resolution images of specimens. The two primary types are Transmission Electron Microscopy (TEM) and Scanning Electron Microscopy (SEM). SEM captures images by directing an electron beam onto a sample's surface, where electrons interact with atoms to produce signals that reveal surface topography and composition (Boltovskoy et al., 1983). SEM offers superior magnification and resolution compared to light microscopy (LM), allowing for detailed examination of both biological and non-biological specimens.

Empirical experimentation starts with scientists formulating hypotheses and then gathering information through experimental investigations to support or refute them. They design their analytic systems to ensure data accuracy, quality, and integrity; flawed data collection methods lead to inaccurate analysis. Empirical evidence can be observational or experimental, and this process is a key component of the scientific method.

Energy Dispersive X-Ray Spectrometry (EDX) is an analytical technique for chemical characterisation of materials. Typically used with Transmission Electron Microscopy (TEM) or Scanning Electron Microscopy (SEM), EDX analyses X-rays emitted from a specimen when electrons or protons are focused on it. When a high-energy electron fills a core hole, it emits an X-ray, producing a spectrum of the sample's elemental peaks. This technique enables elemental mapping of the material.

Empirical rationality refers to the use of discernment and experience in acquiring knowledge. Empiricists argue that sensory experience is essential for validating our beliefs and understanding.

Fluorescence microscopy uses fluorescent dyes (fluorophores) that absorb one wavelength of light and emit another. As most cellular molecules are not fluorescent, scientists add these dyes to visualise them. This technique can distinguish multiple fluorescent compounds simultaneously and image single molecules in low abundance, with epifluorescence microscopy using the same objective lens for both illumination and detection.

Fluorescence Resonance Energy Transfer (FRET) Microscopy is based on the capacity to collect fluorescence signals from labelled molecules interacting in single living or fixed cells. When FRET happens, the donor channel signal is lowered while the acceptor channel signal is activated.

Human neutrophils are white blood cells that play a crucial role in the immune system by helping the body combat infections. They are among the first immune cells to respond when pathogens, such as bacteria or viruses, invade the body.

Human-stem-cell-derived cardiomyocytes are non-heart cells capable of differentiating into heart muscle cells. They can form 3D muscle strips by beating muscle layers in a dish.

Light Microscope (LM) magnifies an object's fine detail by focusing a beam of light onto or through it. Convex lenses enlarge the image. Binocular eyepieces and a screen display the image.

Multiphoton microscopy provides advantages over confocal and deconvolution microscopy for three-dimensional imaging. Two-photon excitation is especially effective for imaging living cells within intact tissues, such as skin (Piston et al., Nd.).

NanoBRET assay (employs NanoLuc® luciferase as the BRET energy donor and HaloTag® protein tagged with HaloTag® NanoBRETTM 618 fluorescent ligand) as the energy acceptor to evaluate two binding partners in live cells.

Natural auto-fluorescence is the emission of light from biological structures such as mitochondria and lysosomes after they absorb light, helping to differentiate between these structures and chemically added fluorescent markers (fluorophores).

Objective lens is the key imaging component in an optical microscope. This complex multi-lens assembly focuses light from the specimen to create an intermediate image that is further magnified by the eyepiece. The objective lens significantly impacts image quality, magnification, and resolution, making it the most intricate part of a microscope.

Optical colour achieving accurate colour balance in optical microscopy is challenging, even for experienced microscopists using film or digital cameras. While electronic capture allows for white balance adjustments, noticeable colour discrepancies often arise when comparing digital images to live views through the microscope. These issues typically go unnoticed until a recorded image is reviewed in a different environment.

Pharmacology examines the effects of medications on living systems, focusing on how drugs interact within the body, their influences on various biological processes, and the development of new treatments.

Photoactivated Localization Microscopy (PALM) a method to surpass the diffraction limit uses photoswitchable fluorescent probes to achieve super resolution. Individual molecules are stochastically activated to a bright state, imaged, and photobleached, allowing spatial separation over time. Combining these positions across cycles produces a super resolution image. This probe-based strategy, developed in 2006, includes techniques such as PALM, FPALM, and STORM.

Receptor is a protein that binds specific molecules, called ligands – such as minerals, proteins, hormones, or neurotransmitters – at a binding site. When a ligand binds, the receptor undergoes a conformational change that alters its function. This change can activate enzymatic actions or other cellular processes. Receptors, found inside or on cell surfaces, play a key role in cellular responses and can be quantified mathematically in receptor theory, which models pharmacological effects and helps refine our understanding of biological systems.

Scientific visualisation standards for image data integrity require that any image processing be minimal to ensure accuracy and meet community guidelines. While some image adjustments are allowed, the final image must faithfully represent the data. Editors may employ software to detect alterations and can request original, unprocessed files for peer review. If these files are unavailable, the review process may be paused until concerns are resolved.

Stereomicroscope is a low-power optical instrument designed to closely examine three-dimensional specimens, providing greater detail and depth than a hand lens.

Stochastic Optical Reconstruction Microscopy (STORM) fundamental idea is that a photo switchable molecule emits enough photons while activated to allow accurate localisation before deactivating or photobleaching. Furthermore, each activated fluorescent molecule must be spaced beyond the Abbe diffraction limit (more than 250 nm) to allow simultaneous recording of independent emitters with distinct lateral coordinates.

Structured Illumination Microscopy (SIM) is a wide-field imaging technique that uses a structured (typically striped) excitation beam, rotated in steps between captures. The beam interacts with the sample, creating a Moiré effect that encodes otherwise non-resolvable details. Specialised software reconstructs images at double the resolution (up to 100 nm). SIM excels at imaging thicker sections, producing 3D images, and visualising live cells more effectively than other super-resolution microscopy methods.

Super Resolution Microscopy (SRM) surpasses the resolution limit of optical microscopy while maintaining low invasiveness, enabling observation of life's finest structures at 10–100 nm resolution. This technique allows for quantifying biological mechanisms, such as protein subcellular colocalization (Allen et al., Nd.).

Three-dimensional topologies and rotation views provide new insights into specimen structures. Maximum intensity projections (MIPs) convert 3D data into 2D images by using the brightest pixel from each layer. Typically viewed along the Z-axis, MIPs can be generated from any axis.

Rotation movies show a series of MIPs at different angles, creating the illusion of a spinning 3D object. These projections reveal details that single-plane images may obscure, sometimes requiring only a few adjacent planes for clarity.

Units Of Concentration Measurements:

Molar (moles/litre): M

Millimolar (millimoles/litre): mM

Micromolar (micromoles/litre): µM

Nanomolar: nM

Picomolar: pM

Z-stack imaging compiles photos taken at set intervals between the first and last focal planes. These images create a short real-time video, enabling users to explore the specimen from any plane of focus without a microscope.

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Appendices

Appendix One: Outputs

Recent publications, *Leonardo* Volume 58, Issue 1, doi: https://doi.org/10.1162/leon_a_02604 (September, 2024) and *Drawing: Research, Theory, Practice*, 9(1), pp.35-53.https://doi.org/10.1386/drtp_00127_1 and the Related Systems Thinking and Design (RSD12) Symposium (2024).

Dissemination in non-scientific exhibitions:

Art–science interplay, The Coningsby Gallery, London. 17 July – 29 July 2023. Available at: https://www.coningsbygallery.com/exhibition/new-works-by-jo-berry-july-2023.

The exhibition showcased all three art projects (digital prints, silk creations). Interpretation material explained my research and my wish to dismantle silo mentalities.



Figures 99–102. Berry-Frith, J. (2023) Coningsby Gallery, London. © Jo Berry-Frith.

A group exhibition and symposium: What is Drawing Research? Birmingham School of Art, Margaret Street, Birmingham (2023).

Conference *Presentation: Drawing Along University Borders.* International Conference on Drawing, University of Porto, Portugal, 16–18 October 2024.

Other opportunities that have happened from networking with specialists beyond my field of expertise:

2025–2030 Wellcome Trust grant titled **DIALOG: Understanding Disorganisation: A Language-focused Global Initiative in Psychosis** (Reference: 314138/Z/24/Z). This project involves a global team of researchers from Canada, Italy, Australia, Germany, the United Kingdom and the United States, and focuses on mechanisms of 'thought disorder' in psychosis, often referred to as 'disorganisation'. While this symptom is experienced by all psychosis patients at some point, it often goes unreported due to diminished awareness. Historically, this concept has remained largely within clinical circles and is rarely articulated to the public, particularly to families and individuals with lived experience.

Principal Applicant: Lena Palaniyappan. **Main institution:** Douglas Hospital Research Centre, Montreal, Canada. **Co-applicants**: Valentina Bambini, Neil Harrison, Tilo Kircher, Gina Kuperberg, Susan Rossell, Krish Singh, Iris Sommer. **Collaborators:** Maria F. Alonso, Sylvain Baillet, **Joanne Berry-Frith,** Marta Bosia, Erik de Vries, Oli Delgaram-Nejad, Frederico Frau, Hashwin Ganesh, Micheal Mackinley, Milica Miocevic, Frederike Stein, Philip Sumner, Sunny X. Tang, Philip Tibbo, Alban Voppel, Lin Wang.

Berry-Frith will assist with the project's knowledge translation arm, creating visual data montages and art exhibits incorporating lived experience perspectives. See for example, https://douglas.research.mcgill.ca/news/understanding-psychiatric-disorders-wellcome-trust-dialog/. Berry-Frith has previously collaborated with Palaniyappan in an art projects see for example, https://joberry.co.uk/commissions/commission/light-it-up.

Appendix Two: Cultural Producer interviews

The baseline shift in this PhD, which I used to understand this environment from an institutional point of view, includes specific audio transcripts from the Wellcome Trust and Science Gallery, London. They were used as a tool for comprehension while bridging the gap between art and science.

1.1 Meeting with the Director of the Science Museum, London Daniel Glaser

Date: 19th April 2018

Daniel Glaser: DG and Jo Berry: JB

JB: Thank you for meeting me. So, I am an artist doing a part-time PhD, and I am working with a number of scientists.

DG: I have read everything you have sent.

JB: Okay.

DG: It's good to hear.

JB: Right let me just get.

DG: Yes, okay.

DG: When you went to listen to the recording, the big gap is when I went to get a cheese toastie.

JB: I went to see Rosie Stanbury and Ken Arnold last week, and he [Arnold] was talking about the cleaners in his gallery.

DG: Yeah, yeah.

JB: And that was the first bit; it was quite funny, so I will let you [continue].

DG: It’s much more efficient if I just plough on.

JB: Okay.

DG: Please forgive me again for eating and enjoying the sandwich. You have one of those days when you.

JB: Its one of those days. Yes, I am working with different scientists—two groups. One [is] in Nottingham, and one [is] in Birmingham, and the one’s in Nottingham and Birmingham are linked and are called COMPARE, and they are cell signalling and pharmacology specialists. So, I have been working with Nottingham for over ten years. I have been going into the labs and observing them, taking data from them, and, er, creating work from them with the data. And the other people I have been working with are scientists in Gothenburg, in Sweden, and they don’t really have an Arts–Science [background]. You know, they have never ever worked with an artist before, so I went over nearly two years ago, and I am going over in October to Malmo to show them the work that I have been doing that is based on the research [that I did] when I was there, and then I am going to show it again in Gothenburg as well. So, it will be a series of films—some digital drawings, some animation—that is all to do with their research.

DG: Okay nice.

JB: And.

DG: And to do with is where the interesting question lies?

JB: And yes, I'm really interested in finding out, you know what you think about what are the distinct approaches, as to understanding and communicating ideas that, you know artists bring to er, to science. I wanted to know what you thought really and, er, yes, because of all your experience, if you wouldn't mind talking about it.

DG: I think the right framework for this really is to think about it in terms of interdisciplinary practice, and most of my thinking is around the structural nature of interdisciplinary practice. And although I do think that there are quite a few practical questions in terms of how you curate, direct, manage, or maybe even evaluate things like this which are distinctive and interesting, but I think they mainly arise through structure.

JB: So, tell me about structure.

DG: So, I will tell you about structure. So, I guess if you are thinking about inter-disciplinarity, I think the first ingredient that you need in the story is disciplines. And unless you have clear views about disciplines, it's hard to be smart about interdisciplinarity.

JB: Right.

DG: I think.

JB: And what sort of disciplines do you [or] have you come to decide are necessary?

DG: I think, no its alright. So, I think that you need distinctiveness. Is my point.

JB: Okay.

DG: So, the most conventional mode of this in the UK in SciArt and blah, blah, blah, would be that one discipline is saying "research science", so that's usually professional scientists, usually in universities, usually with government or charity funding, er, conducting research. You can have some clinical groups that can work, and then the other discipline is the practice of art, which I am just labouring the point, but I think it's a lot of this stuff is forgotten.

JB: Yeah, it's really important.

DG: And the first critical thing 'em [in] arts practice is well established, as it is 'em my joke about this is that the main difference about scientists and artists is that scientists have salaries and artists don't. So, the institutional structures around the two disciplines are very different. Arts practice is a professional domain; you have qualifications, markers of success, and quality; and also, and I think this is forgotten, you have the whole professional practice of curation and then also the technical aspects of mounting an exhibition and all that kind of stuff, which are well established. The reason I say that is because I think historically with SciArt, it's kind of been assumed by. I don't now – scientists and administrators that they kind of ignore all that and they think we will just get some art in.

JB: Okay, do you still think that's what scientists think, do you?

DG: Largely. So, I know some scientists who have quite a track record of engagement, but there's one who said, "Yeah, so Guy, who has been writing musicals [and] musical theatre about the stuff we have him to come into the lab and perform musicals". And I am like, "So how much are you going to pay him?" and she or he, the scientist I am talking about, says we don't pay him, but it's great exposure [and a] great opportunity to be able to show his work in a lab. It's interesting. But I am like he's got nothing coming in. So, 'em often in curatorial decisions and production decisions are made by university administrators. We get some theatre or some artist in, and I think it's quite inefficient.

JB: And how do you think you as an organisation, you as curator make it more efficient – what do you bring to that sort of that collaboration?

DG: A) Professional curators to do curation; B) Pay artists to do work.

JB: Do you have a budget?

DG: Yes, we do. The Science Gallery by Kings we are part of Kings University, London. We have an operating budget of about £1.5 million a year. Of that, probably a little bit more than £600,000 is [the] programming budget for [the] season. We do three seasons a year [for] probably £200K each a little bit less.

JB: And that is for an exhibition.

DG: Each season is an exhibition, I mean the building will only open this year, September this year. We have done four lead-in seasons which have been in pop-up locations around the campus and around London. The last one was on "Blood", and we did that at the Copeland Gallery in Peckham. So, because we are already engaged and committed to engaging with young people from marginalised groups as well as non-marginalized groups 'em we think that it's quite useful to engage in spaces where they feel comfortable. Each season, once they are running, will have an exhibition and events programme.

JB: What was the footfall, the one in Peckham.

DG: Several thousand people saw it over three weeks.

JB: And what sort of response did you get over, you know the different groups who looked at the exhibition?

DG: [It was a] reasonably systematic assessment of the exhibition. Because it was about blood, people didn't really think about blood in that way before. We like to choose topics where you can't understand them from just one perspective. So, this is back to interdisciplinarity, right? I could give you a complete description of blood from a biological perspective or from a medical perspective, but it still would not explain why a certain proportion of people pass out when they see it.

JB: Right, okay.

DG: Or why menstruation is such a big taboo, or why white blood cells are so interesting, especially in the context of cancer. You Know. So, commissioning artworks to engage with this kind of stuff meant that visitors thought about blood very differently at the end of it than they did at the beginning. An interesting point in view of taking someone through an exhibition.

JB: And what were your I suppose guidelines; did you give the artist? What do you want the artist to bring?

DG: There best work 'em stuff they /she couldn't do elsewhere. Because we have quite a long period between choosing the theme and the show coming on, it's about two years. We are quite interested in a proportion of at least our artists developing a deep engagement with researchers over that period.

JB: How do they do that? How is that facilitated?

DG: It's not automatic, and it's not trivial. We have worked. You know we spend a lot of time in the team making links and then trouble shooting. This stuff does not happen automatically. And if you leave artists and scientists to their own devices, as if [you] put them in a room together, it almost never works, really? So yeah, having set the agenda by talking to young people, we then have an open call, so anyone can submit an idea or experience. You know there is a Science Gallery in Dublin, right?

JB: Yes.

DG: But experience from there is and ours has now been the case that sometimes you get most of what you need from the open call maybe you need one or two additional bits.

JB: Right.

DG: Sometimes you get a few wild cards in from the open call, but basically you are going to have to commission most of it directly, so we are not committed to using only the open call.

JB: Why have you decided to use the open call?

DG: So, there are two reasons. There are two answers to that. One answer to that is that it's in the model. So, there is a Science Gallery model which Kings has taken from Dublin. But the other reason. Well, the other reason is because. The other set of reasons are intrinsic. So, one thing that you can say is [that] it's a way of asserting – a rhetorical asserting openness. Closely related to that is [the fact] that you really do get work in that you would no way find if you had set out to look for it.

JB: Right, okay.

DG: From people who would not normally be part of the story.

JB: Right.

DG: One of the pieces we had from "Malfy", which was the season that ran two years ago was from a young Spanish artist who happened to be in London called Inés Cámara Leret and she came up with a proposal called 'spit-crystal'. [Science Gallery, ND].

JB: Okay.

DG: She had been collecting her own saliva for months and found a way of making rather beautiful crystals out of it. And since spit is very interesting in the context of the mouth [and] something we generate quite often [and] get rid of, [it] leave[s] your mark. So, we commissioned her to make *Spit Crystal*.

JB: And the exposure that that gave her has that been fantastic for her?

DG: As part of the show, she ended up working with the X-ray crystallographer from Kings to look at the protein structure of [the] crystal which she formed. She's not a well-known, [she is a] very young artist, not very well known. [She has] made a few pieces and no way we would have found her but [for] the open call you know. She is part of a project now with the researcher, professor which is part of a new technique for desalinating water.

JB: And how did that come about?

DG: There was something about the way she'd been. What happened was that he had been.... [and] he said, "I don't think the crystals you are making are *Spit Crystals* at all. How do you make them?" She said Well, "I add Alum and then I". And he said, "Well, there you go, it's an alum crystal, not a *Spit Crystal*".

JB: Right.

DG: Well, she said, "Well, I tried it with that, and it is definitely different", and he said, "no". Well, he said, "Alright, let's have a look at it", and he said, "oh, actually, it is". And so, it turns [out] that the way the proteins in the saliva are crystallising out was not all, and when they followed that through, it turned out that that was a new technique for getting salt out of water. So, to the interdisciplinary point. So, you asked what is it that we want from our artists. I said [it was] their best work. But I also say, I would say that we get good work from them by putting them in an interesting environment.

JB: So, are you the person that always facilitates that then?

DG: In the general case we are the ones who make that link. But—and that is another point about interdisciplinarity—you almost always find that there are benefits in both directions. So, actually as in this case the researcher. And this is a very direct case the researcher sees her work differently as a result of the collaboration, just as the artist does, and so to your point about interaction in science and art, the question, by making situations where people who see the world differently can interact ideally on an equal basis but on a level without power relation[s], you generally find that both groups see there worlds differently as a result.

JB: How do you manage the power relation. You know are artists going into scientific labs and working with scientists?

DG: It can work both ways. You have to make the scientists behave well. Generates that well.

JB: What sort of instructions do you give them to do that?

DG: Talk nicely, listen.

JB: Do they have a certain set of protocol, wish list?

DG: To a certain extent. Yeah, they do, and they don't, and I think you know this: Emm bum, bum, bum, so, er, all researchers now in the UK have to do what they call "pathways to impact", and that's part of the structure of research as it's funded by research and research councils by charities. And I think it's good news for me. It's good news democratically and socially, and it's a good idea. So, but one of the consequences of this is that they need to write this into their grants, and they don't know how to [do it]. Why would they? If you think about three percent being a good rule of thumb for the amount of the percentage of the grant [that] should go on engagement well a ten million grant that's three hundred thousand pounds. Most of the researchers are not in a position to write incredible proposals of three hundred-thousand-pound engagement.

JB: So, do a lot of people come to you?

DG: Yeah. So, we run a service called engagement services where we offer people free consultancy, you see on how to do engagement.

JB: Right, that's good.

DG: And if they want to, they can write us in to help them deliver it. They don't have to and so in a way that can feedback into our budget, line into our programmes. But whether they want to do that, we help them think about [art–science collaboration] in a respectful way [and] the contribution of the artist to the project.

JB: Right.

DG: So, many researchers still have what you would call a very instrumental view of art. That it's there to beautify or to explain. But of course, it can do. There is nothing wrong with paying an artist if you are going to do a public presentation. You probably do want someone with a bit of graphic design sense to help you design the slides. Because as a scientist, that's not your bag, and likewise, if you want to put an exhibition on, in the lobby of your research building, it would not be stupid to get an artist to help you think about that space and structure.

JB So how do you get the scientist to see beyond that?

DG: Well, eh, what you do is you say that they are going to need that their proposal is going to be peer reviewed, so they better have.

JB: By?

DG: Ideally, if it's a big one, by artists, but otherwise by engagement professionals.

JB: Okay.

DG: So, they better have a convincing proposal as to how they are going to engage 10,000 young people, or whatever, and quite a lot of that is by involving engagement professionals, artists, or people with good sense. And in fact, in peer review, if you are a researcher reading someone else's proposal for 100,000 pounds worth of engagement and they have no track record and they are not involving any professionals in engagement, you are going to be quite sceptical about whether they are going to deliver it or not.

JB: Yeah, fair enough.

DG: So, explaining that to the researcher can help to focus their minds a little bit.

JB: Right and do you give them packs of information to help them or is it generally a discussion or is it a conversation over a period of time.

DG: We have to be a little bit careful of our time, so we can't give unlimited time to our researchers. We do, yeah, we looked at, so we did think. So, I used to be at Wellcome Trust, you may know so I was seven years at Wellcome, and I was in charge of all their funding of public engagement in the arts.

JB: Oh, really, when did you leave there?

DG: To come here 2012/ 2013

JB: Okay, Okay.

DG: I know Ken [Arnold] and Rosie [Stanbury] very well, and so, er.

JB: So, Rosie was a grant officer for my grant, which I just didn't realise was her until I saw her again. Yeah, it was really nice.

DG: So, er, you know, what if all researchers are going to be doing engagement projects? The important principle – that's quite a lot of engagement projects to review, and so one of the approaches that you could take is to use standard models—off-the shelf packages [and] prepare materials, and so on. We shied away from that a little bit because, we just, in the end, [we] didn't trust researchers to do that without a bit of guidance, and we found that when they were writing the application, they weren't really thinking it through, and you know, yeah, so it was risky, especially when they were writing the Science Gallery into the proposal. They would often if they were not talking to us, they would often say things that were impossible. So, we felt the need to police, I suppose. Engage in advance.

JB: And obviously, you know like that the scientists [whom you] have engaged [with] and have produced these public outputs and exhibition outputs and worked with artists. Do you think it's radically changed their [scientists] thinking?

DG: So, there is increasing evidence that you know that engagement people are not you or me; they do better research, right? So that can be if you are a biochemist working with a biologist or a physicist working with a mathematician or whatever, but it can also be, as we have said, with [an] artist working with a scientist. Having to explain what you do to a bright nine-year-old, is probably a good idea every two years or so, [it] is probably a good idea for research. Yeah so, I think, I thinks it's a... and there is increasing researched evidence for the idea that you get that, you get better research outputs when you have done engagement. And so, in a way, they have to do it anyway; the funders demand it, so in a sense, that argument has already happened. And...

JB: What's your ideal sort of... I know they are different, and it's evolving, so what's your ideal take on what public engagement can be?

DG: I don't think it's a single thing em, er and the history of the term is quite well it's quite specific. I don't know if you know the history of public engagement as a term.

JB: Not specifically.

DG So, there was a 1999–2000 Select Committee report from the House of Lords called "Science and Society". And one of the things which it identified was a lack of public trust in science, and so what had been public understanding, which was very much this push for dissemination, was replaced by the term "public engagement", and what that spoke to was the notion of two-way engagement. A process that listens as much as it speaks that recognises other perspectives, is non-hierarchical. Now public engagement now covers the whole range, so actually producing a handout to give to patients coming into your lab is kind of okay, making a TV programme its fine, but not really two way, [but] it's fine. The stuff I really like, it doesn't have to be symmetrical, but it does have to be a perspective from both sides, you know, a change of view from both sides. That's the exciting bit. You can't force that to be the case but if you genuinely create a space where both parties are sharing honestly what they are doing you will get a new view of the world from each side.

JB: And how do you sort of record that?

DG: We do questionnaires with our researchers.

Total recording 27.26 minutes.

1.2 Meeting with Ken Arnold and Rosie Stanbury, The Wellcome Trust, London

Date: 27th April 2018 at 11am.

Ken Arnold (KA); Rosie Stanbury (RS); Joanne Berry (JB).

KA: For posterity, we have this cleaner. She is terrific in some ways, but the notice on the desk is something I am very familiar with. She is terrific in some ways, finding different ways of telling us off. [For example, a] notice on [the] desk telling us off. [She] puts signs on top of photographs, on the decorations, slightly telling us off, [such as] please remember to. Tell us what you are doing and what you want to get out of this.

JB: What do you think personally is the distinct, what do artists bring to science, and I know it's really wide ranging, but I would like to know from you what do you think they bring, how do they challenge concepts [and] illuminate ideas? How do they challenge perceptions?

KA: The glib answer is that we don't know, and that's why we do it in different ways so often. So, I think I have a slight sense that there isn't a formula, and it isn't predictable. Oh yes, we will get an artist in as its always a good way of eh, so eh, so in some ways my sense is that we have an instinct that they are often a really interesting part of the conversation, but artists come in all shapes and sizes and er if there was one thing, they could do then you would do it for a couple of projects then maybe most of the projects you wouldn't. So, I suppose for me partly it's in the hope that it won't deliver what is expected of them. And having said that I suppose another thing, that almost to contradict that, there is a sense that much of what Wellcome is interested [in], is at the scientific end of the spectrum but given that we are a health-based organisation, I think we are mature and interesting enough to know that health is not just about objective, statistical, biological [facts]– it's not just about atoms and molecules and organs. And it's an incredibly important part, it's about human beings with personal experiences and that art is sometimes an interesting way of excavating that aspect of it, so in our efforts to bring the subjective and objective together sometimes doing that in the company of artists can very much enrich that interest, that range of interests.

RS: So, rather than Ken's answer of "you know, we don't quite know", I guess my answer would be, like many things 'em, which is kind of the same answer in a way 'em, but, and I guess thinking about that in a very generic way without specific examples at this stage. And if it's helpful to talk about shared qualities perhaps across many different practices, I think like openness and real like serious interest and interest in investing significant amounts of time but in a very open-ended way is something that, I have seen that consistently over many years. I think that sometimes real challenge or disruption or provocation in relation to particularly social or cultural context of science, health and medicine and I guess linked to that a real ability to sometimes be a bridge from the lab or from the research landscape to either public audiences or people who are significantly affected by that research, whether that's people with acute lived experience of health challenges which the research is linked and a kind of an ability to dive deeply into the understanding of those different perspectives and creating something new in response. I think it's difficult to talk in generic terms as it's so varied. I think it would be worth, and I don't know if you have looked at it; it's very old, but it's quite valuable [in terms of] the evaluation of the SciArts awards grants, helpful in terms of the case studies.

JB: I went to the SciArts in 2002. [It] would have been in your time. That was fantastic. There was some hits and misses, but it did start an interest. That was the first time I encountered something like this, collaborating with a different discipline and with science. It really did start an interest for me.

KA: As you were talking Rosie, I think one of the other things that and it's not universal at all, but I think a lot of the artists that we work with over the years the artists we are drawn to, are interested in applying their art in a sort of inquisitive way 'em and actually sometimes there can be er some people in this theory, [field of] science and art [which] are very dismissive of any art that is purely illustrative. There is often a sense in which that, that barely counts as art at all; that's just design. I don't believe that I do think that there are some great projects that are about visualising or but having said that quite a lot of the art certainty in terms of curatorial projects often come with an interest to use their art practice to find things out. Rather than to just translate things that are already known 'em and that can be quite exciting and as Rosie said their work often involves patients or other people who are interested maybe from a personal perspective in whatever that topic is. But come at it from a very different angle to some of the other inquiries. I think the other. There is an exhibition at the moment called "Somewhere in-between" (KA hands me a catalogue).

RS: Have you seen that?

JB: No, but I am going after this, thank you.

RS: That gives you a lot more context on the relationships between the artists and the scientists.

KA: No, well I think I am right in saying it's an unusual exhibition comparing with two or three others that feel as though they have the same quality which is an exhibition very specifically about the relationship and the counter and interaction, collaboration between artist and scientist. And actually, right from the beginning, the Wellcome Collection and before that what Wellcome has done [in the] world of arts and culture, have involved the sense in which art and science are part of the piece. But almost all have been other disciplines [with] other points of view too. And officially, I guess we don't use this officially, anymore when we started, we had almost a triangle of medicine, life, and art – [it] was our kind of tagline.

JB: Has that changed? Obviously, the arts award and obviously they have changed [and] over the years arts award changed. Has the ethos changed?

RS: Has the ethos changed?

JB: Has the direction changed?

KA: Specifically in the arts award?

JB: Has the direction changed? Maybe within public engagement?

RS: So, neither I nor Ken work specifically within public engagement but there has been some quite significant change/shift within public engagement. There has been a move away from 'form', specifically so the arts awards don't exist anymore. We used to have broadcast development awards; they don't exist anymore. There was essentially an acknowledgement that we had maybe 17 different grants, don't quote me on that, but it might be more maybe less, but they needed to be rationalised to make it less confusing for people who were applying. And then someone called Imran Khan [2016] started about two years ago, and he has quite recently launched a new strategy within public engagement which puts much greater emphasis on specific outcomes. So, there is much less emphasis on the different forms and, to some extent, the quality of, for example, a broadcast project or an arts project in and of itself. There is more of an emphasis in terms of… Well, what will this project mean in terms of what we are trying to achieve, and you can find it all out on the public engagement area of the website. That's all quite early stages, and the strategy toward the start of this year. But that's quite a significant shift, and to be honest and because nothing has been really funded through those channels yet, we don't really know what that will mean in terms of shifts of in terms of, the kinds of different projects that will be funded.

KA: I suspect in terms of external communities; it will gradually become less er. What's the best way of putting this that Wellcome for ten or twenty years, maybe has been partly known as an organisation that's been focused on engaging with artist communities and arts practitioners, and my sense of that the case next door. I think art it's still part of the external facing explanation of what is the content but on the public engagement side it might end up that there is as much arts as there was before but its less in the name of deliberately finding artists and arts organisations to work with and as Rosie says much more a sense of here is a topic we are interested, this is what behaviour or idea changes we are interested in and if art seems like a convincing part of the piece then let's do that, but we are not going to do this because we think in and of themselves working with artists [is key]. And then actually, that makes it for me, [it] makes it a more interesting organisation because, in one place, and certainly in my work, which is much more international now ‘er, I still hold onto a sense [that] it’s interesting to engage artists and work with them without not knowing explicitly what you are up to and that’s almost the opposite to what we say on the public engagement side which is [there is] no point getting someone involved unless we know what we are doing. I said that it almost looks like we are an organisation that is a bit confused, or [that] we, it just says [we are] doing lots of interesting things in different ways.

JB: So, do you approach artists? Just approach people now and just obviously approach people, do you do that – not through grants, do you have a topic or do you?

KA: Yeah, I should just say what I am doing, so my work here now is their cultural projects that start elsewhere in the world. They are topic led, and they are co-produced, so we do exhibitions, events, radio programs, and a variety of cultural forms, but they happen; they didn’t start here, as it were, and [are] taken on the road. They didn’t start here. They are an idea that we had in a place where we want to work, and then we find people, we find people we hope will be interesting to work with there. And they develop locally work there, but with topics that have a broad interest and appeal. So, in that context, in my work, yes, we are very much still finding people [with whom] we want to work and then commissioning them to do something, often with a sense that we don’t want to be too prescriptive. If they don’t want to do our topic, then that becomes a problem, and they don’t want to [do]that. For example, if we have an exhibition about diseases and they want to do something about heart transplants, that becomes difficult to accommodate. Apart from the fact they are on subject and that they will have a public outcome we try and work collaboratively.

JB: Do you with this work as part of this new work, do you really try to work with local artists people who are based in that place?

KA: Yes absolutely. So, a project—have I got a leaflet? So, that's just an initial flyer about this project (he hands me a flyer) that will become public at the end of the year. It's based in New York, Hong Kong, and Geneva, so we have got an artist or group of artists involved in each specific context. So, the one in New York lives in New York. The one in Hong Kong, lives in Hong Kong. Interestingly, the artists that we have commissioned in Geneva are based in Brighton. But actually, they are working with the World Health Organization (WHO, ND), [they are] in residence at a room that the WHO runs to do with disease preparedness. And actually, their topic is already a self-consciously international one. I don't know how much you know of Geneva, but it is a strange city in some ways in some ways, it is feeling like that you are not quite in Switzerland. Ten percent of the population are international and there is even a bit of tension between the Genevans, who are Swiss and born there, and the nationals and those who are there on behalf of the world, as it were. And it almost feels like an accident.

RS: So that's through Ken's portfolio, [which] is one of the ways that we work with artists internationally, and then obviously through the programmes in the Wellcome Collection in terms of the temporary exhibitions programme and also our public events programme and also our research hub on the fifth floor. We work with artists in many different ways.

JB: Yeah, I wanted to ask a bit about that because obviously it's only been happening in the last few years, they are quite large grants that are given to a group of people, aren't they?

RS: Yes, we have had two hub residences so far.

JB: Have they been very good? Have they been successful?

RS: I think they have been absolutely fascinating. So, the first research group was looking at rest and busyness. I think that they felt a huge amount of pressure in terms of reflecting on what the interdisciplinary process is. So, they wrote a book on that.

KA: Two books.

RS: As well as doing loads of events in Wellcome collections, as well as producing many research papers, as well as doing [a] national rest testing collaboration with Radio 4, as well as putting on an exhibition in mile end, they did all sorts of stuff.

JB: Did they think they were going to do that in the beginning, or did it just grow?

RS: Well, you were in on the interview panel?

KA: Well, no they had ambitions to do publicly facing things and I suppose part of the offer, the pitch for the Wellcome collection for The Hub in Wellcome collection is to have a research agenda but they should be very broad and almost promiscuous in who they think might be involved in the research. It's not just academics, not just multi-disciplinary its maybe trans-disciplinary the word now, it's co-produced as well and that they should make best use of being in a public space and part of that is maybe drawing on public attitude on the supply side and maybe sharing some of their methodologies, some of their findings with [the] publics in the opposite end. Yeah, in some ways it's been incredibly successful, and it's been fascinating, and they have been very productive.

JB: So, is it set up like a proper lab, is it set up?

RS: No, it's not like a lab setup; [it's] like an office space.

JB: And how do people meet? Do they come and have meetings there and go off to different sites and places too?

RS: And it varies across different projects, so the group who are in residence at the moment, who are called “Created out of Mind”, are looking at the relationship between arts and dementia. So, they significantly changed the infrastructure of the space before they got in, so that they could have lots of workshops with dementia patients in the space, which has been really interesting for us in Wellcome Collection.

JB: So that must be really interesting. So, people with dementia have been coming here?

RS: Coming here but also coming next door (where Wellcome collection is) ‘er and their carer’s and lots of the group came from UCL and those are the kinds of patient. They particularly work with people with rare dementias and the kinds of workshops they would normally run in the university. So, for them, it’s been fantastic to have somewhere slightly more publicly accessible to engage in some of that work. But they also have—yeah, they use their space in many different ways. And the next group is slightly confidential at the moment as it hasn’t been announced, but I think it will be announced in the next month or so. The next group are.

JB: I won’t.

RS: The project is called *Gerhug*, and the application predominantly came predominantly from an organisation called “Heart and Soul” [Wellcome, 2018–2020] and they are an organisation who profile people with learning disabilities as artists in and of their own right. And they are looking at questions around human value, human productivity, and human well-being and co-developing that research with people with learning disabilities. So again, they will use the space in very different ways, I think.

KA: But interestingly there is almost a kind of trajectory you can see. So, the first group were dominantly academic and very broad ranging and with a broad cast and some other people involved too. And the second group have had a focus on involving the subjects of the topic that they, in a co-productive way. And I think the sense we have from interview and just as we get to know the "Heart and Soul" group, it's even further in terms of the people. The people who run the "Heart and Soul" group are themselves people with learning difficulties to a significant extent and therefore it's not just them as subjects and co–production; it's almost their agenda or extend seeing how much research in a public space can be done, set-up in that context. It's a difficult thing for an organisation; that's not traditionally how research is done. And I think, for us that's a really exciting challenge is how can we, it immediately makes it that we can't simply orchestrate it how things are done that's reverting to how research is normally done. On the other hand, quite what that research is, remains to be seen. So, I think for us its really exciting and I am sure it will be a challenging context to think about quite what we are up to, but that's the affordance of next door.

RS: Of a very different context and in all of those very different incarnations the space their artists have been involved in different ways 'em but its evolved significantly and to some extent it still feels like early days because the grants last for two years and because there is only one residency at any one time. So 'em yep.

JB: Do you think you will try and make them longer, or is the plan just two years?

KA: No, there is always a temptation we get to know them and they are nice people and we are nice people so there is always a kind of human tragedy at the end of the two years and it's great to be able to, for us to pay for these unusual ways of working, but mostly I think the people, its challenging and it's a lot but it's a huge privilege so there is always a sense of shall we extend it for another six months or a year? [It] probably shouldn't be. It should be kept for two years, then hopefully the energy that we have built up should be taken elsewhere because for us, it's a little bit of a pipeline; if they stayed, another group wouldn't be able to come. Sorry, I interrupted you.

JB: No, no, I am just thinking, is it becoming more, I don't know, in a funny sort of a way more localized. You know it's a big organisation, isn't it? Do you think you're becoming more, I suppose it's the human element isn't it, the becoming more human element more grounded as possible and or?

KA: My work, these international projects that the women I am working with on this one has come up with a very neat phrase, I think. That echoes that, Danielle talks about – local conversations about global challenges and that sense in which, that if you want it to be real for specific people you probably have to be local but by being local you don't just have to talk about things that are only resonant locally and its, then the interesting tension is how can it be both at the same time? You know it's interesting the language of ecology has some of the same you know local action terms, whatever the phrase is global effect in some ways in terms of what we are doing in "Contagious Cities" and maybe some other international projects have the sense that their parallel worlds as a big overarching issue but also culture has, is a great way of bringing it down to specific people with specific experiences and how they want to express them in a specific way.

KA: Forgive me, and I could have reminded myself, so this has been done for?

JB: This has been done for a part-time PhD.

KA: Where are you doing that?

JB: Birmingham; I work at Birmingham City University.

KA: Aha, right, yeah.

JB: And I teach illustration, and I have had a long relationship with Nottingham University because I got a Wellcome Trust grant ten years ago, and I work with the school of biomedical sciences, and then I worked at the Neuro Translational Imaging Center at Nottingham University as well. And I have done a number of projects with people from different disciplines, and I really like working with scientists. I spent a lot of time listening, looking, and observing what they do, and anyway, this is an opportunity for me to go back. I wanted to work again with Nottingham, and I wanted to work with the microscopists and the advanced imaging people, so I have been going back and observing them. But also, obviously, they have another network of people, so through them I have had other links with people in Sweden. I did an Erasmus thing at Gothenburg University for a week. So, they were doing some experiments on cells and creams and looking at the crystallisation of some skin creams, so I have been getting loads and loads of information. I have been filming on a little camera, spending a lot of time listening and filming sort of the imaging specialists while they are conducting experiments, and then I have been getting that data and using Nottingham's software for Zeiss, which is Zen, and playing with it and making little movies and 3D topologies and all sorts of things like that.

KA: So, will your PhD be partly practice?

JB: Yes, it is practice-based.

KA: Right.

JB: It's all about visualisation, really, [and] how you can visualise science in a different way. Maybe that can say something to scientists, and maybe that can say something to the public. So that's what I have been doing. So, I have been working with the scientists, and they have let me, like, show my work at a couple of conferences. In Nottingham, they have organised this thing called COMPARE, which is a collaboration between Birmingham University and Nottingham

University, and they are sort of working together on different [things]. You know sort of scientific problems and questions and they have conferences. So, I have been showing my work at these conferences, like artwork. What's changed is that we are a very different breed of people, and you know that you are trying to make something that has some relevance but also takes it on a journey. So, I have been taking some of the pure scientific imagery and putting it into some of the images I am making. But what I want to try and do is show some documentary footage but [it is] playful and quite surreal in a way, like little bits of footage [of] imaging people doing experiments and then some films of me animating and playing with data, and then I do a lot of drawing in Illustrator. I am interested in the whole idea of digital making them into pixilation and I find the whole environment fascinating. It's going to be partly a comparative study; somethings are in common, somethings are completely different, and some relationships that I have are very good and easy and some are more complicated. And, like, what is the value? What is the value of an artist going into a lab and, you know, working with scientists? Is there any value? Do they see any value in it? And some people do, and some people don't? It's really complicated.

KA: There is a science communication course and a PhD written a good ten years ago by a friend and colleague called Stephen Webster [2024] and he now runs the science communication course at Imperial. His PhD was, I think, he did it at the Open University and he did it based on interviewing a dozen or so artists who were working on scientific projects. To try and unpick what he could discern from almost a sociological perspective. I suppose which you should be able to find that at the Open University, which might be interesting to look at.

JB: Yes, I will definitely look at that.

KA: Yes, Rosie, you were talking. And Rosie might know a number of other examples from the Wellcome Collection's back catalogue. I can't quite remember how much documentation there is online about them, but there are two exhibitions that I think we're pretty much simultaneous that have a much more, if you like, straight-forward science meets art agenda to them. I think one was with 'er the dancer and choreographer Wayne McGregor [2013], and I can't remember what that project was called.

RS: "Thinking of the body".

KA: And he [worked] for a decade or two worked with a group of artists, oh, sorry, a group of scientists interested in trying to understand his working methodology, even trying to peer inside his mind and then.

RS: Cognitive scientists, mostly.

KA: What's his name, David? He was from California. And the other project was a previous international initiative projects done by the same person, Danielle Olsen, which was called "Art in Global Health", (no date) and that was based on six different international centres of science research that was funded by Wellcome in Thailand, Vietnam, Malawi, South Africa, Kenya, and Cambridge. And in each place, Danielle found an artist or group of artists to work collaboratively with the scientists to develop work that was shown in those countries, sometimes very specifically in the scientific institutions, and then they were brought back together. I think it was a show on here at the same time as the Wayne Macgregor one, and it was called "Foreign Bodies Common Ground"[2013–2016], and they are both examples of how they touch on issues of how do you visualise science and then maybe, working in the opposite direction, how does science try and understand part of the creative artistic process?

RS: Do you know about the show that is on at the Crick at the moment as well? That would be worth showing.

JB: No.

RS: That will be worth seeing. That would be worth going to.

JB: No.

RS: Have you heard of the Crick Institute?

JB: It's just been built?

RS: It opened a couple of years ago, a year ago. A ginormous new Science Research centre. But they have an exhibitions programme run by a wonderful women called Bryony, and they have a show on at the moment called "Patterns" [2018]. And it was the product of various different artists working in collaboration with scientists from the Crick. 'Em so that would be well worth looking at while you are in town. It depends [on] how wide you want to spread your net; the Sanger Institute have got their own. I don't know if she is called, [and] I don't know if her role explicitly is about the arts or of its [an] exhibition's role, but 'em she might well be interesting to talk to in terms of artists in residence and exhibition contexts within a scientific research institute.

JB: Who's that?

RS: I can't remember her name, but I can dig it out—she used to be at the Museum of London quite a few years ago. OK and she has been there for a little while em err

KA: Another reference for you. There is a "Journal of Interdisciplinary Science" [Ball and Ede, 2017], which I have to confess it's not something.

JB: Is it Leonardo?

KA: No, Leonardo is explicitly about science and art and has been going for decades. Er, em, yes, there are thousands of articles about science meeting art there. No, this is a slightly different thing. To be honest, I don't even know quite what the remit of the "Journal of Interdisciplinary Science" is, but I do know two people who [do]. One is Sian Ede who used to run the Gulbenkian and actually has written a couple of books about science and art and then a science writer called Philip Ball they collaboratively edited [it]. I think it was two editions; it's an online magazine, and two editions of it were explicitly about science and art. And I know because I wrote a short piece for it, and it ranges quite widely, I think, and again, you could, as I am sure you know better than us, just spend your time reading books and articles that have been published in the last decade about science and art. It is a vast realm of scholarship in and of itself now, which is good that in some ways yours is practice-based, so you don't have to just read what other people have written and thought about it; get on and do some of it too. It does, and there are courses now. There's a course at Central St. Martins [2023], which you probably know all about, and then Westminster [2023], have a course, and 'em where else? There are a number of places that study science and art together.

JB: Do you think SciArt is like a really old-fashioned word?

RS: I think you can answer that, Ken.

JB: Do you think it has any relevance, or do you think it's one of those past terms?

KA: Yeah, it sort of caught on for a while. We, we, I guess it came from our initial efforts in this area 'err and em. You know, typically, [when] using titles, we went round and round. For a while, we were going to call the scheme "Strange and Charmed". Anyway, we had all sorts of titles and sort of came around to SciArt. We had all sorts of titles. Yeah, that was in the mid-90s when we set it up; probably by the early 2000s, we were beginning to wonder whether we had created a monster. But the word seemed to be, so anyway, to be, and it was killed off here. No one uses the term here anymore, or maybe they do in a descriptive way, but it’s not attached to a scheme.

RS: No, I don’t think they do, and I guess, I think em, I guess to me it does feel outdated, and maybe, just because it feels too simplistic in a way because it’s about life as well. It’s about so much more than just science and art coming together, and that somehow that feels almost slightly reductive in a way. It makes it feel much less complicated than it really is. I mean, we haven’t really ever got together as an organisation and said, "Why don’t we talk about SciArt anymore?" ‘Em, but for me personally that’s why ‘em.

KA: And I, I was involved with it back then, so I still feel a kind of soft spot for it, but and it is occasionally you will still see it used. But yeah, maybe this is a more serious point when courses are set up to study it, and when vocabulary gets cemented, there is a bit of that. [I] think it's slightly lost its way. Maybe just because when it becomes a thing then it’s no longer. For current purposes, let us make 1993 our point of departure this was the year the arts agency Arts Catalyst was set up with the aim to foster links between artists and scientists through commissions and strategic projects. In the same year, a large permanent exhibition, “Science for Life” [2009], was opened in the Wellcome Trust's London headquarters on the Euston Road. The exhibition was a notable example of the way science museums were building into their design philosophy major commitments to interactivity. Subsequently, Lawrence Smaje, Head of the Wellcome Trust’s Medicine, Society, and Health division, began discussions within the Trust that led in 1996 to the setting up of a funding stream for art-science collaborations, the SciArt scheme. The tool to chip away at the other When it started, the whole idea for SciArt was [that it] isn’t sensible to break down these barriers. If it becomes its own thing then there is a danger, a slight danger that it becomes….it starts setting up its barriers. And, interestingly, within the world of people that do this stuff, there are huge arguments. You know the people are very interested in bio art, etc., and they despise the people who just do illustration and decoration; they see that as not art at all.

JB: What do you think of people who do bio art and biolabs?

KA: I really don't know that that also seems a bit ...Well, it's interesting... well.

JB: I am interested to know what you think, really.

KA: We have done bio art projects here.

JB: Is it something you would be interested in doing or not at all?

KA: We are just about to open a show in my gallery in Copenhagen. It's a guy called Thomas Feuerstein [2018], who er is certainly on the bio art spectrum, so I am not intrinsically against it.

RS: I think it just depends on the 'em; it depends on the quality and potence of whatever that of the work. I don't think it; I don't think it for me it's not possible to have an opinion about that sort of whole body of many different artists working in that area. I think that there are some bio art works that I have seen that I have found really arresting [and] interesting, and some that have left me totally cold, and that, it, it's all incredibly subjective, isn't it? I think 'em.

KA: I think, I slightly think and actually Oran Catts the person who set up Symbiotica, which probably is the best known of the organisations that hosts that sort of work. He had a very canny phrase, I thought, for describing quite a lot of these projects. He said that often it had the aesthetics of disappointment about it. I think one of the things that I am interested in my work in general is almost showmanship. Really, when you put on an exhibition or an event, you should not be shy.

The fact that you are going to put on a show for people—my sense of a lot of these projects is that it is fascinating to read about and totally uninteresting to look at.

RS: And totally interesting to be a part of, so the process is absolutely fascinating for the artists and the scientists to be a part of, but, actually, does the final work actually stand up? And that's in the context of running a public venue; that's got to be a primary concern, isn't [it] really?

KA: But also, really you want to do the stuff and surprise yourself really, or that's my sense of it or it can be a bit dull really, well that's my sense of it. So, on May 22nd, [2018], we will open this show with the Thomas Feuerstein, in Copenhagen and I might be totally overwhelmed by the newness of life. I am going to have to go, I am afraid.

JB: Okay, thank you for your time.

KA: Great pleasure meeting you.

JB: Thank you very much and thank you for your time.

KA: Fantastic good luck with your work and your research, yeah fantastic.

JB: Thank you for your time.

KS: It's really nice to see you. It's sort of, we haven't got all the answers.

JB: No.

RS: And in terms of you know I mentioned Sanger are there in terms of the stage that you are at with your research, are there other people that I should try and think about that you know? that I am aware that we have many networks, but I don't want to just randomly send you a load of...

JB: In what sort of sense? I guess people to disseminate or people to

RS: People in the same context to talk about.

JB: As many people as you think would be relevant would be.

RS: Okay.

JB: That would be fantastic, actually.

RS: I will have a think about including artists, just that I have worked in this area.

JB: If you have some contacts [both] scientists and artists, I can have a think about that and then you can just think about that –Andrew Carnie?

RS: Do you know Andrew Devcic? He runs GV Arts [2024]. He might be a good person to talk to.

JB: They are hard to contact, so it would be good to have a personnel intro, please.

RS: A bit of a personnel intro.

JB Yeah, that would be great, please.

RS: Yeah, I will have a think.

JB: And people like maybe organisations, artists, universities that are interested in data and technology and visualisation because, I think there is one part about science but there is one point about its data and using information in a different way. So, I am quite...

RS: I am probably less good on that, but I will have a think.

JB: Or maybe scientists who are interested in new media and maybe people who are about advanced imaging.

RS: OK, brilliant I will have bit of a think. Well, good luck with it all. Sorry, sorry, I have to dash off and let us know when it's done; shall I leave you here to type up?

Total recording 48 minutes.

Appendix Three: Art projects

Specimen examples of how I recorded evidence from working with individual scientists in the lab and imaging lab, including transcripts, lab book notes, and email correspondence.

2.1 Art project one: Dr Joelle Golding

Golding explains the reasoning behind each stage of her experiment in layman's terms. I asked numerous questions about what she was trying to find out as she compared cellular shapes.

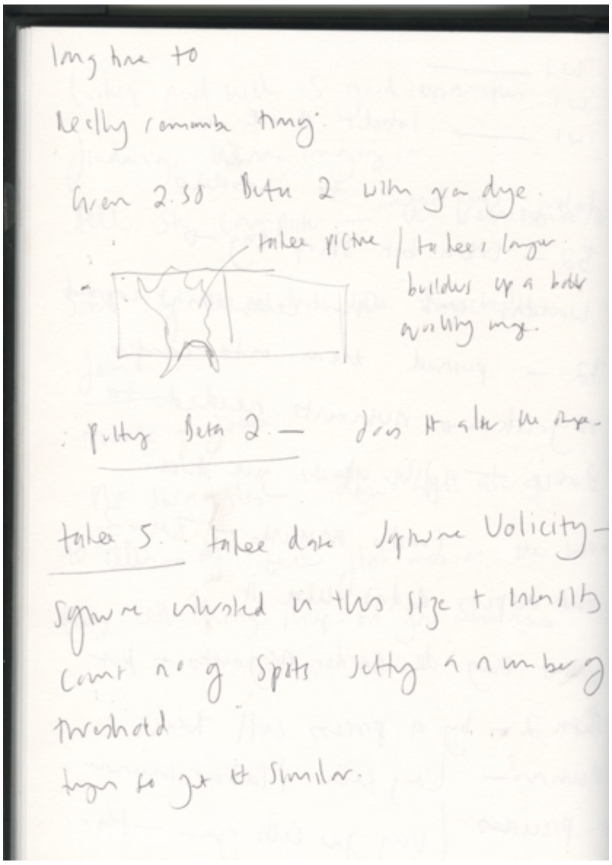


Figure 103. Berry-Frith, J. (2017) Sketchbook and lab book notes and drawings while observing Joelle Golding

Dear Jo

That is very exciting that your work and my images have been presented – I would love to get a print one day if that's ok. Would I also be able to reference any of your work so I can have a log of it on my CV etc. in terms of the use of my images?

I am not primarily a stem cell biologist, but I will do my best to answer your questions.

1. The Human stem cells were originally made by Harvard University and a cell line was created which can now be purchased and used in research worldwide (subject of course to ethical regulations). The particular stem cell line we used is termed 'HUES7' which stands for HUman Embryonic Stem cells. The 7 I think must refer to the batch as you can buy HUES 1, 2 ,3 etc.
The big aim behind our research is to create a reliable and characterised model with which to test and research into new drugs for diseases of the heart. Previous models (on which our current drugs are researched and tested) are either non-human based eg. Rat heart muscle or human-based from biopsy (short supply and possibly diseased) or immortalised cell lines. These obviously do not truly reflect the normal adult human heart. A potential way round this is to develop a system where we can reliably create cardiomyocytes in culture from human stem cells – in this way we are using the right species!, the physiology should be correct and the supply is plentiful. Of course before we do this we have to test that these cardiomyocytes do behave as they should in many aspects and that's where my research come in.
In more detail I am interested in how the beta-2 adrenoreceptor functions and indeed how genetic variation that exists within this receptor can affect its functioning.
2. Cardiomyocytes basically means heart (cardio) muscle (myo) cells (cytes). These heart muscle cells are derived from stem cells (HUES7). So within the Denning lab (with which we collaborate) at the University they are able to stimulate HUES7 cells, using a particular environment (a precise mix of nutrients and conditions), to turn into cardiomyocytes. These HUES7 cells are capable of turning into ANY cell given the right conditions – we are interested in cardiomyocytes and hence use HUES7 derived cardiomyocytes.

I think I have written a bit of an essay here so please feel free to ask more if needed or indeed explain a point that is not clear.

Hope to see you soon

p.s. we have another research forum on the 16th November afternoon if you'd like to come along.

Best Wishes

Joelle

Figure 104. Golding, J. (2017) Email Correspondence.

2.2 Art project one: PhD student Rachel Richardson

2nd December 2015, observations of an FCS experiment investigating neuropeptide Y (NPY) as an appetite regulator: The neuropeptide Y (NPY) is being investigated as an appetite regulator. It requires a series of different concentrations of the drug rhodamine. The Snap-Tag fluorophore receptor is used to label the cells, which have a green excitation wavelength (excited at 488 nm). On the day of the experiment, we go into the main laboratory and get an 8-well plate that was seeded with live cells in media yesterday out of the fridge. All of them have the same concentration of snap tag agonist added, and each well is treated for half an hour before being analysed. The laser beam is then calibrated to the correct alignment for an FCS experiment using the compound rhodamine (TAMRAs) and the snap tag fluorophore receptor (488 nm). Initially, it is left to warm up for half an hour. Once the microscope and plates are ready, the cells are imaged over the course of an hour and a half. The laser's volume of light is set up to line up at the right volume and is measured by eye from the bottom of the glass well plate. The volume of excitation at 488 nm wavelength causes a burst of photons. The molecules move randomly around, with the intensity of the photons changing during excitation. These intensities are measured for each pixel point and recorded as an amalgamation of graded pixel points from the changing intensities of photons. Rachel records ten cells per well, with ten reads every ten seconds, in order to obtain a good trace and a good data set. She locates the healthy cells by eye using the microscope's eyepieces. She explains that she will do this sort of experiment many times in the next year to characterize the dimerization system. The second plate has a higher concentration of the compound snap tag fluorophore receptor. By measuring changes in the molecular brightness, an activated split analysis is captured as an image. Images acquired as part of this experiment are used for reference only and are quite grainy. What is expected to be seen in the trace image and data set is that a lower concentration of the compound has a higher intensity read, and a higher concentration of the compound has a lower intensity read. Long algorithms are used to measure time compared to intensity. These results are compared to a different time point and are logged as a decoy curve.

February 3, 2016. Four plate-reader imaging experiments to characterize the cell line.

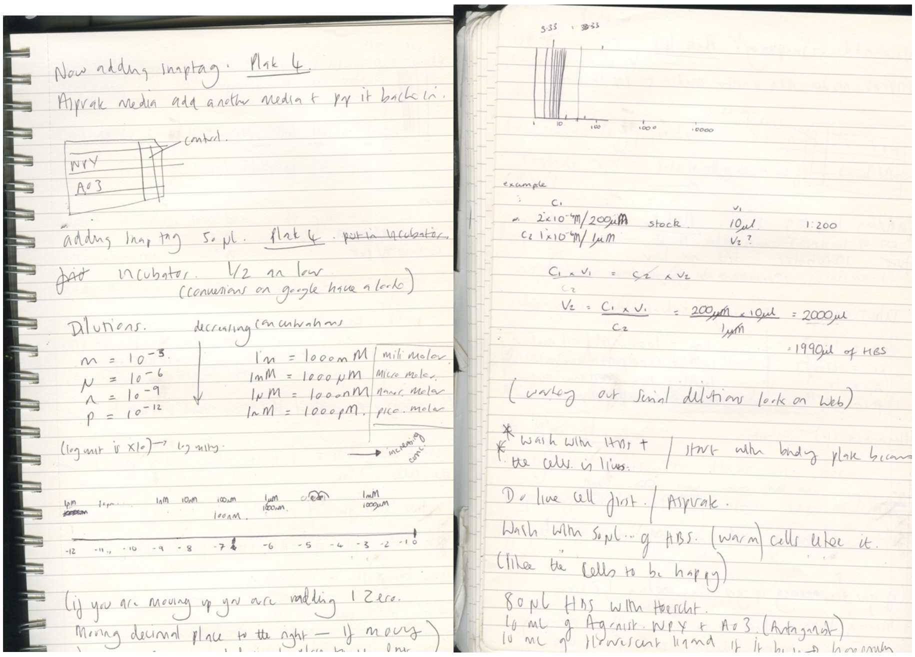


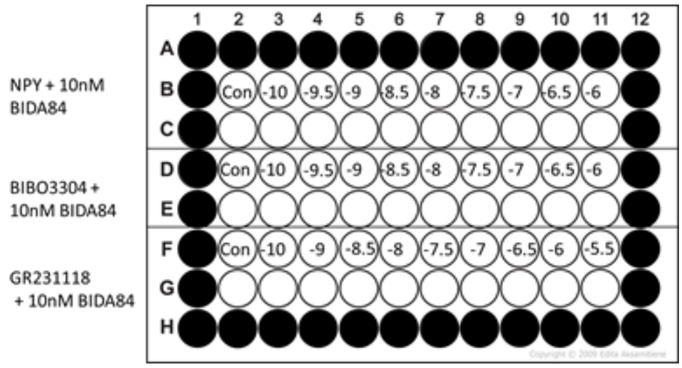
Figure 105. Berry-Frith, J. (2016) Examples of Sketchbook notes from the observation of four plate-reader imaging experiments to characterize the cell-line.

Hi Jo,

Unfortunately, I won't have time to read this until the end of next week as I also have a report due in. When are you handing this in because I would like to have a read through it before you submit it.
In terms of the experiments, I have listed the protocol below with an example of the well layout. I hope this helps! Like I say let me know when it's due and I will try and read it through for you at some point next weeks.

For the binding: -
Cells were labelled with 0.2uM SNAP tag AF488 (they were incubated for 30mins, 37 degrees, 5% CO2)
- They were then washed with 50ul HBS/0.1%BSA
- Then 80ul HBS/0.1%BSA with H33342, a nuclear stain, was added to all wells
Then 10ul of agonist NPY, antagonist BIBO3304 and

antagonist GR231118 at varying concentrations (0.1nM, 1nM, 3nM, 10nM, 30nM, 100nM, 300nM, 1uM) to corresponding wells
10ul of fluorescent peptide BIDA84 at a concentration of 10nM was then added to all wells (they were incubated for 30mins, 37 degrees, 0% CO2)
The cells were then wash with 50ul of HBS/0.1% BSA twice
They were then imaged immediately on the ultra while cells were still alive.



For the internalisation: -
Cells were labelled with 0.2uM SNAP tag AF488
(They were incubated for 30mins, 37 degrees, 5% CO2)
- They were then washed with 50ul HBS/0.1%BSA
- Then 90ul HBS/0.1%BSA with transferrin-633, an intracellular compartment stain, was added to all wells
Then 10ul of agonist NPY, and agonist PYY at varying concentrations (0.1nM, 0.3nM, 1nM, 3nM, 10nM , 30nM, 100nM, 300nM, 1uM) to corresponding wells
Cells were then incubated for 30mins, 37 degrees, 0% CO2
They were then fixed with 3% Paraformaldehyde for 15mins at RT (in the dark)
They were washed once with PBS and then stained with H33342 for 15 mins at room temperature
- They were then washed twice with PBS, and imaged.

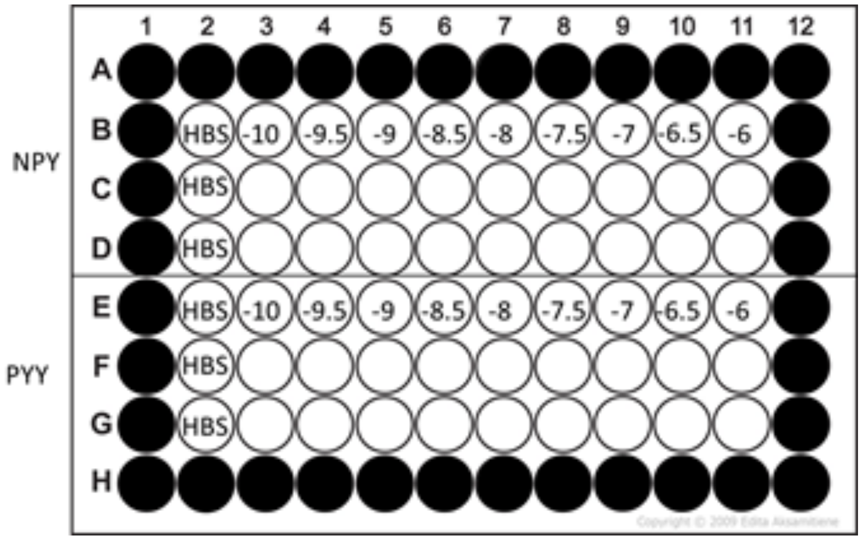


Figure 106. Richardson, R. (2016) Email correspondence four plate-reader assaye protocol. © Rachel Richardson.

Holliday is Richardson's supervisor. He devised the basic set-up for the four experiments. These experiments are repeated three times to confirm that the results are correct. The characterization of the cell lines is for one of Richardson's PhD chapters, and this data will be used as part of the characterization process. As Richardson works out the serial dilutions for four imaging experiments with different concentrations of the compound drugs added to four plates, first-year degree student pharmacists are being taught by Holliday and Briddon—it's busy and noisy. I felt a little uncomfortable. Her aim is to see it in the intracellular compartments of the dye, which I note is "very blue and tiny, lovely" (Berry-Frith, 2016).

Assay 1: Drugs are added to a 96-well plate of live cells to induce an antagonist shift. Assay 2: Is a binding NPY A203 concentration curve using live cells. The compound with the lowest concentration is added first in each column, increasing in dilution. In Assays 3 and 4, a different cell line (A03) with another binding ligand and the antagonist BIDA0 are tested for potency. All are plotted as concentration response curves. Four plates are loaded onto the Plate reader, and Image Express software is set up. Each plate is imaged for ten to twenty-three minutes. As I wait for Richardson, I look at her lab books and document the lab bench and its objects. Richardson questions herself constantly, for example, she cannot find the other fluorescent ligand and must go back later and locate it. I am interested in how she organises her plates and why she has laid them out in that way. She explains that the plates are the same because they use the same controls.

2.3 Art project one: Post-Doctoral Researcher Mark Soave

Amino Cytochemistry ECL2 Competition Protocol (as of September 10, 2015) is a radioligand binding experiment. Post-doctoral research scientist Soave starts by preparing and sorting out pipettes and tips. He explains that because the detergent is gloopy and viscous, it will form globules around the lipids to perforate the cell membrane. He spins it into solution before adding it to the cells for twenty minutes. He uses the same three cell lines (human beta 1 and 2 turkey cell lines, one high- and one low-expressing). He then aspirates the cells. He keeps the plates so that he can analyse the data. Soave (2015) states:

"So, if I accidently add the compound in the wrong row, I write it out on the lid [he shows me an example], and I exclude the data from the results, so I keep the lids to verify results. If I screwed up, I will exclude it; it's a good way to see it for the exclusions".

He adds the detergent, leaving it on the cells for 20 minutes in the incubator. Soave (2015) states:

"This is classic pharmacology. Radioligand binding is a way to measure how well your drugs bind to a specific receptor. So, what you do is use a drug that has a specific drug that has a radioactive bit at the end of it, then add your drugs of interest at different concentrations, and you can see how the drug of interest behaves at low concentration. You can see lots of binding, and the more concentration you can take in as you increase your drug of interest, the concentration curve decreases — it's called affinity, and the receptor is the rare molecule used to bind to the receptor.

The radiation can then be added to your drugs of interest and the drugs to the eradiated bit – you can see how the drug with radiation interacts”.

The drug of interest is located, and the radiation is aspirated off. He leaves for 20 minutes and prepares the compounds ready for imaging.

2.4 Art project two: NHM specimen lab notes with Dr Alex Ball

Using the Zeiss GEMINI Ultra Plus SEM Microscope, Ball explained that the software used is SEM Software, which is microscope-specific and possibly not available. I think Balls’ hand-drawn illustrations for his PhD were stunning. Ball noted that Gaudi's natural art forms affected his drawings. We discussed photogrammetry and the fact that it contains a wealth of information about a specimen’s chemistry. It utilises a distinct set of electrons in a particular way. I am fascinated with how the microscope transforms and renders the invisible visible. I note that the NHM core-imaging lab is an unknown space, and most people don’t know it exists and don’t see this work. It seems to me like it is another world, and, in my opinion, it creates a type of visual magic. I am aware that I cannot reproduce that degree of precision or detail, nor its aesthetic aspects, but I may reinterpret the data as a 3D sketch and/or 2D drawings. We discussed the artist Joanna Love and what she did when she entered the laboratory. Ball asks me what I observe and what drives me, and we explore how artists and scientists approach their work in different ways.

Specimens I looked at included beetles and butterflies, butterfly wings, and a tiger beetle (which looks like sand). I zoomed into the surface of the tiger beetle and butterfly eyes, focusing in on their compound eyes. I looked at fossils and microfossils, plankton samples in different types of water, which were fascinating. Coccoliths; hard remnants of a series of marine plankton; remnants of a collapsed cell. Dinoflagellate plants, which can be very toxic to fish (red tide plankton). I studied sea urchins and sea urchin spines, which have a recursive, fractal nature; the structure is different but repeated and led to a discussion about Ernst Heckle. Images resemble fairy grottos, with salt crystals resembling solid square boxes attached to the surface and diodes resembling lunar landscapes. I move up, down, and around the image carefully, seeing it as another wonderful structural universe. Next time, I'd want to examine crystals.

2.5 Art project three: Specimen sketchbook notes and a transcript

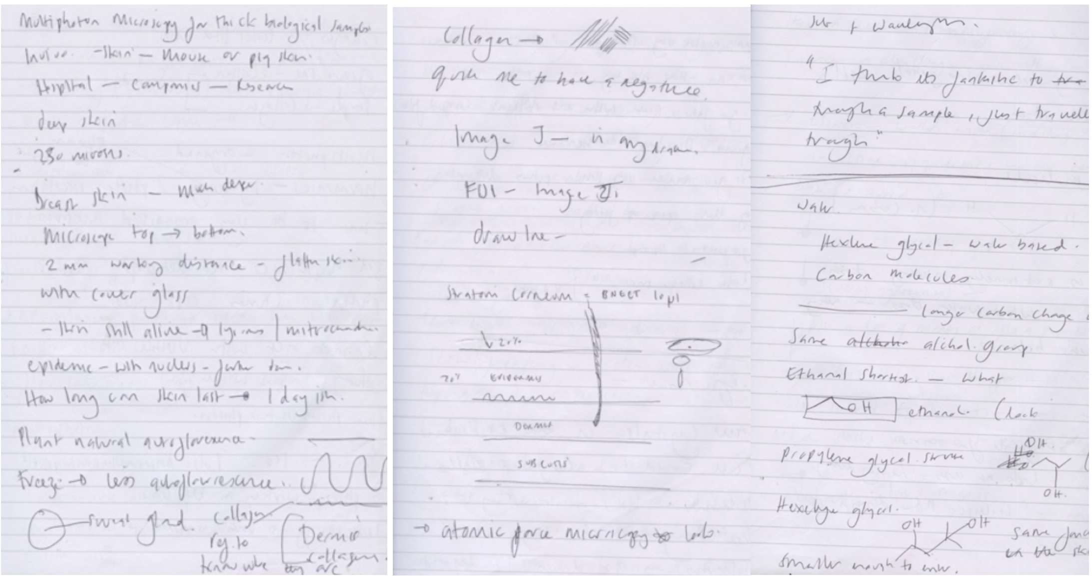


Figure 107. Berry-Frith, J. (2016) Sketchbook/ lab book notes Core Imaging Facility, Gothenburg University.

2.6 Art project three: Specimen transcript Gothenburg University

29th August 2016

Jo Berry (JB), Johan Engblom (JE), Julia Fernandez Rodriguez (JFR), Marija Jankunec (MJ).

JFR: See if there is any complaining; if we get red, I mean, I just heard they move, mmmmmmmmmm.

JB: Sorry, Julia, is that all right if I keep that on?

JFR: Yeah, sure.

JE: Well, it's whether you get a good angle.

JB: No, I don't think I will. I'll move it. It's just that...

JFR: Let me do something here.

JB: Yeah, but it doesn't really; it's just.

JFR: Something here.

JB: It's just too, sorry…

JFR: I had to go.

JE: Lots of space.

JB: It's a big table.

JE: Yep.

MJ: Okay, we have the…

JFR: Don't worry.

MJ: Is something wrong?

JFR: Yeah, the machine. It's alright. If I reset, right. Don't worry, we saw right something. Yeah. I think it's always bad on Mondays. For some reason sometime on Monday the guy for some reason sometimes I see it… But this morning, I didn't have time, before we start the meeting that I switch it on. And then the sensor where it needs to set that everything is alright. And you have seen the software and things…. Ahhaa.

JB: Where do you want me? Do you want to go past?

MJ: No, if you push, the table goes down.

JB: Oh.

JFR: Because that's what we were discussing earlier. I had a problem with a technician before they had the air – is that's what I tell you, that the microscopes are floating in the air.

JB: Oh wow.

JFR: And this one of course they have more air and its thicker because… that's the laser you can look at from that side you want to. Careful with your head. That's the laser and you see the big box it's called the Multiphoton laser with all the TI: Sapphire [Femtosecond Laser for Two-Photon Microscopy]. To go out and [hit] the two beams, the wave goes into this box, called the acoustic modulator; that's the one we use to decide which wavelength to use. Helping us to tune-in and then the light goes inside [it] get[s] into this scan head – once it gets here it scans head to scan.

JB: Right.

JFR: We need to have not just the light like this, and we need to have it here that moves the beam. The laser being inside, and this will go into the microscope. Go down. So yeah, see if I restart the system, it will behave.

JB: Okay.

JE: Can you open the...

JBF: Oh yeah, I thought there was someone there.

JB: I will take some more [photos].

JFR: Something weird because now it's even so, the laser is moving so.

Appendix Four: Questionnaires

Respondent #9

COMPLETE

Edit | Delete | Export

Collector: Web Link 1 (Web Link)
Started: Wednesday, October 18, 2017 9:41:17 AM
Last Modified: Wednesday, October 18, 2017 9:46:01 AM
Time Spent: 00:04:44
IP Address: 128.243.2.39

Page 1: Jo Berry @ COMPARE (Centre of Membrane Proteins and Receptors) Nottingham and Birmingham University

Q1

What forms of advanced microscopy do you use?

Confocal, super resolution, TIRF, HCS, EM

Q2

What excites you about science?

Fascination in seeing something new each day

Q3

What excites you about imaging?

Its visual appeal and ability to answer many scientific questions.

Q4

What do you think of an artist coming into the laboratory and using scientific information to make art?

I think it is a rewarding and stimulating exercise and the artist brings an interesting perspective to the study.

Q5

What do you consider are the playful and creative elements of your work?

Image processing, preparing images for display and outreach activities.

Q6

Do you think art interpretations sourced from scientific imaging experiments can be used as an interpretive tool?

No

Q7

Can you see any scientific value in arts interaction and creative activity for your discipline ?

I see Art as a real opportunity to promote science to the public and to stimulate discussion.

Figure 108. Berry-Frith, J. (2017) COMPARE Questionnaire.

Respondent #2

COMPLETE

Edit | Delete | Export

Collector: Web Link 1 (Web Link)
Started: Monday, February 11, 2019 2:27:59 PM
Last Modified: Monday, February 11, 2019 2:32:20 PM
Time Spent: 00:04:20
IP Address: 90.224.49.11

Page 1: Jo Berry @ Biofilms, Research Centre for Bio interfaces, annual research centre conference,

Q1

What excites you about science?

Not knowing how things will turn out

Q2

What do you think of an artist coming into the laboratory and using scientific information to make art?

It's an interesting idea!

Q3

What do you consider are the playful and creative elements of your work?

Creation of appealing formats in which to present data

Q4

What forms of advanced microscopy do you use?

Confocal microscopy

Q5

What excites you about imaging?

The ability to actually see what is going on - if all goes well!

Q6

Do you think art interpretations sourced from scientific imaging experiments can be used as an interpretive tool?

Not sure what you mean - tool to interpret what?

Q7

Can you see any scientific value in arts interaction and creative activity for your discipline ?

Absolutely - as part of our mission to spread knowledge about, and de-mystify, our work!

Figure 109. Berry-Frith, J. (2019) SCANDEM Questionnaire.

Appendix Five: Email correspondence

Robert Markus <Robert.Markus@nottingham.ac.uk>
To
J BERRY Laura Kilpatrick
Today at 22:10 2018
Hi JO

I hope you had a good insight into how we feel about research, and I think we share a lot with Laura, on all aspects,
How we work, think, and approach problems. We are alike, but now in different roles, me as an imaging technician,
Laura as researcher.

It was interesting to me to voice things, which we had in our mind, just rarely spoken out loud.
I hope you can write up the core of it.

I would like to read your PhD work, definitely.

Have a nice evening,
Robert

Laura Kilpatrick <Laura.Kilpatrick@nottingham.ac.uk>
To
J BERRY
CC
Robert Markus
28 Jun at 10:14 PM 2018

No problem, Jo, it's always great to chat to with you about all our crazy science shenanigans :)

Sorry that some of the slides were not very bright, but hopefully you still got some images you can use. If you need more, then you are welcome to use those slides again, or I will be preparing some more next week that will hopefully behave this time! I also have some plate reader images (nuclei staining plus receptor) that you are welcome to look through and use. Also, it is not imaging based, but if you ever wanted to observe a bioluminescence BRET experiment then just let me know.

See you soon!
Laura

Laura Kilpatrick <Laura.Kilpatrick@nottingham.ac.uk>
To
J BERRY
CC
Robert Markus
28 Jun at 10:47 PM 2018

I think how the SLIM team operates is a fantastic example of what we were talking about earlier in respect to the strength of collaboration in science (and I'm not just saying that because Robert, Seema and Tim are always fixing things I muck up/politely tolerating my crazy research ideas :)). For example, I would never have even attempted/considered doing super resolution, without Robert's help as he helped me with all aspects - from how it could answer the research question I wanted to address, how to prepare my samples, optimising and then teaching me how to acquire good images. Basically, a scientific paper is usually the work of a lot of people and speaking as a researcher I couldn't do my job without the expertise and advice that technicians bring. It takes a scientific village!
I know we mentioned it being 'play' but to be brutally honest you do this job because you love science as there are many practical aspects about the job that aren't necessarily ideal. However, I do think having a natural inquisitiveness and as Robert mentioned a shared way of working helps. He is also correct that regardless of our official roles we are all alike as scientists together in the end which I think really helps.

Funny story about the flexibility side of the work that we were also discussing– my friend is a teacher and once asked me what I actually do on a day-to-day basis. I told her it depended on how my cells were doing and some days I may not know until I walk into the lab. She found that weird as her days are so regimented, but I think that's what I mean when I say it is play as I can't think of many other jobs that give you that intellectual freedom.

Or maybe I've just never really grown up and got a 'real' job :)

I would also be really interesting in reading your PhD!

Tim Self<Tim.Self@nottingham.ac.uk>
To: Joanne Berry-Frith

Reply | Reply all | Forward

Mon 02/12/2024 16:19

You replied on Tue 03/12/2024 08:47

** THIS MESSAGE ORIGINATED OUTSIDE LOUGHBOROUGH UNIVERSITY **

** Be wary of links or attachments, especially if the email is unsolicited or you don't recognise the sender's email address. **

Hi Jo,
Nice to hear from you and you have caught me in time as I retire next week.
In answer to my question your time in the lab was valuable in that it opened up new ways of thinking for myself and the SLIM team to think more creatively (within the bounds of scientific process). Your work has led on to promoting our images not just as purely scientific but also as works of art in themselves. We now run annual SLIM art image competitions for the user base of the facility (over 300). We also apply the artistic methodology and approach to our outreach activities at under represented schools and also through the national technicians networks.
Hope this is enough for your conclusion.
I may be retiring, but the outreach will continue and hopefully a chance to market some of my images. I'm on Linked In if you have any interesting future projects that we could connect on.
Best,
Tim

Principal Experimental Officer,
Head of School of Life Sciences imaging (SLIM),
School of Life Sciences,
C89A, Medical School,
University of Nottingham,
Nottingham. NG7 2UH
T:+44 115 82 30090
nottingham.ac.uk/go/slim
My working hours are Monday to Thursday
Don't forget to acknowledge SLIM in your publications

Stephen Hill<Steve.Hill@nottingham.ac.uk>
To: Joanne Berry-Frith

Reply Reply all Forward
Tue 03/12/2024 11:29

** THIS MESSAGE ORIGINATED OUTSIDE LOUGHBOROUGH UNIVERSITY **

** Be wary of links or attachments, especially if the email is unsolicited or you don't recognise the sender's email address. **

Hi Jo,

Doesn't time fly!!

I think your input was invaluable. Our job is not only to do clever science but also to communicate with the public on what we do and why we do it. Your input has provided an artist's perspective on the imaging work we do and your displays prompt the public to ask what they are showing and what is the science behind it. Which has to be a good place to be.

Yes we would have artists in the lab again – no question.

Good luck with the final submission and keep us posted.

Best wishes,
Steve

From: Joanne Berry-Frith <J.Berry-Frith@lboro.ac.uk>
Date: Friday, 29 November 2024 at 08:21

Laura Kilpatrick<Laura.Kilpatrick@nottingham.ac.uk>
To: Joanne Berry-Frith

Reply Reply all Forward
Mon 09/12/2024 15:33

** THIS MESSAGE ORIGINATED OUTSIDE LOUGHBOROUGH UNIVERSITY **
** Be wary of links or attachments, especially if the email is unsolicited or you don't recognise the sender's email address. **

Hi Jo,

Great to hear from you! I hope you and your family are well. Apologies for the late reply, I've been snowed under with teaching and then got walloped with a bought of COVID!

In regard to your questions:

On reflection do you think having me conducting research in the lab was valuable?
I can only speak for myself, but I found it valuable as it made me better appreciate how science can not only be informative but also beautiful. When it's your own research you can often lose sight of this, and it has almost become routine to 'see' my cells and I often forget how incredible being able to do that actually is. Additionally, it made me appreciate how other people who are not scientists may view these images - i'm looking at it understand what it may show scientifically, whereas non scientists may be looking at it wholly aesthetically. To me, the image may show an experiment that 'hasn't worked' but to others it may just look cool!

Do you think things changed post my research?
I think the fact that your work is still hung up in multiple places (in the corridor outside of our lab next to scientific posters, in our coffee room and in the microscopy analysis suite) shows its resonance. We have had multiple visitors to the lab comment on your work and they are all fascination by your re-interpretation of the scientific images into art. I think it also reminded a lot of us within the research group the creativity inherent to doing scientific research (the need for 'bluesky' thinking), which is an aspect of science I also think is underappreciated in general.

If not why not?

N/A

What impact did it bring and would you employ or have artists in the lab now?

I think the impact has come from the number of visitors/new starters that comment on the images and want to know the story behind them. Additionally, I think your work brilliantly shows the different ways that science can be communicated and can capture the interest of other scientists and the general public. It also shows that science doesn't have to be explicitly 'functional' in the traditional sense to have social value. For these reasons, I would absolutely be interested in employing an artist if I was running a research institute.

Best of luck finishing off your thesis! Happy to answer any other questions you may have.

Best wishes,
Laura

Julia Fernandez-Rodriguez<julia.fernandez-rodriguez@cci.sahlgrenska.gu.se>
To: Joanne Berry-Frith

Wed 04/12/2024 10:24

** THIS MESSAGE ORIGINATED OUTSIDE LOUGHBOROUGH UNIVERSITY **

** Be wary of links or attachments, especially if the email is unsolicited or you don't recognise the sender's email address. **

Dear Jo,
Sorry, I have been very busy and outside my office for quite a while. My answer:

Having artists conduct research in a core facility lab can bring unique and valuable perspectives, particularly by fostering creativity, enhancing communication, and promoting interdisciplinary collaboration. Artists often approach challenges from unconventional angles, offering fresh insights that can inspire innovative methodologies or alternative ways to visualize and interpret data. Their expertise in visualization is especially beneficial in scientific research, such as microscopy, where they can create compelling representations of complex data to effectively communicate findings to both scientific and non-scientific audiences.

Collaborations between art and science can result in novel hybrid projects that expand the boundaries of both fields. For instance, artists may develop new techniques to visualize dynamic biological processes using state-of-the-art imaging technologies. Furthermore, the presence of an artist in the lab can enrich its cultural environment, fostering open-mindedness and encouraging the team to approach their work with new perspectives. This can strengthen collaboration and enhance team dynamics, creating a more innovative and inclusive research environment.

Best wishes

JULIA

Julia Fernandez-Rodriguez<julia.fernandez-rodriguez@cci.sahlgrenska.gu.se>

To: Joanne Berry-Frith

Thu 05/12/2024 08:00

Hello, a new one:

Having Joanne, an artists, conduct research in a core facility lab can profoundly influence scientific work by introducing a creative and exploratory mindset that challenges conventional approaches. In my experience, working alongside an artist encouraged me to rethink my methodologies, embracing experimentation and playfulness as a part of the scientific process. Their ability to reimagine data visualization and interpret biological processes through innovative, artistic perspectives significantly enriched how I approached microscopy and imaging techniques.

This collaboration cultivated a sense of curiosity and adaptability in my practice, enabling me to view scientific challenges as opportunities for creative problem-solving. The artist's focus on storytelling and visual communication also transformed how I present and share scientific findings, making them more accessible and impactful to diverse audiences. Ultimately, this interdisciplinary exchange reinforced my belief in the value of integrating art and science, fostering a more dynamic and collaborative research environment."

Best wishes
JULIA

On 5 Dec 2024, at 08:27, Joanne Berry-Frith <J.Berry-Frith@lboro.ac.uk> wrote:

Appendix Six: Specimen consent forms

Appendix C: Consent Form
Birmingham City University
PHD Research candidate –Joanne Berry-Frith
Email: jo.berry@bcu.ac.uk
Telephone:01629-540476

The research I am undertaking is investigating what role playful creative visual methodologies can have on scientific discourse and how can this knowledge be utilized to reassemble and reconstruct data in order to discern what impact these can have on scientific discourse and its dissemination.

The research involves taking part in interviews to discuss:
1]What is the unique and important role that an artist can play in science, its dissemination and communication.
2]How can artists distinct approach to understanding and communicating ideas illuminate and challenge perceptions within society.
3] Your institutional strategies, code of behavior and ethos for the promotion of social, ethical and cultural issues. I will also ask you to discuss how government strategy is influencing this cultural exchange.
4] What roles do culture, imagination, argumentation, creativity, discovery and curiosity, play in scientific enquiry.
5] How can playful creative methodologies add value to a conventional analysis of scientific subject matter.

None of the questions I ask will be too personal, and I will only ask you to give as much information as you feel comfortable with.

Conditions of participation
Participating in this project is completely voluntary. This study does not involve any risk of any kind to you. It will involve individual interviews at your organization/ institution. During this process I may take some photographs and film.
I would like you to take part in the whole of the research process, but you are free to withdraw from it at any time, both during the interview and after. If at any time, you feel uncomfortable and wish to leave the investigation, you may do so. If at the end

of the research you wish your contribution to be removed, it can be. Any information you give me will be kept confidential, as will your identity. If I wish to quote anything you say, I will ask your permission first.

Your identity will never be revealed and your personal data will remain confidential during research.□Any data collected will remain confidential and will be analysed only by myself as the PHD researcher involved in this study.
The findings from this research may be published at some time in the future, and may contribute to future research. I would like to have your permission to include any information you provide. I also plan to tape record our interview, and I would like your consent for this.
Results will only be used for the purpose of this research. This may include presentations at research conferences and seminars, for which I would inform you before the event, and may be included in future publications.
Thank you for taking part.
If you want to discuss any aspect of the research, or your participation, at any time, you can contact me by phone or email.

Consent

I have read the information above and I was given an explanation of the purposes and aims of the study, and given the opportunity to question and clarify all the aspects that seem relevant. I believe and understand the objectives, benefits and risks of the study and I give my informed consent to be a participant.

I agree to take part in this research, and consent to any information I give being included in future research or in a possible publication. I also agree to my interview being recorded. I understand that my identity and the information I provide will be kept confidential, and that I have the right to withdraw from the research at any time.

Signature

______

17/10/18
ROSIE STANBURY

Appendix D: Consent Form
Birmingham City University
PHD Research candidate –Joanne Berry-Frith
Email: jo.berry@bcu.ac.uk
Telephone:01629-540476

The research I am undertaking is investigating what role playful creative visual methodologies can have on scientific discourse and how can this knowledge be utilized to reassemble and reconstruct this data . The research involves taking part in observation and interviews with scientists in their research laboratories and the collection of Microscopic and Advanced Imaging Data. This project aim is to understand how scientists work from their perspectives, compare attitudes across cultures, and explore common themes. I would like to have your point of view of how an artist can play a role in science, its dissemination and communication. How do you as scientists benefit from this cultural exchange. I would like to comprehend from your perspective what roles do culture, imagination, argumentation, creativity, discovery and curiosity, play in scientific enquiry and how can playful creative methodologies add value to a conventional analysis of scientific subject matter.

Conditions of participation

Participating in this project is completely voluntary. This study does not involve any risk of any kind to you. It will involve observation of scientific experiments and interviews at your research institution. During this process I plan to take some photographs, film and to tape record our interview, and I would like your consent for this.

I would like you to take part in the whole of the research process, but you are free to withdraw from it at any time, both during the interview and after. If at any time, you feel uncomfortable and wish to leave the investigation, you may do so. None of the questions I ask will be too personal, and I will only ask you to give as much information as you feel comfortable with. If at the end of the research you wish your contribution to be removed, it can be. Any information you give me will be kept

Appendix Seven: Big Data in the Arts and Humanities Theory and Practice

Big Data in the Arts and Humanities

Theory and Practice

Edited by
Giovanni Schiuma
Daniela Carlucci

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **Informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed on acid-free paper

International Standard Book Number-13: 978-1-4987-6585-5 (Hardback)

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Contents

Editors

Giovanni Schiuma is professor of Innovation Management at the University of Basilicata (Italy) and visiting professor of Arts Based Management at University of the Arts London. He is widely recognized as one of the world's leading experts in arts and business and has authored or coauthored more than 200 publications on a range of research topics particularly embracing strategic knowledge asset and intellectual capital management, strategic performance measurement and management, innovation systems, innovation management, and organizational development. He is an inspiring speaker and facilitator, with extensive research management expertise and excellent ability to coordinate complex projects and lead research teams. Giovanni holds a number of visiting professorships and research fellowships appointments with renowned international universities, and as a visiting lecturer, he regularly gives seminars, workshops, and master classes around the world.

Daniela Carlucci is an assistant professor at the University of Basilicata, Italy. She teaches Business Management, Project Management, and Project Evaluation and Management. Her research interests focus mainly on knowledge assets management, performance measurement and management, decision support methods, and organizational development. She has been a visiting scholar at the Cranfield School of Management, visiting professor at the Tampere University of Technology, and visiting researcher at the University of Arts of London. She is author and coauthor of several publications, including chapters of books, articles, and research reports on a range of research topics. Her researches have been published in internationally recognized journals such as *Expert Systems with Applications*, *Production Planning and Control*, *Healthcare Management Science*, *Measuring Business Excellence*, *Knowledge Management Research and Practice*, and many others. She systematically carries out referee activities for international scientific journals. She is actively involved in relevant research and consultancy activities as researcher and has worked in research projects involving national organizations and institutions. Moreover, Daniela is systematically engaged in teaching activities in public and private institutions.

Contributors

Alexandra Albert is an ESRC (Economics and Social Research Council)-funded CASE doctoral researcher at the University of Manchester and Lancaster University. Her PhD research examines approaches to citizen social science. She has just completed an internship with the United Nations Educational Scientific and Cultural Organization's Inclusive Policy Lab. Her research interests include participatory data initiatives, citizen science, big data, cultural metrics, cultural policy and inclusive development. Prior to her PhD, she worked as a social researcher for Arts Council England and The Work Foundation.

Kostas Arvanitis is a senior lecturer in Museology at the University of Manchester. His research interests cross the fields of museology, archaeology, cultural heritage, and digital media. His recent work has focused on the emergence of a "data culture" in cultural organizations, digital media professionalization in museums, heritage activism through digital and social media, and collecting of spontaneous memorials.

Jo Berry, originally from Lancashire, has studied natural history illustration, illustration, graphic design, and printmaking. Exhibiting regularly and widely throughout the country and internationally, her work is highly regarded, with pieces in the Victoria & Albert Museum (V&A), Arts Council England (ACE) East Midland Collections, Nottingham University, and Zeiss, Munich. Her residencies include the Florence Trust Studios, London; the Natural History Museum, London; and Lakeside Arts Centre, Nottingham University. Her public art commissions include Millfield Sculpture Commission, Derbyshire Moorlands, Sheffield Galleries and Museums Trust, New Shetland Museum & Archives, and Blackpool Illuminations.

In 2005, she completed work at Loughborough University as an advanced research fellow, where she developed her interest in digital drawing and technology and created light drawings using laser cutting, computer software, material exploration, and light. Since then, she has continued to develop and explore her understanding of all these processes in the design and production of artwork, light work and animation for exhibition, commission, and for public art outputs.

Over the last six years, she has contributed to a number of Art and Science Collaborations funded by Arts Council England and the Wellcome Trust, including "Brain Container" (2014), "Hijacking Natural Systems" (2011), and "Bridging the Gaps" (2012), an ESPRC funded project at Loughborough University.

Her current research is an exploration of advanced imaging from a visual arts practitioners perspective in collaboration with the Cell Signalling and Pharmacology Group and Molecular and Cellular Biology Group, University of Nottingham; the Natural History Museum, London; and the Centre for Cellular Imaging, Sahlgrenska Academy Gothenburg University, Chalmers and Malmo University.

Marilisa Biscione (https://www.researchgate.net/profile/Marilisa_Biscione; http://cnr-it.academia.edu/MarilisaBiscione) graduated with a degree in Conservation of Cultural Heritage (Archaeology) at Università degli Studi della Tuscia (Viterbo, Italy) and diploma of University Master, II level, in Geotechnologies for Archeology at Università degli Studi di Siena. She is a research fellow at IBAM-CNR (2011; 2012–2015) in location-based services for traceability of artistic mobile heritage, landscape archeology, and spatial analysis for the study of deserted medieval settlements in Basilicata.

She is a research technician at the Institute of Archaeological and Monumental Heritage of the Italian National Research Council (IBAM-CNR), seat of Potenza. Her work includes three main fields. The first regards the multidisciplinary research on landscape (from the archaeological point of view) through Global Information System (GIS), interpretation of remote sensing and geophysical prospecting, cartographic processing, historical cartography, and archival research; the second involves the use and the application of low-cost and noninvasive technologies for the monitoring and the surveillance of cultural heritage (location-based services for integrated and low-cost approach to theft and dispersion protection of artworks in high-risk context); the third is finalized to give a contribution to the knowledge, fruition, and promotion of the fortified architectural heritage through the integration of the Information and Communication (ICT) (Technologies and Applications).

Her participation in national and international research projects includes the following: ATHENA—Remote Sensing Science Center for Cultural Heritage; PRO-CULT—Advanced Methodological approaches and technologies for Protection and Security of Cultural Heritage; Ponte dell'Elce—research project on the Medieval and Early Modern complex in Ponte dell'Elce, Viterbo; Cancellara Cultural Heritage—a new life for the cultural heritage research through the cognitive framework update; and BasiliCastle: the digital Atlas of Castles in Basilicata (Southern Italy).

Maria Danese has been a researcher at IBAM-CNR since 2015. In 2010, she obtained her PhD in "Science and Methods Forum European Cities and Territories" at the University of Pisa. She carried out her researches at the IBAM-CNR, at the University of Basilicata, and at the National Center of Geocomputation in

Chapter 12

Visualization of Scientific Image Data as Art Data

Jo Berry

Contents

> Artists have a distinct approach to understanding and communicating ideas that can illuminate and challenge perceptions within society. (Wellcome, n.d.)

> We easily forget that research is actually a creative process. When we want to explain things, we often look for illustrations on the internet, instead of creating our own illustrations of conceptual insights. If we would dare illustrate and visualise our research, we might get both new insights and better contact with the general public. (Ericson, University of Gothenburg, 2016)

This chapter maps how art created from scientific image data from different imaging laboratories can help and influence how such data can be visually communicated, and how working closely with imaging specialists and scientists was an opportunity to present new insights into the application, use, and analysis of advanced imaging technology and data in new visual depictions. The research project described is situated within contemporary visual arts and communication, drawing upon the knowledge of the discipline as practitioner and academic. This chapter maps out important aspects of this research investigation as it unfolds while working in the field and in the studio. It is a "multi-dimensional zone of considerable complexity" (Kemp, 2016: 217) originating from experiencing science in action. It provides a straightforward process of engagement and a fertile arena for interaction where useful insights into scientific research themes are discussed, establishing an accumulative understanding of methods of observation that are impacting positively on both fields of expertise.

Interest in industrial technologies, material exploration, color, and light* had already been developed by the author over 15 years of art practice, which led to working with pharmacists in the Life Sciences Department at Nottingham University from 2010 to 2012 on a project called "Hijacking Natural Systems."† This highly successful project was nominated by the University for The Times Higher Education Award and cited by the Wellcome Trust as an exemplar of a successful Arts and Engagement project.‡ And over the last nine years, work with scientists who use highly sophisticated imaging technologies and processes has resulted in projects such as "Light It Up: Brains, Psychosis, Neuroimaging & Us"§ and "Bridging the Gaps."¶ The rationale for this current study is an exploration of advanced imaging and microscopy from a visual arts practitioner's perspective, where this artist engages in a constructive manner with scientists to interpret data differently. The new visualizations (as shown in Figure 12.1), which are being created, offer new insights into scientific imaging, which have value beyond pure science, as these scientific data are visually rich and have the potential to be exploited from a visual viewpoint. The work being created is generating interest for exhibition and commission, on web platforms to show to the general public.

* 2001–2005, "Light drawings: a contemporary artistic medium." Advanced Research Fellow funded by the Arts & Humanities Research Council (AHRC) and Loughborough University (£52K).

† 2009–2011, School of Bio-medical Sciences, Nottingham University, funded by Wellcome Trust Arts Award (£29K) and ACE (£28k).

‡ This project was funded by Wellcome (£29k), ACE (£28k), Derby City Council (£500), and Derby Museum & Arts Gallery (£2K).

§ 2013–2015, Neuro Translational Imaging Department, Nottingham University, funded by ACE (£29K).

¶ 2012 ESPRC Funded Award, the Organic Chemistry and Fine Art Department, Loughborough University.

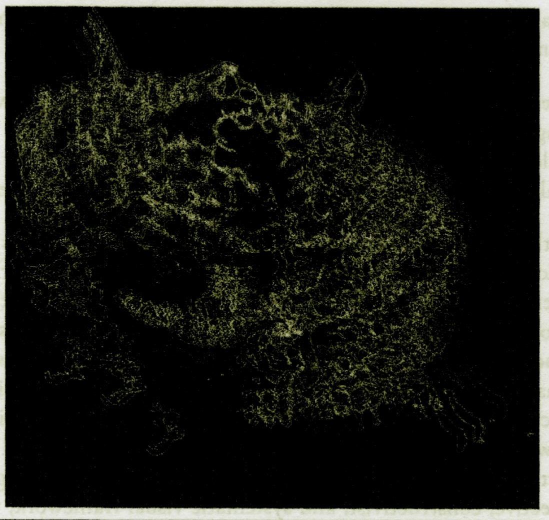

Figure 12.1 Radiolarian: a digital drawing rotated at a 5° angle six times.

As technologies become more sophisticated, ways of viewing samples (static and live) are continually being developed. The super-high-resolution machines that scientists use today to image samples are not normally accessible to nonscientific specialists, yet imaging technologies present a rich, underexplored area for artistic exploration. All scientific collaborators see this exchange as an opportunity to generate interest and understanding about their research among expert and nonspecialist audiences. They recognize that their working methods can appear extremely opaque to the public and difficult to understand but believe that key concepts normally beyond those who might attend science exhibitions or read scientific literature can be communicated to audiences using a different perspective. They acknowledge that scientific images are increasingly travelling outside laboratories and entering news magazines, courtrooms, and media and understand that these images rely on cultural preferences to create persuasive representations. They have identified this artist/designer with her skills, knowledge, and experience as an ideal candidate to share findings and to generate impact outside the scientific context.

From September 2015, work began with three different laboratories to gain first-hand experience of working with research scientists using advanced imaging as an important visual tool in their scientific investigations. Each academic research institution is a core-teaching facility, allowing scientists the space, time, and resources to collaborate and gain knowledge without direct commercial pressure. The resulting research project involving these specialists is designed to offer new understanding in the topic of data visualization through the lens of an artist working as an equal on three different themed case studies:

I. Experiencing internal structures of cells using microscopy with different imaging technologies.
II. Versatile imaging as a three-dimensional sketch.
III. Dermal drug delivery—how to increase bioavailability in viable skin.

The first three sections of this chapter describe appropriate aspects of this investigation, which already have extended knowledge and appreciation of cutting-edge imaging experiments and scientific procedures. Acting as a participant and observer using the model cited by Robson after Spradley (Sutton, 2011), observations are recorded (space, actors, activities, acts, events, time, goals, and feelings) in a process of analysis that is extending knowledge of these art–science collaborations by establishing an accumulative understanding of the precedents of art and science conceptualizations where methods of observation arise through enquiry and reflection.

The fourth section describes how pure scientific data are being reprocessed within a reflective, constructivist, and systematic visual framework, where digital technologies are being employed to expand visual possibilities and where this practitioner is researching through creative action and "reflecting in on action" (Schon, 1983). Digital drawing is being used as an explorative, generative tool, leading to design decisions (Schaeverbeke, 2016). Industrial process production methods (laser cutting and three-dimensional [3D] printing) and moving image and animation are employed to further explore complex ideas and structures (Doloughan, 2002), giving rise to new visualization and material models and revealing new insights into the study of complex systems invisible to the naked eye. This is an example of research *through* practice where experimental methods are evidenced (Rust, Mottram, and Till, 2007: 21) and where a range of innovative ways are identified in which creative practice can add to research knowledge.

The fifth section describes how this inquiry is centered on critical feedback from the collaborating scientists, who will be invited to inspect new visualizations and material models and reflect and comment on their understanding of this approach. This visualization process is being undertaken and used as a vehicle to create a "space" for new interaction and new responses, building mutually beneficial relationships over a sustained period of time, which impacts positively on both fields of expertise. By comparing viewpoints, it is expected that this information will contribute to the production of more refined visualizations.

Experiencing Internal Structures of Cells Using Microscopy from Different Imaging Technologies

One aim of the research project is to show how capturing and understanding data (Coffey and Atkinson, 1996: 85) through visual processes can make a valuable contribution to understanding scientific image data so that they can be communicated and distributed effectively to new audiences. The project described here is based at the Cell Signalling and Pharmacology Group (CS&PG), University of Nottingham. The School of Life Sciences Imaging department encompasses three units, all under one consistent structure: the Advanced Microscopy Unit, Cell Signalling Imaging, and Super Resolution Microscopy. This department houses some of the most sophisticated imaging technologies available, providing cutting-edge imaging facilities to researchers across the university and external collaborators. They are trying to understand how cell systems work, right down to a molecular level, examining in detail individual cell mechanisms. Advanced imaging is used as an important analytical tool to collect a range of data. It is the scope of advanced imaging methods and data that is proving so fruitful for the other research aim: the creation of art.

Over the last year, observations of individual members at work on practical scientific activities have taken place, with in-depth discussions about the major themes and imaging techniques being investigated. This experience enriches understanding of scientific concepts and how scientists use a range of data. As it is important to have some understanding of technical and analytical methods used in the acquisition of data, the following paragraphs detail specialist scientific procedures from observed experiments.

A highly developed imaging and processing technique used frequently is confocal microscopy (CM). CM illuminates the sample through the objective lens,* which is set as a pinhole to focus a laser beam of light.† The microscope adjusts to fluorescent molecules‡ that excite the sample at a certain wavelength of light and uses a special dichroic§ mirror to direct different wavelengths of light¶ to allow light longer than that wavelength through. Fluorescence, a member of the luminescence family** of processes, is an important visual imaging tool used with this technique. Fluorescence lights up live and fixed cells with luminous color to create extremely complex and visually interesting imaging experiments. From formal scientific experiments that follow a rigid protocol, super natural microscopic fluorescent images of cells can be seen on screen and captured in a number of ways. This technique can be refined to achieve highly detailed ways of seeing samples. As the laser scans over the plane of interest, a whole image is obtained, pixel by pixel and

* For articles about objective lens see, for example, https://www.microscopyu.com/microscopy-basics/properties-of-microscope-objectives

† For articles about galvanometer-based scanning system, see, for example, https://www.olympus-lifescience.com/de/microscope-resource/primer/techniques/confocal/confocalintro/

‡ For articles about fluorescent molecules, see, for example, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3805368/

§ For articles about dichroic mirrors, see, for example, https://www.rp-photonics.com/dichroic_mirrors.html

¶ For articles about wavelengths of light, see, for example, https://www.microscopyu.com/microscopy-basics/resolution

** For articles about luminescence family, see, for example, http://zeiss-campus.magnet.fsu.edu/articles/basics/fluorescence.html line by line. Longer, slower scan times result in a better-quality, higher-resolution image with a lower "signal-to-noise ratio."*

The CM computer system interface uses a range of different ways of viewing cells as 2D and 3D projections. One technically interesting method of obtaining data from cells can be imaged as a Zed stack.† By changing the position mode and scanning, a 3D Zed stack image is produced where an image is taken from the ultimate bottom of the slice of the cell to the optimal top of the cell to build a 3D image. The laser reads and captures features from each slice of the cell to construct an image. By mathematically enhancing the cell's appearance, a flat cell can be made to look thicker by configuring the software and making a 3D projection.

One observed assay (an experimental test) of a confocal imaging experiment using fluorescence microscopy on an eight-multiwell plate‡ was especially productive in terms of acquiring image data. Five healthy cells in each well were selected and imaged. The computer accurately marked the position of each cell so that an image could be captured before and after the drug had been added. The information obtained was relatively small but was important as it revealed whether the membrane receptor had internalized.§ The images acquired show visually beautiful and structurally unfamiliar, brightly colored human-stem-cells-derived cardiomyocytes.¶

One of the newest fields of imaging experienced, and of great visual interest, was superresolution microscopy** (SRM). SRM is an emerging and rapidly evolving field of microscopy. It is a form of light microscopy that captures images at a higher resolution than the diffraction limit of light. This process is set up to counteract the fact that high-resolution microscopes are not infinitely sharp. Today, through the development of technology, optical imaging processes are progressing into the realms of electron microscopy. Through understanding how data are acquired, unique opportunities to exploit data as a visualization tool are becoming apparent. This exploitation is influencing how data can be used creatively to visually communicate extremely complex ideas.

One superresolution encountered breaks the diffraction limit of light by using mathematics to calculate the distances between individually blinking dyes attached

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* For articles about signal-to-noise ratio, see, for example, http://www.olympusmicro.com/primer/techniques/confocal/signaltonoise.html

† For articles about Zed stacks, see, for example, https://greenfluorescentblog.wordpress.com/2012/04/29/basics-in-confocal-microscopy-and-image analysis/

‡ For articles about the multiwell plate, see, for example, http://www.museion.ku.dk/2010/11/the-history-of-microplate-technology/

§ For articles about membrane receptor internalization, see, for example, New England Bio labs at https://www.neb.com/applications/cellular-analysis/receptor-internalization

¶ A medical definition of cardiomyocyte, Sigma-Aldrich (no date), can be seen at http://www.sigmaaldrich.com/life-science/biochemicals/biochemical-products.html

** For articles about Zeiss systems, see, for example, Zeiss online campus at http://zeiss-campus.magnet.fsu.edu/articles/superresolution/index.html to proteins to increase resolution. A major barrier to increasing the resolution of the image is the wavelength of light. This technique uses a pointillist application of light, calculating its mathematical optimum in relation to a sample's ideal excitation value. This enables scientists to increase the resolution of the microscope to see individual receptors on a cell membrane.

Scientists can push the boundaries of imaging by utilizing their knowledge of fluorescent properties, fluorescent molecule behavior, optics, and computer software. Scientists today can hit the live cell with low enough power to image a single molecule and look at localizing individual molecules and see them shine. By altering the laser excitation wavelength, molecules can be turned off and on. The process of superresolution is extremely difficult to grasp as a nonspecialist observer, but it is a very interesting process to view and demonstrates how the manipulation of a number of factors impacts the acquisition of data. The resulting imaging data focuses on minute details of complex and fascinating visual scientific information. This is seen during a number of imaging sessions. One in particular is when the scientist records the surface of regular bacteria where individual frames were taken at 1/10th and 1/30th of a millisecond to produce a movie. The position of each flash of light is recorded as a pixel on a charge-coupled device (CCD)* camera. A map of their locations is created, and from this, an image is derived. Another observed SRM assay tested how deep the microscope could image the tissue with oil- and water-based immersion solution. This was from a fixed sample, stained with antibodies of neurotissue from the spinal cord of a mouse, using structured illumination microscopy. By using this system, the difference between wide-field microscopy, where the image is out of focus, and SRM, where the image is detailed and resolved, can be seen. A large data set of imaging experiments was acquired as brightfield, structural illumination and Zed stacks. Files are saved at the highest possible resolution, which becomes 15 times smaller after processing. These acquisitions are aesthetically interesting. They are categorized and selectively reprocessed into a range of visual outputs that rely primarily on digital applications.

For a visual practitioner, there are particular technical details of considerable interest and conceptually important to understand. First is the fact that once the sample was set up on the stage,† everything is then viewed, imaged, and processed via the computer screen, and second, images are calculated using a 16-bit number of shades that encompass 65,000 gray-scale shades. No screen or printer could print these nuances, but it is there as digital information and can be seen if the color histogram on screen is stretched. A stereomicroscope is used to view the high pixel definition visible on screen, made up of a tight grid of millions of red, green, and black squares. The grid pattern is shifted or rotated in steps between the capture of

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* For articles about CCD cameras use in SRM, see, for example, http://zeisscampus.magnet.fsu.edu/articles/superresolution/palm/practicalaspects.html

† For articles about Zeiss systems, see, for example, Zeiss online campus at http://zeiss-campus.magnet.fsu.edu/articles/superresolution/index.html

each image set, creating what could be described as a Moiré (interference) pattern. Viewing these beautiful colored images on screen, it is difficult to comprehend that they are made from optical technology and mathematical strategies but they open up possibilities for a visual practitioner to play with all the modalities of this system to build new information in collaboration with imaging specialists.

Versatile Imaging as a 3D Sketch

Thus, whatever the particular scientific technique being explored, the artist is seeking to explore the visual results while, through collaboration, reflecting the processes involved. At the Core Research Laboratories Imaging and Analysis Centre, Natural History Museum, London, over a three-day period, samples were selected to image on scanning electron microscopes (SEMs). SEM is used to investigate the fine structure of biological and inorganic material *by making visible the invisible.* The specimens selected were chosen because they contained much structural information and are highly detailed. Two different SEM systems were used: the Zeiss Ultra Plus and the LEO 1455VP. Each system uses a beam of accelerated electrons to produce strikingly detailed images at up to a 100,000 times magnification of the sample. The intention is to reveal and describe unexpected structural details, such as the strange calcification objects that are attached to the main structural body of these microscopic samples (as shown in Figure 12.2).

One of the new processes being piloted at NHM is photogrammetry, which involves creating a large data set of images of a specimen over a 360-degree rotation. This builds up a wealth of visual information, which is then used to create a 3D digital representation. This is processed using 3D software and outputted as a 3D print. Ideas using these techniques will be tested to generate data from a range of specimens.

Dermal Drug Delivery—How to Increase Bioavailability in Viable Skin

A rich source of imagery came from a study of how to increase bioavailability in skin. Skin is important to us and has many important functions; it is our largest organ and is designed to help keep our bodies working properly. A multidisciplinary project at the Centre for Cellular Imaging (CCI) Sahlgrenska Academy Gothenburg University, Chalmers University, and Malmo University is applying optical microscopy techniques within experimental skin research, such as creating a mechanistic understanding of how a topical drug delivery system can be designed to target, for example, eczema at exactly the right place and not to be systematically taken up by the body.

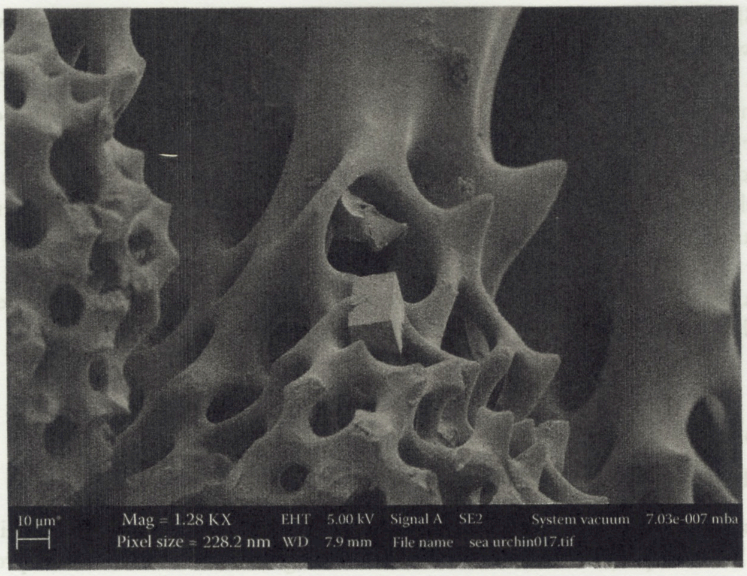

Figure 12.2 Acquired original Zeiss Ultra Plus SEM image of the details of a sea urchin spine.

Through participating in a weeklong imaging and analysis project, it was possible to see how scientists investigate the release of drugs in the skin and how they collect data to demonstrate their hypothesis. Multiphoton microscopy* was used to image "deep" samples of the skin and to test different creams. Pig skin samples were used as it has similar properties to human skin. The main benefit of this method of imaging is that by using two exciting photons,† pulsed at the same time, less energy is used and deeper samples can be imaged. What is fascinating to view is how the ultrafast laser system images data by concentrating more visible light on one point of a sample as an instant pulse measured in femtoseconds‡ and the fact that the two-photon absorption spectra excites two fluorophores equally well with less power.

* For articles about multiphoton microscopy, see, for example https://www.nikoninstruments.com/en_GB/Learn-Explore/Techniques/Multiphoton-microscopy

† For articles about photons, see, for example, http://www.olympusmicro.com/primer/techniques/fluorescence/multiphoton/multiphotonintro.html

‡ For articles about femtosecond laser, see, for example, https://www.rp-photonics.com/femtosecond_lasers.html

Skin, when imaged, naturally emits light, called autofluorescence,* which allows the deeper layers of collagen to be imaged without adding extra fluorescent dyes. In this experiment, images were taken after being treated with three different creams: immediately, after 6 hours, and at 24 hours. Each experiment was repeated three times and reaped a rich reward of still images, 3D movies, and Zed Stacks. The data collected, describing how the fluorescent dye and cream interact as they travel through the different layers of the skin (stratum corneum, epidermis, dermis, subcutis, and collagen), are visually captivating as they are richly colored, with each layer detailing the complex framework of the anatomy of the skin.

After an interesting and productive week of study, the scientists commented that having an artist as part of the team brought a new perspective.

Evolving Data Sets through Creative Visual Reconstruction

The research project discussed in this chapter is a pioneering multidisciplinary visual arts enquiry about new modes of utilizing data. It is a distinctive process of visual investigation to analyze and interpret scientific data from the viewpoint of the visual artist to find out if this process and the strategies employed can lead to new translations. Using experimental, avant-garde art and design strategies to extend the scope of this enquiry, the methodology employed is centered on the notion of play and visual probing that is happening in both the scientific computer laboratory and the studio and selecting for reprocessing any material considered to have potential visual qualities. Data used include equations, words, figures, graphs, computer-generated imaging material, and pure scientific image information. Characterization of the new data visualizations is emerging from using a range of different digital technologies and material processes. In the laboratory, software image data are categorized, selected, and reprocessed using a range of scientific software programs, including Zen, Fuji Image J, and Q-capture Quo.† The strategies and techniques employed to reprocess material expands the possibilities and enhances conceptual ideas, and by reworking material using different digital commands, complex visual iterations are developed, which dramatically restructure data both as 2D and 3D outputs (as shown in Figure 12.3). Instructions used include scale, color editing, timing, maximum-intensity projection, flying speed, Z scaling, 2.5 projections, histograms, rotation, surface, map-ortho, plane, rendering, and interpolation. Scientific terminology such as intracellular, binding,

* For articles about autofluorescence, see, for example, https://www.microscopyu.com/techniques/multi-photon/multiphoton-microscopy

† For articles on scientific software, see for example, https://www.zeiss.com/microscopy/us/products/microscope-software/zen.html Fuji and https://imagej.net/Fiji and https://www.qimaging.com/products/datasheets/qcapturepro7.pdf

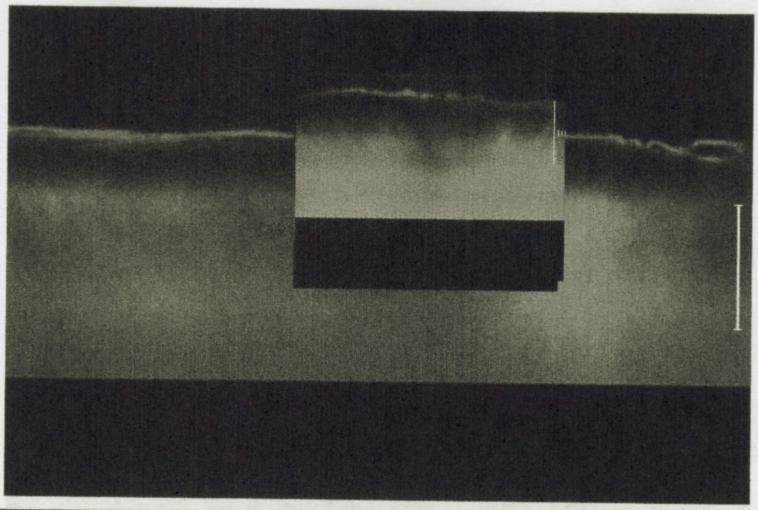

Figure 12.3 Reconstructed image of skin (stratum corneum, epidermi, dermis, subcutis) treated with Ovixan001 for 6 hours.

fixed-concentrations, internalization, transfected, synthesis, localize and track, downstream, chain reaction, and cycle are being used to further stimulate ideas.

In the studio, research is concentrating on three important elements to further extend the scope of this study: drawing, 2D and 3D prototyping, and the moving image. The work produced at this point is speculative and responsive in order to try out visual ideas and to expand the design-thinking process.

Data are reconfigured as complex, multilayered, structurally intricate digital design drawings, making use of a subtle interplay of visual information. An intense period of investigation is required to create highly detailed design drawings, which are produced by hand using digital drawing software from extensive observation (see, for example, Figures 12.4 and 12.5).

This drawn investigation of the photographic image is a process of identification. It picks out and maps important structural shapes and elements—what could be described as the "deep organising building principles behind natural form" (Kemp, 2016: 19). The drawing's intent is to reveal the mathematically precise pixellated image underneath in a simpler manner. The drawings pick out negative and positive shape through tracing elements of the shapes and structure of scientific data. Simple squares are used to construct and define shapes that are then amalgamated with a tool called Pathfinder.

The generative character of drawing and its activity is an inherently iterative process where one drawing inspires the next. In this situation, drawing is used as a tool for thought and for communication, as the act of drawing and its "extended states help to gradually explore and clarify design thinking" (Schaeverbeke, 2016).

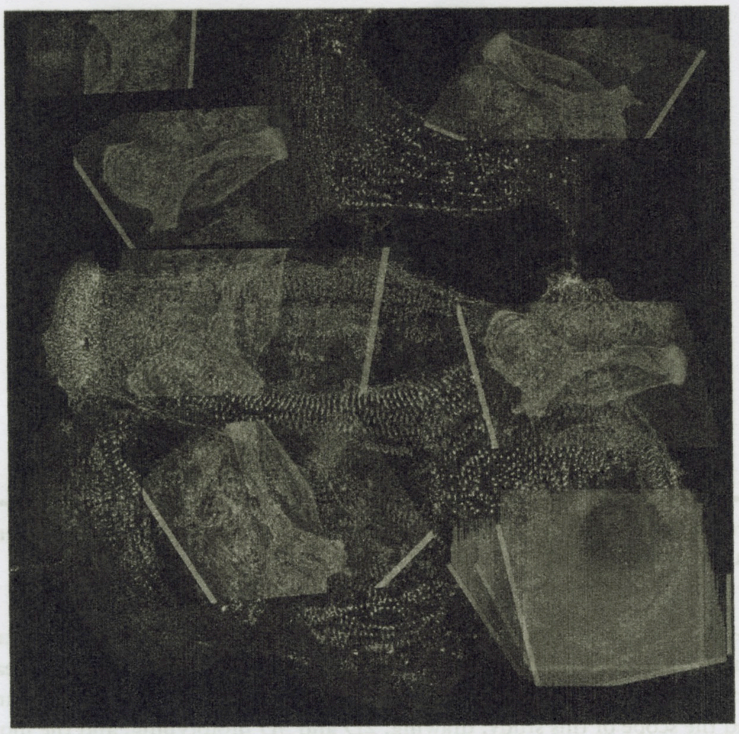

Figure 12.4 Fixed human stem cell (with antibody marker for cardiomyocytes). An image compilation from pure scientific image data, 2.5-D projection stills, digital drawing.

It is intended in the next phase of this inquiry to create 2D and 3D prototypes using these drawings as a core element in the construction of both 2D and 3D prototypes, where a series of design features including structure, movement, and rotation can be examined.

The other intended development is the production of a series of animated films that interweave documentary film footage with image stills inspired and sourced from the library of collected reprocessed image data.

Analysis, Reflection, and Feedback

Central to this inquiry is critical feedback from the collaborating scientists, and there will be a range of opportunities to gather these data, creating new insight

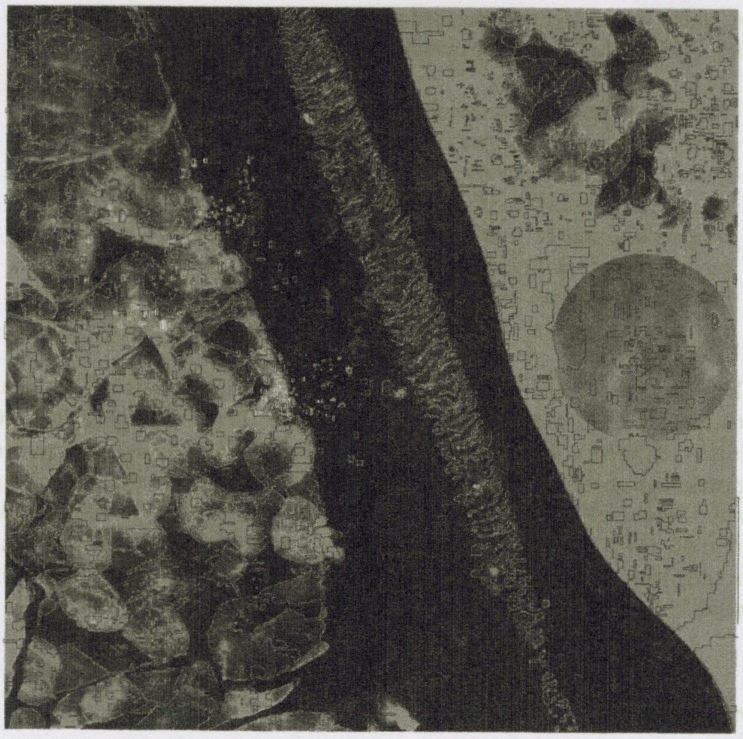

Figure 12.5 Bitesize, a deconstructed digital drawing compilation of skin imaged on a multiphoton microscope.

into image data visualization and contributing to the production of more refined visualization models. This feedback/communication enhances professional working knowledge for all collaborators, who can exchange ideas fluidly through the use of digital platforms.

Direct observations have already been recorded from interaction and dialogues with scientists. One has been pursued with Dr Joelle Golding,* an experienced postdoctoral researcher. These image data, remodeled using Zen Software and Adobe Illustrator, have been presented as examples of successful art–science collaboration at national and international conferences and published in international magazines (*Gothenburg University Magazine*, 2016; Varoom, 2016a, 2016b). The scientific collaborators at the University of Gothenburg, who had never worked with an artist

* Dr. Joelle Golding is a senior postdoctoral researcher working at the Cell Signalling and Pharmacology Department at the School of Life Science at Nottingham University.

before, stated that this experience had already had a transformative impact on their practice. As Dr. M. Ericson commented:

> We easily forget that research is actually a creative process. When we want to explain things, we often look for illustrations on the internet, instead of creating our own illustrations of conceptual insights. If we would dare illustrate and visualise our research, we might get both new insights and better contact with the general public. We can actually get inspiration from artists, and maybe this will make it easier to get funding because we can then show our research in a really interesting and new way! (*Gothenburg University Magazine*, September 24, 2016)

There have also been opportunities to publish research at a local, national and international level (*Gothenburg University Magazine*, 2016; Varoom, 2016a, 2016b; Cumulus Conference, Open Design for Everything Hong Kong), and research is being presented at a number of academic presentations for scientific specialist audiences and interdisciplinary, creative audiences. Opportunities for the exchange of information are being showcased and explored through various exhibitions, now and in the future (including "Bridging Nordic Imaging, Enabling Discoveries from Atoms to Anatomy," 2nd Symposium, Gothenburg.)

Conclusion

"Artists have a distinct approach to understanding and communicating ideas that can illuminate and challenge perceptions within society" (Wellcome, n.d.). The Wellcome Trust in this statement credits the arts with having an invaluable role to play in engaging the public with science, inspiring interdisciplinary research that benefits both artists and scientists. In *Art & Science,* Sian Ede (2012) identifies art and science as creative disciplines with common rationales, claiming that there is immense value in art engaging with science in complex and nondirect ways. Explaining how artists knowledgeable about the natural and scientific world approach this formal academic scientific world in an unconventional, personal, and emotive manner, Ede demonstrates her conviction about the immense value in art engaging with science in complex, and nondirect ways. The relationship between research and art practice in this research project is like an "iterative cyclic web," with activity alternating between practice and research (Smith and Dean, 2009: 19). This activity illustrates how the connectivity of ideas can work with many different strands as information is redirected and represented in new ways. And it works particularly well because it uses digital platforms. It exemplifies a process in which documentation, theoretical frameworks, contextualization of artwork, and the creative process of making it can offer knowledge of distinctive systems of investigation, enquiry, and reflection.

A fundamental premise for this visual investigation is to see how art and design strategies can impact in a positive manner on this seemingly formal academic scientific world, where unorthodox visual methods and strategies can add value to how scientific data can be interpreted and visualized. The new conceptual models reveal how expert visualizations can make intelligible ideas visible, offering a credible way of representing science in an original manner, creating significant new representations that can enhance scientific concepts (Faure Walker, 2013). It aims to critically engage different audiences, from scientific specialists, the arts, and the general public, by generating new work for exhibition, publication, and social media production. Importantly, the project is also providing insight into how big data can be managed. Accessibility to a wide range of subject specific software and the transferability of information through digital platforms is immense and can be overwhelming. But from an artist's/designer's perspective, data have much visual potential to be explored and novel data visualization through art can support communication and distribution. This research project has spotlighted a methodology of working and of data visualization that is ripe for development not only in science and in art but also potentially in other fields of expertise.*

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* Contextualising the key areas of knowledge, foundational theories and critically reviewing the discourse for national and international networks can be accessed at http://www.joberry.co.uk

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Appendix Eight: Drawing: Research, Theory, Practice

DRTP 9 (1) pp. 35–53 Intellect Limited 2024

Drawing: Research, Theory, Practice
Volume 9 Number 1

English language. https://doi.org/10.1386/drtp_00127_1
Received 7 September 2023; Accepted 22 January 2024; Published Online June 2024

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Advancing art–science collaboration through a framework of play: What is the purpose of generating hand-drawn representations of technologically advanced, high-resolution image-data?

Keywords
interdisciplinary
interplay
vectors

Abstract
Today's scientists depend on advanced imaging and microscopy techniques as scientifically accurate forms of representation and developments in advanced imaging and microscopy are altering how we perceive and comprehend images. The focus of this paper is a discussion of how images of scientific data

are generated by artists in distinction to scientists. Since 2010, a central part of my drawing practice has involved contributing to advanced imaging and microscopy research projects. I wanted to discover if and how an artist-researcher can contribute to interdisciplinary approaches in advanced imaging and microscopy by working as one of the research team. I conducted research to find out how an artist-researcher might contribute to new interdisciplinary methods in advanced imaging and microscopy and introduced play as a disruptive concept to trigger a reactionary response to scientific method. Discussion centres on a collaboration at the University of Nottingham Medical School in the Department of Life Science which happened over several years. The drawings illustrate how non-standard visualization techniques complement biomedical data. In outline, I suggest artists should be given access to scientific labs and work with scientists as part of the team to break down disciplinary barriers, and to generate new understanding. This body of work aims to elevate drawings status as a meaningful contributor to cross-disciplinary collaboration.

microscopy
collaboration
observation
subversion
zooming-in

Introduction

The focus of this paper is a discussion of how images of scientific data are generated by artists in distinction to scientists. Today's scientists depend on advanced imaging and microscopy techniques as scientifically accurate forms of representation and developments in advanced imaging and microscopy[1] are altering how we perceive and comprehend image. Since 2010, a central part of my drawing practice has involved contributing to advanced imaging and microscopy research projects. I wanted to discover if and how an artist-researcher can contribute to interdisciplinary approaches in advanced imaging and microscopy by working as one of the research team. I identified a lack of understanding between the disciplines of art and science in approaches to imaging and its potential. I conducted research to find out how an artist-researcher might contribute to new interdisciplinary methods in advanced imaging and microscopy and introduced play as a disruptive concept to trigger a reactionary response to scientific method.

Psychological and evolutionary research indicates that play is critical to our success as a flexible species. Play's role in language and other representational skill development, as well as its support for metacognitive and self-regulation qualities, appear to be the processes behind these relationships (Whitebread 2012: 5). Csikszentmihalyi (2008) asserted that play might lead to self-actualization and peak experiences like 'flow', or complete concentration on a given task. Gaining 'flow' through drawing encouraged me to consider playfulness as an important creative process with its ability to adapt. I wanted to discover the consequences and implications when an artist collaborates with positivist fact-checking life scientists and conducts interpretative research of

1. Advanced imaging and microscopy are broad terms that encompass the processing, analysis and presentation of image data obtained from a microscope using digital-image techniques.

Life Science. I investigated contemporary theories of play that have tried to increase our understanding of the phenomenon of play, both through the explanatory power of the theoretical views they describe and through the research they have stimulated (Mellou 1994: 99–100; Takhvar 1988: 221–44). This led to the selection of the three twentieth-century specialists I used to underpin this philosophical model of practice, informed by the writings of Johan Huizinga (2016), Donald Winnicott (1994) and Hans-Georg Gadamer (1998). Their theoretical perspectives influenced how I approached Life Science as a visual practitioner. Huizinga's (2016) writing about art and aesthetics as a unique cultural sphere encouraged me to seek out the play-elements in science. Winnicott's (cited in Winnicott et al. 1989) expression of play's significance as a driver of innovation and an essential part of creativity was an important consideration as I responded to scientific data imaginatively. I found Gadamer's (1998) objective – to describe the claims made in the arts in ways that cannot be reduced to or explained away by the methods of the natural sciences – inspiring when working with life scientists and reinterpreting their data. According to Gadamer, a culture built on playfulness may extend our understanding of aesthetics and the arts. I decided to navigate science using a subjective, unrestricted approach. Knowing that being playful expanded my preconceptions about what art may be. I utilized play as a strategy to foster debate and make science less intimidating (Gadamer 1998: 12). I deployed play systematically as a drawing strategy to innovate so that the unexpected could happen.

Context

The research undertaken is grounded in the long-established tradition and culture that exists in art and science collaboration elucidated by contemporary thinkers, such as artist-researcher's Gemma Anderson (2017), Lucy Lyons (2009); writers on art and science Siân Ede (2000, 2012), David Rothenberg (2013), Martin Kemp (2011, 2016), and art–science collaborators Anna Dimitriu and Bobbie Farsides (2014). These authors explain the important connections between both disciplines. They describe critical terms of reference from historical and contemporary sources and clarify how they have stimulated fresh thinking and debate in the acquisition of knowledge, which in turn has promoted social, ethical and cultural issues to be discussed by diverse audiences. They state that there is abundant evidence throughout history of the influence of representations made by artists who study science and its importance as another translation of knowledge. Conversely, Kemp (2016: 209) maintains that art and science became divergent occupations at the point where science chose precise representation over artistic interpretation. Publications such as the iconic learning manual Henry Gray's *Anatomy: Descriptive and Surgical*, with its 363 drawings by H. V. (Vandyke) Carter (1858) led the way to creating a distinct technical non-style of drawing and the depiction of the human body underwent a substantial change. The quest for scientific certainty resulted in medical image invention, which provided a new mode of visual access to the inner body, facilitated through the advancement of photography and techniques of imaging which reached beyond the human eye to microscopy,[2] with the X-ray invented by Röntgen in 1895. These brought new methods of visualization to the fore.

Ede (2012) believes new scientific explanations for the structure and functions of the human body and mind are needed. Our ability to visualize, abstract, create, pretend and reinterpret things is just as significant a sign of human achievement as the ability to reason and communicate facts about science. She encourages us to look at things from a variety of perspectives because, without daydreaming, serious scientific advancement would not be possible; conversely, art requires careful planning and conceptual thinking. She describes how theoretical discourse in the arts and humanities is evolving in tandem with new scientific findings, which is leading to a universal philosophical framework and methodology. She states the ethical implications of science and its new technologies need to be discussed in a wider context as our perceptions of information and knowledge production are evolving. In *Trust Me, I'm an Artist: Towards an Ethics of Art and Science Collaboration*, Dimitriu and Farsides (2014) note how art–science collaboration has led artists, scientists and institutions to re-consider their roles and responsibilities. They state scientific patriarchies are beginning to take on new meanings, and there appears to be a desire to introduce into public scientific discourse new issues of ethics arising from the intersection of art and science.

According to Rothenburg (2013: 20–21, 34–35, 57), scientists are intrigued by the subject of why life has developed into the complicated and spectacular universe that it is. He believes art can be utilized to reveal deeper meaning in the natural world, as it can change the way we see the world. Rothenburg (2013: 63) admires evolutionary scientist Richard Prum's work, because he takes beauty seriously. He claims that focusing on aesthetics and the creation of beauty will help us progress beyond the constraints of one system of thinking as it enhances our capacity to accept science's strangeness and how gloriously bizarre nature can be. Artists such as Anderson (2017), and Lyons (2009), investigate complex fields of scientific subject matter through an ongoing process of dialogue, and in doing so have made new discoveries in both the arts and sciences. Anderson's *Drawing as a Way of Knowing in Art and Science* (2017: 15) offers a philosophical and practical investigation into drawing as a method of interrogating science. She introduces tested ways in which drawing is used to examine the creation of elegant symmetries and constructions of animal, mineral and vegetable structures. She engages in the act of drawing as a survey tool to improve morphological understanding, informed by collaborations with natural scientists, mathematicians and curators (Anderson 2017: 4, 15). She subverts rigid classifications through drawing using the camera lucida as an aid for her observational drawing when handling specimens and studying natural materials. This demands practice, hand–eye coordination, analysis, delineation and improvisation.

2. Although it is not clear who invented the first microscope, Zacharias Janssen (*b*.1585) is credited with making one of the earliest compound microscopes. For articles on Janssen see, for example, https://www.livescience.com/39649-who-invented-the-microscope.html. Accessed 16 December 2022.

However, as she moves away from the specimen's natural context via 'free association', her sketching style begins to resemble an imaginative, reflexive evaluation process (Anderson 2017: 43). Lyons (2009) uses delineation as a drawing tool to inform her pathological inquiries into diseases such as fibrodysplasia ossificans progressiva,[3] a perplexing medical condition. Her drawings emphasize the interactions which form between herself as the delineator and her subjects, which include patients, anatomical samples, skeletal forms and medical demonstrators. She describes delineation as a phenomenological activity since it enables her to engage with her subject matter from the first-person point of view. She details how through the process of drawing; she gains an understanding of phenomena.

Like Anderson (2017) and Lyons (2009), I use drawing as an innovative tool – it is just as important as language (Petherbridge 1991: 7). Like them, I focus on the natural sciences and art, by investigating the relationships between subjectivity and objectivity, gaining new insights into drawing through exhibitions and designing educational models of practice. This approach to developing knowledge through science is an analytical technique that connects its inquiry of quantifiable stimuli to imagination, structure and process; thus, it is comparable to the history of scientific and artistic drawings. For example, Goethe's *The Metamorphosis of Plants* combines scientific and artistic perspectives on plant shapes (Anderson 2014: 232–40) and Leonardo Da Vinci's (1452–1592) scientific study of anatomy demonstrates how drawing can be employed to record, gather information and think through ideas and theories about the human body (Lyons 2009: 62–63). Drawing creates a common ground between artist and scientist, it can foster an interesting and enlightening discussion between disciplines that can lead to a paradigm shift (Anderson 2017: 18). In this article, I demonstrate how play, art and science as hybrid occupations may coexist when engaging in biomedical research. I explore how the re-presentation of scientific data has enriched the perception of artists and scientists.

Stage one: Face-to-face collaboration

Discussion centres on a collaboration with SLIM[4] and COMPARE,[5] at the University of Nottingham which happened over several years. I immersed myself in this important imaging centre to learn about their discipline processes, interacting with individuals and small groups of scientists. I, like Prum, value aesthetics and wanted to investigate this core-imaging lab as an underutilized resource for artist-researchers who are conscious that art may operate as a counter-measure to scientific quantification (Rothenburg 2013: 63, 130). I took onboard scientific concepts and developed new conceptual ideas to convey an understanding of aspects of science I found interesting, such as its visual significance. I expanded my knowledge of advanced imaging and microscopic systems capabilities, computer visualization techniques and software. I conducted a series of creative experiments

3. Fibrodysplasia ossificans progressiva (FOP) is a rare musculoskeletal disorder, muscles and tendons gradually turn into bone (a process known as ossification) beginning at birth and continuing throughout life. As a result, there is an additional 'skeleton' of bone that prevents mobility.

4. For articles on SLIM see, for example, https://www.nottingham.ac.uk/life-sciences/facilities/slim/cell-signalling-imaging/index.aspx. Accessed 16 December 2022.

5. For articles on COMPARE see, for example, https://www.birmingham-nottingham.ac.uk/compare. Accessed 16 December 2022.

to see what occurs when an artist collaborates with scientists and reframes the issue by introducing the concept of play as a disruptive concept to scientific representation. Understanding this subversion of the precise and rigorous methods employed by scientists was essential to advancing our understanding of aesthetics. I developed a four-stage approach underpinned by action-research (AR). AR was selected as the methodological approach because of its cyclical reflective nature; it encompasses contemplation, planning, action, observation and reflection (Dickens and Watkins 1999: 127–40). I used play as a tactic, embracing a performative, process-based approach while participating in scientific research projects as a member of the research team (Kestner 2013: 1). Knowledge was generated through empathetic interaction as I 'played out' scientific activities, performing the role of a positivist fact-checking scientist, dressing up in a white lab coat, and using a lab book to liberate myself from prejudices (Takhvar 1988: 232). As events unfolded, I made the decision to record (sketched, videotaped, photographed and written notes) what I thought was unique. As I carried out each experiment and discussed my findings, I transformed into an inquisitive pseudoscientist involved in dispute, imaginative play and conceptual thinking. As a result of this role, I was able to ask a variety of questions in the lab, at scientific conferences, and in the advanced imaging lab, providing for an ongoing process of interaction (Dickens and Watkins 1999: 127–40). To highlight the crucial role that an outsider may play in research, I gathered unusual, interpretative and factual data and comments from scientists, as well as raw image data from witnessed experiments.

Experienced scientists, such as Tim Self, whom I met in 2010 during 'Hijacking Natural Systems'[6] understood the importance of my presence in their labs. He thought that my continuous presence would be beneficial by assisting scientists at various stages of their careers in discussing their findings in an informative manner to a specialist from a different subject. He wanted the research he conducted to be relevant and easily communicated to the public, service users and other NHS staff. Self said that he was frustrated that his research group's audience was not 'old men in wards having limbs amputated' or 'sophisticated young people'; instead, they were communicating exclusively with pharmacologists and medical students. He was convinced that the public did not understand or value their research and wanted to address this perceived problem. He believed that my presence in his labs and the interpretative research I was conducting could be used to convey scientific findings in a more creative manner.

Taking on board Huizinga's (2016: 20) concept of the 'magic circle', I – as the player – enclosed myself within the safe zone of this lab with several scientists, including post-doctoral researchers and senior imaging technicians. I concentrated on the novel techniques scientists employ to obtain images and the cutting-edge microscopic systems they employ, which revealed the creative, inventive and technical aspects of science. I questioned my collaborators' logic for choosing the cells

6. 'Hijacking Natural Systems' (2010–11) was cited by the Wellcome Trust (WT) as a successful model of Arts and Engagement. See for example, https://www.huffpost.com/entry/under-the-microscope-art_n_868361. Accessed 9 July 2023.

they did. They explained they were not looking at shape or form like an artist would an artefact, such as a drawing; instead, their selection methods were dictated by theory and used to answer a research question. They admitted that they were locked into a scientific way of thinking, with no room to play. I showed them how a different approach to positivist fact-checking science may encourage these scientists to re-evaluate their scientific imaging norms. This resulted in a broadening of each of our perspectives about the potential of scientific image creation (Winnicott 1994: 51). From this activity, scientists began to discuss what they thought about their image-making in non-scientific terms and, more importantly, began to discuss how they felt about being a scientist and what image-making means to them. As collaborations developed, I found that I was able to convey convincingly to them aspects of science that I found interesting beyond empirical measure. Studying the aesthetics of the picture data – its form, colour and peculiarities – opened my eyes to new facets of science. I thought about the human aspect of microscopy as seen, for example, between scientists and microscopic systems. The process of inquisitiveness, instinct, spontaneity and imagination in human decision-making for artists and scientists, as both combine sight, hand–eye coordination, smell and intellect when working at the scientific bench and using technology to examine cells on a microscope. Like Anderson (2017: 43), I appreciated that this activity demanded analysis, improvisation and reflexive evaluation – essential skills that I recognized aided the development of cross-disciplinary understanding. It brought my attention to play's integral potential for advancement of concepts, rules and modes of thinking. All collaborators, stereotypically, pointed out patterns for comparison and all presented straightforward explanations about their methods. However, play's disruptive nature made it possible to see the subtle linkages between our disciplines' attention to observation, incongruity and aesthetics. Our interactions revealed patterns at play (complicated, obtuse and apparent) that could only be discovered by doing AR and thinking through play in this lab.

My desire to contribute as a creative practitioner was seen as valuable to this scientific community, stimulating discussion on scientists' particular acts of non-compliance as a means of discovery. I was able to pose non-scientific questions since I was an outsider looking in. As a result, scientists like assistant professor Laura Kilpatrick enjoyed discussing 'about our crazy science shenanigans'. We attempted to understand and learn from one another by debating science from various perspectives. As a participant, I encouraged scientists to convey complicated terminologies in unconventional ways since I was fascinated by scientific language and terminology. For example, when working with research fellow Joëlle Goulding, she described the reasons behind each stage of the experiment in lay terms while I asked questions about what she was seeking to learn as she examined the cellular morphologies of cardiomyocytes in human stem cells. Goulding demonstrated a clear purpose: her objective was to capture images systematically and record results for her research group. The group wanted to create a reliable and characterized model to test new drugs for diseases of the heart. Goulding gave me a lot of information to work with, such as patient responses, graphs she drew in my lab book, and e-mail correspondence. While this visual experiment was taking place, we discussed our divergent impressions. Using play as a strategy, I noticed how our human and visual interactions shifted between serious, creative and fun (Huizinga 2016: 1). As our play activities developed, more ideas became apparent. I saw how this kind of exploratory engagement blends 'inner' and 'outer reality' (Winnicott 1994: 86). Goulding imaged cells on a single plane, as typically these cells sat on top of each other. I noticed the amount of time she took to find the best cells to capture, as we discussed each cell's aesthetic peculiarities. These cells were amusing to watch since they did not react as they should have. I found it fascinating that these genetically altered cells were capable of becoming anything. I was thrilled to see (see Figure 1) that this cell's surface seemed to be covered with glitter, and when I looked at a cluster of these cells together, they reminded me of tightly spaced squids – a comparison that is neither artistic nor scientific!

I used drawing as a way to capture these unexpected cellular formations and their amorphous structure as I observed live cell activity develop and fluoresce on the computer screen (see Figure 2).

My contact with this lab, its scientists, and its microscope equipment was only possible because I invested in it as a novel play space, and noted how, why and when play occurred. Through the use of play as a catalyst for innovation, it became clear that consistently using play while monitoring and challenging empirical visualization procedures forced these scientists to break with convention and view their data from a different angle. I realized that my approaches allowed unfettered conversational dialogue with scientists. Reciprocity allowed these scientists to focus on the novel and surprising aspects of their subject matter and data. Simultaneously, I described to scientists how a precise, timed experiment that was animated on-screen produced spectacularly unusual imagery, such as reactive sequences resulting from the unpredictable behaviour of cells. I was able to observe visual phenomena that I would not have otherwise observed, had I not been present. In addition, scientists would not have seen or understood my reaction if I had not been there, nor would they have comprehended why I questioned the scientific process they used to form an image and its constituents, and not have witnessed my reaction. Interplay, in other words, made science less daunting and influenced our behaviour (Gadamer 1998: 12).

I discovered something fresh and imaginative every time I returned to this facility. For example, I investigated how drug-treated cells changed state and discovered several points of overlap between our practices, such as our shared interest in laser technology, light and computer-generated images.

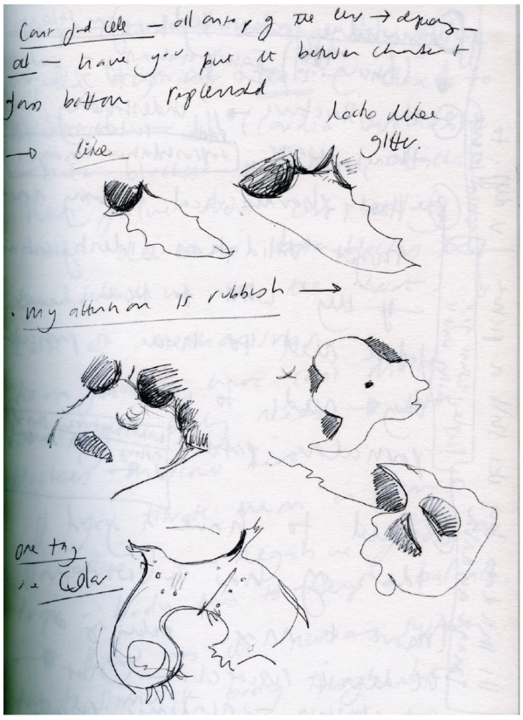

Figure 1: Photographing the cell's surface seemed to be covered with glitter at the school of Life Science Imaging (SLIM) core facility. 14.8 cm × 10.5 cm. Copyright Joanne Berry-Frith.

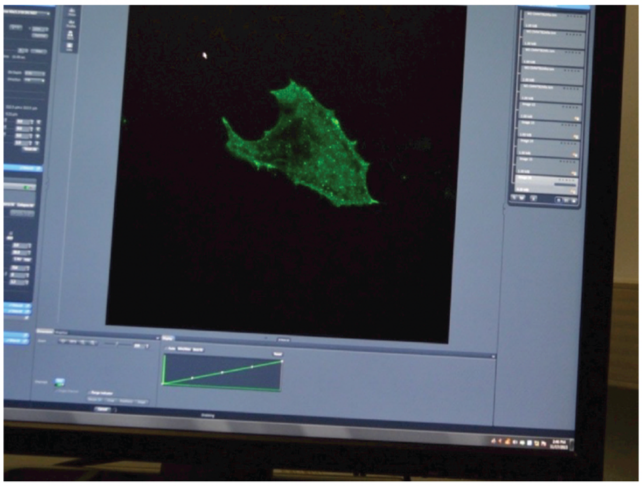

Figure 2: Sketching cells on screen at the School of Life Science Imaging (SLIM) core facility, 2017, CM, 21 cm × 29.7 cm. Copyright Joanne Berry-Frith.

7. For articles about confocal microscopy, see, for example, Wilhelm et al. (n.d.).

All of these technologies are critical components of this lab, and I was drawn to them since they were not available outside of the lab. I focused on fluorescent colour, amorphous form and the scale of human-stem-cell-derived cardiomyocytes taken on the confocal microscope.[7] This generated the first sets of data. As demonstrated in stage two, where data was extended through my approach to drawing, my purpose was to demonstrate how disruptive creative art tactics may extend understanding of microscopic picture data.

Stage two: Drawing as an investigative tool

In stage two of this framework, I concentrated on practice as a method to disrupt scientific image conventions. I did this through pinpointing how the use of advanced imaging and microscopy with the Life Sciences can expand art and scientific methods of imagery. Initially, the scientific computer processing lab became a key space where I returned regularly to extend my use of scientific data beyond singular methods of processing. Utilizing Caillois's (2001: ix) idea of 'rules generate fictions', I used incremental and improvisational strategies to re-imagine raw data from observed experiments, to create multiple visual outcomes (Caillois 2001: 29–31). after which data was extended through my idiosyncratic approach to drawing. My intention to come up with novel ways to visualize image data beyond empirical representation. As Csikszentmihalyi (2008) observed, once I began working on a surface-based analysis of nebulous cellular formations, the process of tracing pixel data took on a structural aspect, and I became completely engrossed in characterizing it. I used Adobe Illustrator software to draw with and developed an introspective drawing strategy, selecting image data for its attributes and constituents. For example, in one observation, I observed the laser scan across a plane of interest as the entire image was acquired, pixel by pixel and line by line. Using a stereomicroscope, I observed a dense grid of red, green and black pixel resolution on the monitor. I wanted to know how many pixels comprised this image because, once the sample size is determined, everything is viewed, processed and reproduced on-screen. I zoomed into data at a high magnification; linking it back to the scientific method used to capture it. I constructed handmade drawings through building vector rectangles and squares, then merged elements using the pathfinder tool (see Figure 3).

I focused on human-stem-cells-derived cardiomyocytes and focused on the supple characteristics of these amorphous brightly coloured cellular forms. Each drawing was constructed out of merged vector rectangles produced in overly bright CMYK colours. I incorporated solid and dashed lines using overly bright CMYK vector lines as a contrast to the highly saturated coloured cellular detail underneath. I used a 0.75-pt vector rectangle unfilled outline by hand. Creating large-scale drawings (up to 2 m tall or wide). Knowing it was impossible to replicate densely populated pixel

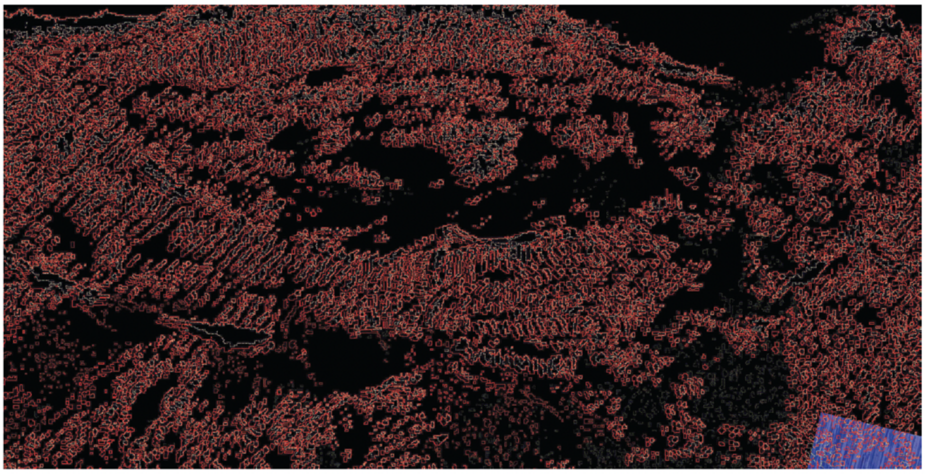

Figure 3: Detail of human-stem-cells-derived cardiomyocytes, 2023. drawing.ai. 100 cm × 100 cm. Copyright Joanne Berry-Frith.

data. My intention was to offset digital drawn uniformity. I made imperfect replications, undertaking a laborious, idiosyncratic method of tracing zoomed in pixel detail at, for example, 1200 per cent illuminated on-screen. The original laborious hand-crafted digital drawings were copied and pasted up to six times using solid and dashed vector lines.

In Figure 4 (see detail in Figure 3) orange, white, yellow and lemon, solid and dashed vector-coloured lines were employed, these intersected and over-lapped so that the overall effect was that the drawing looked out of focus. To create flow within the composition Figure 4, I incorporated stills of animated 3D topologies.

In Figure 5, solid and dashed vector-coloured lines in bright red, orange, flesh, black and brown were copied, pasted rotated at 2–5° angles and slightly offset. Both drawings resemble machine made (computer-generated) artwork, but they are principally generated by hand. The overlaying of linear detail created both drawings' intensity. Reflecting on- and in-action, this act of drawing is a strategy I employed to extend creative thinking (Schön 2013: 18, 49). I asked myself: 'What is the purpose of generating hand-drawn representations of technologically advanced, high-resolution image-data? Why do I need to make time-consuming drawings? What is the point of creating imperfect replications?'.

I came to realize the drawings I created were acts of translation where I formed a unique dialogue with synthetic image data made from mathematical code, this reframed my understanding of scientific data and my understanding of what thinking through play could entail as I generated non-standard depictions of science by engaging hand crafted digital drawing strategies.

After creating landscape and portrait compositions I devised a less conventional compositional device inspired by ancient scrolls. Unlike a traditional poster, I used the scroll format to encourage the audience to interact physically with these images. I found this shift in the compositional frame expanded my drawing outputs further, as it allowed a range of contrasting visual data to be incorporated – the largest scroll created was 300 cm × 41.8 cm. Figure 6 focused on contrasting pictorial elements from the data experiments I created in the scientific computer lab and included a detailed pixelated drawing of a super resolution microscopy experiment.

I uncovered new justifications for using this interpretative obsessive drawing technique to challenge my and my colleagues' image representation-related behaviour contributing to the fields of art and science, and charted the incremental development that occurred gradually over several years. After which (stage three), I used dissemination as a method to allow scientists to analyse their data through my eyes and then reflected on all four phases to build critical linkages (Schön 2013: 308–15, 323).

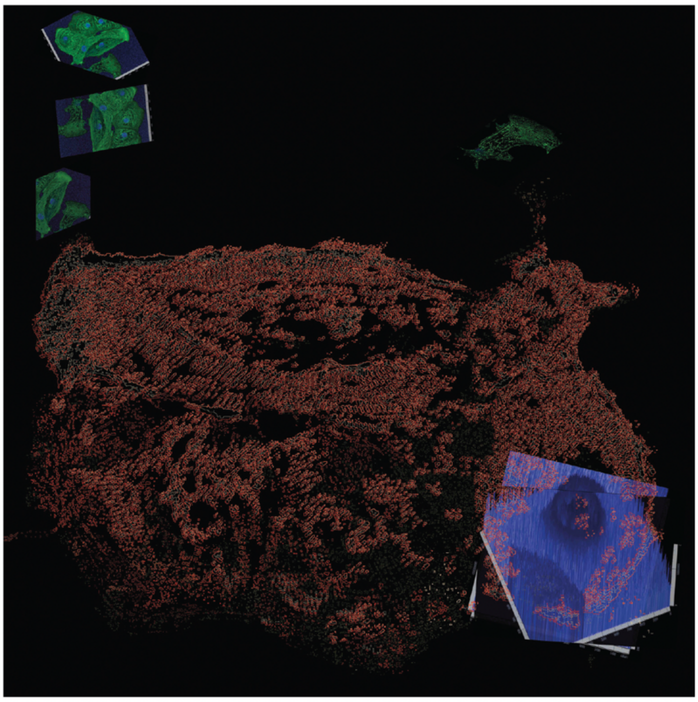

Figure 4: Human-stem-cells-derived cardiomyocytes, 2023. drawing.ai. 100 cm × 100 cm. Copyright Joanne Berry-Frith.

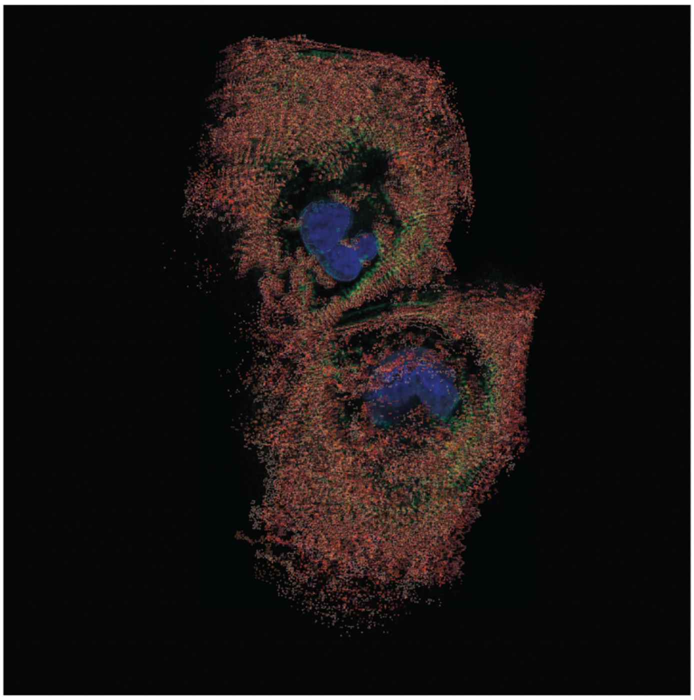

Figure 5: A simulation of human stem-cells-derived cardiomyocytes, 2023. pdf. 100 cm × 100 cm. Copyright Joanne Berry-Frith.

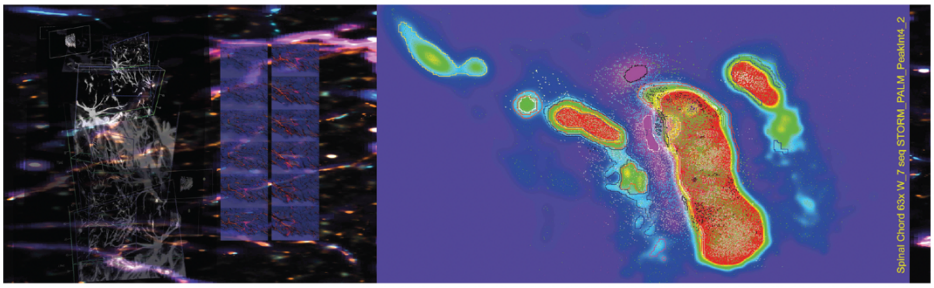

Figure 6: Alternative iteration 4 super resolution, 2023. ai. 157 cm × 41.8 cm. Copyright Joanne Berry-Frith.

Conclusion

Advanced imaging and microscopy labs are underutilized as artist-researcher resources (visually, intellectually and technologically), as artist-researchers are rarely given access to bioimaging labs. My research focused on this gap, with the intention of enabling positive change. Through training and instruction, while operating as an action researcher, I learned advanced imaging and microscopy techniques, procedures and technologies and discovered original ways to visualize image data beyond empirical representation. Although there was an unavoidable and understandable knowledge gap between disciplines, and there is a separation between domains in terms of methodology, processes, terminology, outputs and representation techniques, my involvement has exposed a clear desire for cross-cultural collaboration. I acknowledged that it was acceptable for artists and scientists not to reach the same objectives or conclusions. Interaction has transformed research for me and my collaborators, since we've learnt to embrace our inherent diversity. Creating equity has led to advancement, which has led to deeper partnerships that encourage appreciation it demonstrates how drawing can connect art and science.

In conclusion, this research dismantles silo mentalities so that artist-researchers can collaborate with scientists to create new representations, insights and activate behavioural change. These aims were achieved by fully engaging in biomedical research and allowing play, art and science as hybrid occupations to coexist. Play was used systematically to stimulate the creative thinking of scientists and inspired the digital drawing practice. Play as a disruptive concept removed obstacles, it created a bridge between the laboratory and this artistic inquiry. Play, art and science as hybrid occupations set in motion the creation of an introspective digital drawing method. This drawing method increased mine, my collaborators and the audience's appreciation for technical advances in scientific visualization. They illustrate how non-standard visualization techniques complement biomedical data. Dissemination forced scientists to examine their data differently – through my eyes in my field, this challenged their scientific norms. In outline, I suggest artists should be given access to scientific labs and work with scientists as part of the team to break down disciplinary barriers and to generate new understanding. This body of work aims to elevate drawings status as a meaningful contributor to cross-disciplinary collaboration.

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Suggested citation

Berry-Frith, Joanne (2024), 'Advancing art–science collaboration through a framework of play: What is the purpose of generating hand-drawn representations of technologically advanced, high-resolution image-data?', *Drawing: Research, Theory, Practice*, Special Issue: 'Drawing and Knowledge', 9:1, pp. 35–53, https://doi.org/10.1386/drtp_00127_1

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