Body as Landscape: A Visual Aesthetic Model for Sensual Awareness of Challenges on our Environment

Volume I

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ABSTRACT

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Vicky Isley

Human health is inextricably intertwined with the health of our environment but often they are explored independently in the domain of scientific research. This portfolio of practice-based research, from 2015-2022, has emerged from in-depth art and science collaborations with biomedical researchers in the field of epidemiology, neurology, oncology and immunology. The interdisciplinary collaborations have resulted in the creation of new visual expressions, in the form of three-dimensional computer-generated landscapes, that address wider concerns regarding the connections between human and environmental health.

Central to this body of practice is the consideration of aspects of the scientific research that remain oblique to the central motivations and practices of the scientists but that are vital to their personal engagement with their subject area. The art-science interdisciplinary research presented and reflected upon here, refocuses on these less contextualised aspects of scientific practice, providing a sensual experience of highly technical scientific research.

My distinct contribution to knowledge is in the creation of a *new aesthetic* model in the form of an exemplary: body of practice-based artefacts and a distinct interdisciplinary process that has materialised from the creation of the aesthetic artefacts. This compendium of practice-based research is presented as two volumes:

Volume I: is a written thesis, which provides a reflective and analytical text on my body of interdisciplinary practice in the form of practice-based artefacts. There are four artefacts which form this body of research: *Dreams of Mice* (2015); *AfterGlow* (2016); *In Search of Chemozoa* (2020) and *Call of the Silent Cell* (2021).

Volume II: consists of a portfolio of the four practice-based artefacts in the form of aesthetic visual expressions. This volume provides documentation on the artistic techniques and processes of each artefact and is designed to be consulted as a parallel volume. Volume II is presented as a separate hard-copy and as an online version, please click here to access the online version.

It is advised to view the online version as it includes embedded videos and web links to supplementary material.

This research compendium (Volume I and II) combines to express my new *aesthetic model* that addresses challenges on our bodily health and the health of our environment through sensorial aesthetic expressions. This body of practice-based research has been produced through art and science interdisciplinary projects, providing deeper appreciation of valuable scientific concerns, through my own perceptual experiences of the science research.

The thesis component (Volume I) provides an analytical reflection on the new knowledge that has been achieved through the insights of my interdisciplinary aesthetic processes. The methodology that was used to produce this body of research was practice-based in the field of computational art, supported by the examination of theory in this field by Ernest Edmonds and Linda Candy.

Volume I presents an art and theoretical review (Chapter III), which examines other contemporary artists' theories and practice who are also working interdisciplinary across art, science and technology. This includes a case-study on the practice of artist collective, Semiconductor and reflects on the significance of their interdisciplinary practice over the last fifteen years. Chapter III also includes an examination of theoretical texts from key practice-based researchers who are innovators in the field of interdisciplinary practice including Victoria Vesna and Angus Graeme Forbes, who both critique the importance of interdisciplinary methodologies in the field of new media. Other relevant art and science theory has been examined in Volume I on the importance of: polymathic approaches; different types of models; aesthetics of art to enable new experiences and perception. In the analysis chapter (Chapter IV) the text responses to my initial research questions that are outlined in the Introduction (Chapter I - Section 1.1.2).

This thesis provides a critical investigation of my individual contribution to this significant body of practice-based research, co-authored by Paul Smith under the collective artist name *Boredomresearch*.

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Acknowledgements

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I am completely indebted to my husband and collaborator for over twenty years, Paul Smith. Paul has given me the time and space to find my own voice here, through keeping everything else afloat and keeping me positive and believing in myself.

I am deeply grateful to the following curators and producers for their contribution to this body of work including: Monica Bello, Curator and Head of Arts at the European Organisation for Nuclear Research (CERN) who initiated *Dreams of Mice;* Abigail Addison, Director of arts agency Animate Projects who supported the research and development of *AfterGlow;* Pamela Winfrey, Director of the Cancer Arts Program at the Arizona Cancer Evolution Center for her vision to instigate the amazing collaborative process that I have embarked on to produce *In Search of Chemozoa* and last but definitely not least Dr. Suzy O'Hara, in her position of Project Manager and Curator, Wellcome Sanger Institute for the Human Cell Atlas Public Engagement project 'One Cell At A Time' who brilliantly co-ordinated our project *Call of the Silent Cell* including during the difficult Covid-19 lockdown period.

All of the projects contained in this thesis have been supported by many excellent art organisations, galleries, science institutions and curators - there are too many to list here but if you are reading this you know your contribution and please accept my deep gratitude for believing in Boredomresearch and supporting my practice.

Last but not least I would like to thank my examiners Dr. Samantha Moore and Professor Mike Philips for their feedback and insightful discussion during my viva voce.

Author's Declaration

I declare that all of the material in this practice-based research compendium (Volumes I and II) is my own work. The body of practice-based research in Volume II has been co-authored with my collaborative partner Paul Smith under our collective artist name *Boredomresearch.* My individual contribution for each artefact is outlined in the 'Methodology & Approach' sections in Volume II - Portfolio of Practice-Based Artefacts.

There are some ideas and arguments presented in this thesis that have been covered in co-authored papers written with my collaborative partner, Paul Smith. These co-authored publications are always referenced in the text as 'Isley and Smith'. Here is a list of the key co-authored publications that have contributed to this thesis:

Isley, V. and Smith, P., 2017. Artistic Interpretation of a Malaria Transmission Scenario [online]. *In: Electronic Visualisation and the Arts (EVA 2017)*, London 11-13 July 2017. London: BCS Learning and Development Ltd. 335-339. Available from: http://dx.doi.org/10.14236/ewic/EVA2017.68 [Accessed 7 February 2022].

Isley, V. and Smith, P., 2021a. Fictional Frontiers. In: Riccardi, V., ed. *Creative Responses to Sustainability UK Green Guide*. Singapore: Asia-Europe Foundation, 166-171.

Isley, V. and Smith, P., 2021b. Imagining New Life Systems: Consistency Touched by Chaos Boredomresearch. *In:* Clay, A. and Senior, T. J., eds. *On Media, On Technology, On Life - Interviews with Innovators*. Denmark: River Publishers, 162-174.

Vicky Isley (May 2023)

Notes

Text format

Please note that all artefact titles in this text are formatted in *italics.* Acronyms are in parentheses after the first use of the word.

Translations

The citations which are quoted from translated texts state the date that the translation was published; where possible I have included in the references the original date of the translated text.

Referencing

There are several publications that have been referenced from the Perlego online library, where the majority of these e-publications do not have page numbers. I have used a method of Harvard referencing these sources stating: the chapter, section and paragraph so these citations can be easily found within this online version or in a hard copy of the publication.

Structure

VOLUME I: THESIS

Volume I contains the written component of this PhD by Publication which is a reflective and analytical text on my interdisciplinary practice and the four practice-based artefacts within my portfolio.

VOLUME II: PORTFOLIO OF PRACTICE-BASED ARTEFACTS

Volume II contains my portfolio of the four practice-based artefacts to accompany the analytical text in Volume I. A hard copy of this portfolio has been included and an online version, both copies include: contextualisation text, project descriptive text, a section on my methodology and approach, documentation on research development, exhibition and award information, weblinks to the final artefacts and links to supplementary project specific material.

Please click here to access the online portfolio.

Glossary

Aesthetics

The study of sensory experiences and how they are perceived emotionally by individuals. In relation to art, aesthetics is concerned with understanding qualities, such as beauty and poetics, perceived within an artistic artefact. Here the focus is on the perceptual experience through an art and science collaboration and how this manifests in an artwork that incorporates the aesthetic qualities that have been gained from the interdisciplinary approach.

Aesthetics Model

A term to describe my methodology of art and science interaction, leading to sensorial experiences of scientific research through the creation of artworks. The aesthetic experience of my art is presented here as a unique method which involves the collaborative process between art and science leading to new knowledge, reflection and a new sensorial experience of the science through the practice-based artefacts.

Body as Landscape

This concept challenges the traditional notion of seeing ourselves as separate from our environment, where the human body and our surrounding landscape is intrinsically interconnected. This study focuses on the importance of interdisciplinary art and science practice, that considers the interdependent relationship between the human body and the environment.

Environment

Surroundings which are found in both nature and our body. Here the term is explored in context to a landscape which could be an external natural environment or an environment within our body.

Expression

A creative response to scientific research which provides a visually stimulating experience that enhances the understanding and appreciation of the science models and data. The artefacts are described here as expressions rather than simulations or visualisations to focus attention on the emotional experience of the artworks rather than the artwork being for illustrative or representational purpose.

Interdisciplinary

An approach that involves the integration of knowledge and methods from multiple disciplines to generative new understanding through a collaborative process. Here the interdisciplinary disciplines are art and science which have led to innovative concepts for artworks and deeper reflections on the individual's practices.

Phenomenology

Is a philosophical method developed by Edmund Husserl that aims to explore the essential structures of human experience. In Husserl's original study of science, phenomenology played a crucial role in allowing experiences to be considered as legitimate sources of knowledge. Phenomenology is examined here from the perspective of art providing a valuable subjective experience for a scientific inquiry.

Practice-based

This study explores Edmonds and Candy (2011) definition of practice-based research as embedding practice in the research process, where the research process is primarily based on the making of an artefact in order to gain new knowledge. Edmonds (2018) describes how making an artefact is pivotal for practice-based researchers and the insights from making, reflecting and evaluating may be fed back directly into the artefact itself. This inquiry has materialised in the creation of four original practice-based artefacts.

Practice-led

This study explores Edmonds and Candy (2011) definition of practice-led research as primarily leading to new understandings about practice, where it does not depend upon the creation of an artefact by practitioners but is found in the practice. The practice-led research that has materialised through this art and science interdisciplinary process has enabled enhanced aesthetic knowledge and reflection on scientific research.

Sensual Awareness

In the context of art and aesthetics, sensual refers to the sensory and emotional experiences related to the human senses i.e., touch, sight and sound. In this study these senses are heightened through perceiving the visual artefacts where viewers can engage with scientific research through their own emotional and bodily experience.

Sublime

Is a sensation of something hard to comprehend, that creates a powerful emotion with the spectator which has qualities of complexity and incomprehensibility. In this text sublimeness is explored in the complexity of artworks and within overwhelming scientific research, data and environments.

Chapter I

INTRODUCTION

1.1 Introduction to Art and Science Interdisciplinary Practice

1.1.1 The Allure of Art and Science Cohesion

Throughout all of my art and science collaborations, my scientific partners have expressed that they recognise the value of pursuing their research from an artistic perspective; realising that it will open up challenging and novel ways of thinking about their own work. These interdisciplinary collaborations have enabled me to appreciate scientific fundamentals which go beyond the bounds of comprehension gained from reading a technical scientific paper or journal article. Engaging with scientists' research through artist residencies in science laboratories, in fieldwork contexts and through extensive moments of discourse, allows for an intimate knowledge exchange from scientist-to-artist and vice versa. Once a trust has been achieved within the collaboration this allows receptivity to new ideas and for scientific concepts perchance discarded in the science arena to be artistically challenged. As Ede (2005) describes artists can re-inform and reinvent a view of the science, sometimes honing in on things that are apparently redundant and paradoxically present us with a coherent reflection of a corner of reality that perhaps should not be overlooked.

The rigid constructs of science can sometimes limit the freedom a scientist has to explore their subject and art can provide a platform to explore ideas that remain not transparent. There are ideas that may be more personal to the scientist, but which may not sit comfortably in a competitive funding environment; one that encourages a bias towards science that answers an urgent need. Art provides a vehicle to express what is important to us all, important at a level that transcends the business of science and instead reflects a passion for the beauty of the scientific practice (Isley and Smith, 2021a)[1]. It is fruitful art and science interdisciplinary collaborative processes that has enabled the production of this body of practice, of which the research contains an intricate weave of multiple complex strands from both the perspective of human health and the health of our environment.

The core subject matters within my art and science collaborative projects are complex areas of biomedical research that focus on: cancer, infectious diseases, sleep deprivation and the health of our microbiota. As artists we cannot become experts on all of these topics, especially as

[1] An excerpt from Isley and Smith's 'Fictional Frontier' interview with Invisible Flock of which a transcript is in the *Creative Responses to Sustainability UK Green Guide*, pp.168-170. Published by Asia-Europe Foundation (ASEF) in 2021. Access online at: https://culture360.asef.org/media/2021/05/GreenGuide_May24_spreads.pdf

they are so complex. During the collaborative process, we need to take the time and space to gain an appreciation of the scientific material that allows for a sensibility to be perceived of the subject matter; a sensibility that goes beyond the surface of that which is initially presented. As Ede (2000, p.167) states this involves artists learning the new language necessary for an understanding of science, engaging even in highly technical methodologies.

This body of practice-based research commenced in 2014 when I started my collaborative journey with biomedical researchers in the field of neurology based at the University of Oxford. My collaborations continued with biomedical scientists: in the field of epidemiology at the University of Glasgow (2015-16); with cancer researchers at the Arizona Cancer Evolution Center (ACE), Biodesign Institute, USA (2018-2020) and with immunologists at the University of Oxford (2020-21).

The science embedded in this practice-based research is not only complex but it is also very relatable to us on an individual level. The research covers human health concerns, where the subjects can be sensitive to an audience through their own personal experience. For example, the primary scientific research in my artwork *In Search of Chemozoa* explores radical new methods of therapeutic approaches to cancer. Being a disease that has touched so many, viewers may have had or are having a personal experience of this disease that could stimulate a response that is different from a person that has had no experience. This enables the viewer to interpret their limited sensory experience in the light of their knowledge (Noë 2002). This also is true for *AfterGlow* which is a three-dimensional expression of an infection transmission, many people currently are experiencing the impact of a zoonotic infection with the Covid-19 pandemic and the consequences of this infectious disease will affect how a viewer perceives an artwork expressing infection dynamics. The perceptual experiences that viewers encounter with these artworks, encourages a subjective personal response to the art, which allows for the audience to be more emotionally attached to the subject matter, rather than distancing themselves from the research (see Chapter III, Section 3.2.2 on Phenomenology for further details on experience). Noë (2002) states that art is a tool for phenomenological exploration and enables us to perceptually experience the world. Describing the concept as 'enactive' where the experience is an activity of encounter with the world. The practice-based artefacts presented here are aesthetic landscapes that provide a model in which we can visually *"reflect on the world as a domain for active exploration"* (Noë 2002, p.6).

This thesis (Volume I) is an account of my own practice-based research in collaboration with Paul Smith, under the artist collective name, *boredomresearch*. For this line of inquiry, I have chosen to practice within the field of art and science interdisciplinary research. The body of practice presented here reflects upon how I have advanced the

study of art and science interdisciplinary research. Culminating in my distinct contribution to knowledge being through the creation of a new art and science interdisciplinary model, the *aesthetic model* which has materialised in the form of:

- The creation of four original interdisciplinary practice-based artefacts: *Dreams of Mice* (2015); *AfterGlow* (2016); *In Search of Chemozoa* (2020) and *Call of the Silent Cell* (2021).

- A distinct art and science interdisciplinary process that has led to a sensorial aesthetic interpretation of scientific research.

The *aesthetic model* is an exemplary body of research that has been conducted by myself from 2015 to 2022 that contains the creation of original practice-based and practice-led interdisciplinary research. The aesthetic model has been conceived to express my original art and science interdisciplinary practice where the artist, scientist and audience receives an aesthetic sensorial intersubjective experience (reference Chapter II - Section 2.2 for description of different model types).

> *"Real scientific progress could not happen without daydreaming: intellectual research and logical planning are essential for the making of art."* (Ede 2005, p.2)

The methods of art and science are not completely dissimilar both rely on objective and subjective processes. Even though reason and logic play an important part in the scientific method, it comes as a surprise to learn how much scientists need to see or visualise ideas in order to form understanding (Ede 2000, p.21). Art not only can visualise the scientific ideas but it also creates emotional responses, communicating to audiences through meaningful sensorial experiences in the form of practice-based artefacts.

> *"Meaning depends on countless variables. However, the increasing predominance of science and technology in our daily lives is bound to provide a stimulus for new art and its pronouncements are already being embraced with interest, intelligent questioning and subjective reinterpretation. These are two quite different forms of knowledge, not reconcilable, but mutually curious to each other and as individuals we can accommodate both simultaneously."* (Ede 2005, p.180)

This mutual curiosity enables these two different disciplines, art and science, to form valuable connections through a collaborative process, leading to the dissemination of new knowledge and insight which produces impactful experiences for individuals and communities. Here the focus is on the value of this interdisciplinary research, where art and science unite to explore the affordances of each discipline; the purposeful acts of these disciplines. These affordances allow each discipline to negotiate the meaning of their actions to an audience. This interpretive affordance is very familiar to artists, negotiating meaning

between artist and audience is central to artistic practice (Mateas 2001). In the case of the practice-based research presented here the audience consists of: scientists, artists, general public, commissioners and funders.

The text in Volume I considers my own perspective on my interdisciplinary experience, taking the reader on a reflective journey behind the scenes into the world of art and science cross-disciplinary research.

1.1.2 Research Questions

The interdisciplinary practice that has been conducted within this inquiry, responds to a number of investigatory research questions. The aim of this artistic research is to address wider concerns regarding the connections between human and environmental health. Central to this body of practice is the consideration of aspects of the scientific research that remain oblique to the central motivations and practices of the scientists but that are vital to their personal engagement with their subject area. The four interdisciplinary practice-based projects that form the portfolio, refocus on these less contextualised aspects of scientific practice, providing a sensual awareness of highly technical scientific research. The *aesthetic model* within this inquiry responds to the following research questions:

- Can expressing oblique scientific research, through the creation of a visual aesthetic artefact, reveal hidden scientific processes?
- Can we maintain the integrity of the art through these interdisciplinary projects?
- Can we create an interdisciplinary artefact that addresses the scientists' sensibilities?
- How can sensual aesthetics in art address challenges of both our bodily and environmental health?
- What is the value of aesthetic expressions of science?

1.1.3 Aesthetically Expressing the Science

This art and science interdisciplinary inquiry embodies the science as visual *aesthetic* expressions, in the form of three-dimensional computational landscapes. Bell (2012) defines the term 'aesthetic' as coming from the Classical Greek words *aisthanesthai*, to perceive, and *aistheta*, things perceived. Here, my body of practice-based research, is concerned with how an artistic *expression* can create *sensual awareness* of the science. This creates a new perceptual experience, for an audience, of the hidden underpinning scientific computational models and science research. In this context my interpretation of *sensual awareness* is where the art is stimulating the audience to become aware of the embedded science through an emotional experience through our different senses.

> *"Even at the movies our vision and hearing are informed and given meaning by our other modes of sensory access to the world: our capacity not only to see and to hear but*

> *also to touch, to smell, to taste, and always to proprioceptively feel our weight, dimension, gravity, and movement in the world."* (Sobchack 2004, p.60)

This allows for the audience to gain from a heightened sensorial state where the body and mind of a viewer of the art is transported into the visual expressive world. Using the medium of computational art, Boredomresearch have created aesthetic expressions that have triggered audience responses to the science such as: "*beautiful"*, "*hypnotic"*, *"mesmerising"* and *"captivating."*[2] This audience feedback uses sensory language to describe how they are perceiving the aesthetic artefacts, showing their awareness of the content through a sensorial response. As Sobchack (2004) states cinematic works have the capacity to enable an audience to feel the world we see and hear onscreen, with the capacity to 'touch' and 'move' us offscreen.

By bridging art and science, we can combine the language of objective and subjective and create a sensorial perception of the science through the visual aesthetic expression. This allows an audience to experientially engage with the science content, an experience that goes beyond what we would perceive from viewing the scientific research in isolation. If art is to be a sensual experience it needs to go beyond the orthodox and pragmatic as G.W.F Hegel (1973)[3] reflects in his lectures on aesthetics; art needs to go beyond everyday life *"If poetic expression is to arouse any interest it must diverge from that ordinary speech and be made something fresh, elevated, and spiritual."* Hegel (1973) reflects on the world of science, where data has become the "*prosaic speech of everyday life,"* an ordinary speech that is logical, systematic and comforting with its facts and figures. By creating interdisciplinary computational art, we can augment pragmatic scientific data and produce as Hegel (1973) describes in his reflection on poetic expressions *"a spiritual product"* created from *"an artist's tranquillity and take form in the mood of a seer with a clear vision of the world."*

The practice-based artefacts presented in this thesis are visual *expressions,* embodying my perception of the scientists' observational and sensorial experiences of their scientific material. The artefacts are defined as an *expression,* rather than *visualisation* as this later term firstly gives the impression that this method is just relevant to the optic sensory channel (Hinterwaldner 2017) and secondly within the scientific

[2] Some terms collected from audience feedback during the exhibition of *AfterGlow* from 2016-18 and *Dreams of Mice* in 2015.

[3] The G.W.F Hegel citations have been referenced from "Aesthetics: Lectures on Fine Art," Vol. 1 that has been translated by T.M. Knox in 1973. The originals were edited by Heinrich Gustav Hotho who published an edition of Hegel's lectures on aesthetics based on a manuscript of Hegel's apparently now lost as stated on url: https://plato.stanford.edu/entries/hegel-aesthetics/#HegTexLecAes [Accessed 30 December 2019]

realm the output from the visualisation process can be primarily for the purpose of objective communication. Sack (2011) critiques the aesthetics of information visualisation, and what is the artistic value of works produced in this domain. He reflects on the concept of 'anti-sublime' in the context of visualisation, stating that artists-designers who visualise information in this way are usually described as scientific illustrators. He then further argues how scientists and engineers need to move away from perceiving artistic data visualisation as an exercise in "*beautiful image making*" or making the information more data "*friendly*" or "*easy*" (Sack 2011, p.125). Sack (2011) concludes that most artists and designers are unsatisfied with this method of information visualisation. In this body of research, a clear distinction is made, by using the term *expression*, as my concern is in creating a sensorial experience of the underpinning scientific research that moves away from being a scientific illustration. The artistic interdisciplinary practice model that I have devised to create these artistic expressions is the *aesthetic model* (see Chapter II, Aesthetic Model, Section 2.2.2, p.44 for definition). The act of producing visual artistic expressions of the science, leads to augmenting and generating new sensorial understanding of the scientific data and research, both for the artist, scientist and for a public audience. In the final practice-based artefacts, biological patterns emerge over time to create a sensory perception of the scientific research, one where abstract scientific data becomes a visible tangible entity.

Figure 1: *Black Shoals: Dark Matter* by Lise Autogena and Joshua Portway (2015) Image credit: Portway, 2016

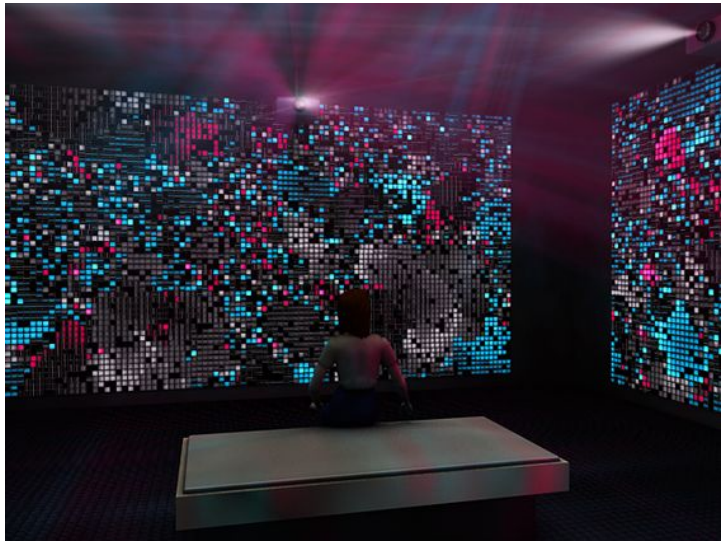


Figure 2: *Flicker* by Jon McCormack and Oliver Brown (2010) Image credit: Jon McCormack

1.1.4 Complexity Through Computation

Scientists use computation to create computer-based models to generate insights and knowledge on our body and world. I have been using the same tools but not to generate insights alone but to create visual expressions of the mechanics, movement and behaviour which can be observed in these scientific computer-based models. In this body of practice, computational technology is being utilised as the primary medium for the execution of the artefacts. Using this medium enables a common language between the artist's and scientist's practice. Often my art and science interdisciplinary process commences with observing the scientists' computational models, utilising these as a vehicle to appreciate the mechanics and behaviour of our biological world. As Manovich (2002) states utilising the power of computation, artists can explore and express data and complex scientific mechanisms, enabling visualisations to be created which are interactive, animated, running in real-time and data can be mapped from one type of representation to another bringing it into the visual domain. The aesthetics of the expressions presented in this body of research provides a visually stimulating experience of complex scientific mechanisms; providing a visual enrichment of the underpinning scientific data and models.

There are many contemporary artists working in the field of computational art, incorporating complex scientific principles, exploring artificial life and generative mechanisms to create aesthetically

stimulating visual artworks. Artworks such as *Black Shoals: Dark Matter* (2015)[4] by Lise Autogena and Joshua Portway have enabled stock market trade transactions to become a visually stunning full dome planetarium of stars, creating an immersive visualisation of the lifeless data (see Figure 1). Jon McCormack and Oliver Bown artwork *Flicker* (2010)[5] provides a visual and acoustic experience of the patterns and forms emerging from fireflies' complex behaviour that allows movement dynamics to be visible (see Figure 2). The underpinning data of all of these artworks are experienced using the same methodology, through the artists' custom generative software that runs in real-time, allowing the art to express the data dynamically, where shifting complex patterns emerge when viewed over time. This adds value to the art by providing a temporal element to the artefact, which is indeterminate and where each viewer will have their own unique sensorial experience of the artwork. Scientific data is also a temporal process, taking time to collect, collate and compute, however the final approach of science communication is to represent this data from an objective perspective.

My practice-based research also uses the medium of generative art, combining different processes of real-time computation and animation, to create dynamic visual expressions of elements within biological systems. The four artefacts within this research compendium are all artworks that have been created using computation, they all contain underpinning scientific data which has materialised from in-depth scientific research studies. *Dreams of Mice* and *AfterGlow* both exist as computational artworks which run in real-time, where an audience can experience the underpinning artistic computational model running live. The scientific data that is underpinning both these artefacts is intrinsic to the final visual expressions, for example if the data files were removed the artefacts would no longer function. *Call of the Silent Cell* and *In Search of Chemozoa* are both moving image video artworks that include film sequences captured from our custom-built real-time software. In the *Chemozoa* project a simulation was created in a game engine and then both myself and Smith captured the film footage live, similar to how a documentary film-maker would capture footage of nature in the field.

This body of practice expresses the complexity of scientific data, showing different states which shift and change over time. Collectively myself and Smith develop a library of three-dimensional environments and biological forms which change their appearance or display to show different scientific states and mechanisms. The methods used to express

[4] This artwork was viewed in the *Big Bang Data* exhibition at Somerset House, London (Dec 2015 - March 2016). Access details on the exhibition at: http://bigbangdata.somersethouse.org.uk/ [Accessed 23 February 2022]

[5] Further information on this artwork can be found at: http://jonmccormack.info/artworks/flicker/ [Accessed 20 December 2019]

these changing states are displayed dynamically through changing: visuals, light, colour and pattern. We use the medium of animation, to enable the temporal elements of the properties and mechanics in scientific research to shift in time and be made visible. For example, firing neurons would be too fast to be humanly perceivable, the animation timing in *Dreams of Mice* is slowed down from real-world time so the neuron firing pulses are made visible through the light animations. In contrast, *AfterGlow* quickens the different infection states from: susceptible, exposed, infectious and recovered to allow spectators to observe an infection transmission scenario which is invisible to see in the real-world.

Manovich (2002) discusses how many artworks driven by data are being created to make sense of our complex world and their unique role is to show us other realities embedded in our own, to show us the ambiguity always present in our perception and experience. In this body of research, the computational artefacts provide a new creative expression of the underpinning scientific research, where the scientific models can be perceived through an aesthetically sensorial experience. Scientific models are finite, even though they run for thousands of iterations, they always come to an end, often when the model is ready for the next stage of the scientific process or needs to be tweaked to test new parameters. Heinrich reflects upon "*artistic freedom"* (Heinrich 2016, p.77) providing artists with the tools to be able to explore the scientific data in a multi-layered approach; this can be an art experience that lasts for years, being exhibited in multiple public venues, allowing the underpinning scientific research to be exposed to a diverse audience.

1.1.5 The Start of Bridging Art and Science

This body of practice-based research was produced in collaboration with Paul Smith, within the artist collective Boredomresearch, which we founded in 1999. It commenced with both artists having a desire to shift from linear artworks, at the time we were producing short films, to develop our work into exploring non-linear systems using computational technology. I have always had a passion for the natural world and the computer as an artistic medium presented an opportunity to capture the breath of the diversity and emergent properties present in biological forms and environments. By using technology, we could create a body of work that runs in real-time where an audience can encounter unique instances, within these artworks, similarly to phenomena experienced when one is immersed in viewing forms, movement and behaviour within a natural environment. It was the beauty and poetics that emerged from observing natural encounters that inspired me to create visual expressions of imagined worlds that contained life-like forms generated by computer programs. Through our practice we were interested in considering diverse forms and the interactions between things and the computer was the perfect tool to provide a unique affordance to create

expressions of environments similar to what can be found in nature. We started generating three-dimensional landscapes on a micro and epic scale so audiences can experience the feeling of intrigue and wonder that you may experience in a real physical landscape environment.

Boredomresearch practice first started with considering diversity in nature but this led to us becoming aware of the fragility of these ecosystems. In works such as the *Lost Calls of Cloud Mountain Whirligigs* (2009-10) and in *Fragments of Lost Flight* (2013) we were interested in generating forms that were ethereal and compelling to observe but also allowed the viewer to experience the loss of that form when it no longer existed. These computational artworks were more complex than our early artworks, which involved producing our own visual anatomical grammar and then creating large libraries of three-dimensional assets which were recomposited together to create a vast diversity similar to the range we might experience with diversity in nature. A connection with the diversity that exists in the natural world and that which can be created algorithmically was explored in *Lost Calls of Cloud Mountain Whirligigs*, inspired by Lepidoptera markations as well as the loss of songbirds (see Figure 3). The *Whirligigs* all have a unique song and set of generated patterns on their body parts. At the end of their life, they fly off never to be seen or heard again. This is the same for *Fragments of Loss Flight* once the fragments of wings are generated, they then dissipate and are never seen again. This became a loss to us as

Figure 3: *Lost Calls of Cloud Mountain Whirligigs* (2010)
Image credit: Boredomresearch

artists, as there were some forms that were exceptionally striking or unusual, so much so that we couldn't resist collecting the generated forms and subsequently producing prints that contain a selection of our chosen forms. As part of the development of these projects I was conducting some research on the Lepidoptera collection at the Hampshire Cultural Trust, Chilcomb House, Winchester UK in 2010. Exploring the structure and forms of the wings and their colour, iridescence and patterns and producing detailed microscopy images for reference. Here, I experienced my first encounter with a retired biologist who happened to be working with the collection during my visit. He was very knowledgeable on the butterfly and moth specimens as he had been maintaining and archiving the collection. This enabled a fascinating insight into the collection which went beyond just observation where the biologist knew intimacies of particular specimens and could provide a narrative on their habitat, environment and evolution, enabling a much deeper appreciation of the cabinets of preserved specimens. It was this encounter that pushed me to seek other science collaborators and partnerships. This exploration into diversity and fragility provided a rich terrain to explore within a scientific collaborative process as it can be considered from the perspective of both the health of our body and our environment.

1.1.6 Contribution to Co-Authored Artefacts

My artistic practice has utilised computational processes to create new artistic expressions which are influenced by the mechanics and visual qualities of the biological world. I have been a professional practitioner in this domain, within the field of new media art, which I refer to here as computational art, for over twenty years. The core body of practice-based research presented in this compendium was conducted during my position of Research Lecturer in Computer Animation at Bournemouth University, UK from 2005 to 2020.

Every computational artwork that is created by Boredomresearch is layered with different aesthetic and technical components, developed in collaboration with Smith, including: custom developed programs, sound and lighting design, three-dimensional models of environments and biological forms, cinematography, graphic user interfaces and interaction design, libraries of animations and images for texturing the models and environments, to name but a few. Each artwork will have a new set of technical hurdles to achieve which needs designing and prototyping in software and in customising the hardware in how it will be installed or displayed in the final presentation of the artefact.

I have contributed to all areas of Boredomresearch's projects research and development and production. My expertise in this artistic

collaboration is in the areas of artistic direction and production including: composition, visual components of environment and assets, exploring the emotion and ambience of the final artefact and designing interactive methods for public engagement. My core individual contributions to the practice-based artefacts submitted are: artistic direction and concept design (including: developing a strong aesthetic identity for each project); research and experimentation of appropriate methodologies both technically and aesthetically for production (including: animation, cinematography, sound design and three-dimensional graphics); producing three-dimensional components (including: biological forms, environments, composition, lighting and textures) and researching the scientific techniques and processes. Please reference the ‘Methodology and Approach’ sections in Volume II: Portfolio of Practice-Based Artefacts for a further breakdown of my individual contribution for each artefact.

1.2 Introduction to Key Terms

1.2.1 Practice-Based and Practice-Led Research

There are four artefacts presented here that have been produced in the realm of practice-based research. Candy and Edmonds (2018) state that making an artefact for practice-based researchers is pivotal, and the insights from making, reflecting and evaluating may be fed back directly into the artefact itself. Practice-based methodology becomes an original investigation undertaken in order to gain new knowledge, partly by means of practice and the outcomes of that practice. The art and science interdisciplinary practice that is examined in this thesis has been embedded in the creation of the artistic practice-based artefacts. This leads to the production of a new aesthetic expression of the science, instilling a deeper appreciation of the scientific complexities underpinning the artworks.

> *"A basic principle of practice-based research is that not only is practice embedded in the research process but research questions arise from the process of practice, the answers to which are directed toward enlightening and enhancing practice."* (Candy and Edmonds 2018, p.63)

This body of artistic practice has been achieved through an exploratory and reflective process, where each development stage of the artefact production entails new research questions to be posed to the scientists. This exploratory practical process has led to new insight into art and science interdisciplinary practice and the research presented within this context is in the realm of practice-led. Both the practice-based and practice-led research that is analysed here is underpinned with scientific principles and processes that have materialised from in-depth art and science collaborations. The practice methods that I have utilised in this body of research are examined in further detail in Chapter II, Research and Practice Methodology, p.32.

1.2.2 Art and Science Interdisciplinary Research

Yang (2012) critiques how artists and scientists still put a lot of energy into keeping their disciplines separate from each other and how terminology such as *sciart* is creating an ambiguity where a project is *"neither quite this nor quite that,"* further reflecting on the framework of the institutions that support both art and science disciplines, arguing if we are to create *"uncharted kinds of meaning"* the institutional framework may need to change to support *"meaningful practices premised on uncertainty to flourish."* Similar to all genres of art, when they are in their infancy, the theoretical framework is shifting and still shaping the emerging art and science cross-disciplinary field. There are still different terms being coined to describe interdisciplinary art and science practice such as BioArt, Artience and SciArt. Similarly, to Yang

I also feel that there is ambiguity in these terms, so within the context of this thesis I do not reference my research under these umbrella terms. However, I do refer to my research as interdisciplinary across the disciplines of art and science. Lury (2018) provides a succinct definition of interdisciplinarity:

> "*Interdisciplinarity is characterized as interaction across and between disciplines. Importantly, this interaction is not oriented toward either a synthesis or a disappearance of disciplines. Instead, interdisciplinarity emerges through interferences between disciplines and between disciplines and other forms of knowledge."* (Lury 2018, Introduction, para.3)

Through collaborating with different researchers that are working with different materials and content this enables the specialist to reflect on their own established practice. Both artists and scientists can cause interferences to normal daily practices. One method that is utilised is by asking questions about each other's disciplines, for example, I have posed the question of how scientist's techniques and processes are being effectively utilised? This can lead to new approaches being explored in each discipline. Piirma (2014) media artist and curator reflects on interdisciplinary processes and how adaptation can emerge from this exchange:

> *"In the case of interdisciplinary research, the research questions and objectives of a different field are adapted to one's own field; thus, interdisciplinarity entails an approach which has the potential to create new disciplines."* (Piirma 2014, p.25)

Polymathic approaches allow for connections to be made which may not usually happen if working in silos. This is extremely beneficial for both the artist and scientist, enabling deeper reflections on their own practice and leading to novel innovative concepts to materialise.

1.2.3 Aesthetic Emotion

Dewey (1934) states in relation to the experience of an art piece, how unfortunate it is that there is no word to describe the combination of *artistic* and *esthetics*. He reflects on the importance of incorporating both these elements in a work of art. Allowing the experience to become receptive, where a beholder creates his own experience through surrendering to the art. It is this complete immersion that allows a viewer of art to have a distinctively aesthetic experience.

Carroll (2020) reflects on how some philosophers of art have argued that there is a specific emotion that is aroused when appreciating art, defining it as an *aesthetic emotion*. Stating that this aesthetic emotion, is by definition, distinct from common emotions, where common emotions are those that shape everyday life, the very thing from which aesthetic emotion is said to afford escape. Highlighting Clive

Bell's theories in the publication Art (1914), Carroll states how Bell contends that significant form is precisely that which arouses the aesthetic emotion in everyone who knows about art.

> *"It is an experience of being transported from the world of practical activity and human concerns where the expectations and worries of our mundane existence are suspended and we transcend the stream of everyday life. We are, so to speak, lifted above it."* (Carroll 2020, Chapter 29, Section 2, para.3)

Carroll (2020) questions Bell's argument further considering how external influences, like events represented within a painting, could trigger an emotional response to something that sits outside the artwork. Providing a more embodied response to emotion where Carroll suggests that aesthetic emotion and common emotion can both contribute to our appreciation of art.

> *"An emotion is a type of feeling that is distinguished from feelings that arise from sense perception, sensual feelings like pleasure, moods, and life-feelings like fatigue."* (Calcagno 2020, Chapter 9, Section 1, para.1)

Calcago (2020) critiques how sense perception comes to consciousness as largely being lived in and through our body. Manifesting through our own individual personal feelings produced by sense perception, sensuality, mood and life feeling. In this body of research, the aesthetic emotion arises from the perceptions of both the artist and the scientist and the observations and studies that both practitioners conduct of their internal world (i.e., in their scientific laboratories, artist studies and their imaginations) and the external world, the outside environment (i.e., scientific fieldwork locations, film locations, forest environments etc.) The aesthetic emotion is often established in an arts and science interdisciplinary process through the artist interfacing with the science on an aesthetic level. The artist provokes the scientist to convey emotional perceptions of their research by posing deep questions where the responses will be about the scientist's feelings on the science.

1.2.4 Body as Landscape

The practice-based artefacts presented in this thesis demonstrate how visual aesthetic expressions can provide a sensual awareness of challenges 'on' our environment. It is with deliberate intent that the word 'on', rather than 'in', has been chosen within the title of this thesis. As it conjures that these challenges come from outside rather than within the environment. Here all of the artefacts explore challenges of the Anthropocene, with the environmental concerns addressed all imposed by human impact. Seen from the perspective of the environment within our body and within our external natural environment. As Bell (2012) states using the world 'landscape' has a utility and flexibility that is

easier to understand as an everyday reality than environment, defining it as:

> *"In the sense that environment includes everything, the landscape becomes that part of environment which is the field of our present actions and its boundaries are defined by the limits of our perception. Landscape is that part of environment that we can engage with at a given time, so linking it to the original use of the word and its modern embedding within the wider sense of environment"* (Bell 2012, p.66).

Landscape within this context is a full encompassing term to include all of the environment that is perceived by the viewer when observing these artworks. On first viewing the artefacts presented here they can be seen as computer generated three-dimensional landscapes. Unlike traditional landscape paintings they do not depict just one view of the environment but multiple camera framings have been utilised. At times the viewer can be engulfed in the visual materiality of the science. Bell (2012) discusses the perception of beauty within a landscape and how during a freer aesthetic experience the observer and the world become one:

> *"However, if during the act of perception of beauty, our mental or physical state requires no control or personal investment of interest in a scene, we are in the right frame of mind to achieve a pure aesthetic experience."* (Bell 2012, p.74)

As seen in *AfterGlow* when the infection is at its most dense, when there are millions of mosquitoes present, the camera takes the viewer through the expression of the disease, where it feels like one is walking through a snow blizzard. Here our senses are overwhelmed by the volume and sound of the mosquitoes. As Bell (2012) describes how this becomes a sublime experience where our senses are swamped by the magnitude of a landscape that is difficult to comprehend and which suggests limitlessness. This sensual appreciation of our landscape is also present in the artefacts *In Search of Chemozoa* and *Call of the Silent Cell* where the virtual camera takes the viewer on a journey inside the fictional *Chemozoa* organisms and through the cellular world of a gastrointestinal tract. In all of these examples the cinematography is deliberately fluid to allow for the transition between the body and its external environment to be seamless.

Maurice Merleau-Ponty, a phenomenological philosopher, explores how we perceive through our bodies and with other embodied bodies. He regards the body as our point of view and as one of the objects of that world. Proposing how the body becomes a shifting entity, where from an experiential perspective it is difficult to appreciate where the body begins and ends.

> *"I only speak of my body as an idea, of the universe as an idea, and of the idea of space and of time. Thus is formed "objective" thought (in Kierkegaard's sense) – the*

> *objective thought of common sense and of science – which in the end makes us lose contact with the perceptual experience of which it is nevertheless the result and the natural continuation"* (Merleau-Ponty 2012, Part One: The Body, Section B, para.1).

Merleau-Ponty (2012) argues the importance of rediscovering objects at the core of our experience and through our lived body. He argues how our body can withdraw from the objective world. Through this act we can unite ourselves to our surroundings and be able to reveal the perceiving subject as well as the perceived world. We do not experience any movie only through our eyes, we see and comprehend and feel films through our entire bodily being, informed by the full history and carnal knowledge of our accultured sensorium (Sobchack 2004). A viewer is also not confined to what they see in a glance, our scope extends to that which is hidden (Noë 2008). As an audience views these artistic visual expressions of the science the camera takes a journey through the landscape where a spectator can perceive all different angles of the environment and imagine elements that are hidden from the view and elements that go beyond the surface. In these visual expressions the landscape becomes body and the body becomes landscape. Where the film experience is meaningful not to the side of our bodies but because of our bodies (Sobchack 2004).

1.3 Introduction to Artistic Research

1.3.1 Contextualisation of Practice-Based Portfolio

> *"In seeking serenity we find ourselves in motion…Sacrificing the sanctuary of the familiar, to imagine a place where health is maintained both in our bodies as well as the spaces through which they wonder. Searching for stability we push against the tide maintaining a restless balance between uncertainty and hope"* (Isley and Smith, 2020).[6]

It is this fluctuation between uncertainty and hope, instability and stability that is present in the four practice-based artefacts that culminate in Volume II. All of these practice-based artefacts feature elements of the body and are seen from a landscape perspective, where you perceive the landscape as body and the body as landscape. It is this merging of the boundaries between what we see as body and what we see as landscape that is an integral component of these artefacts. This body of work provides materiality to matter that cannot be seen. In *AfterGlow* millions of mosquitoes become visible and leave colourful, spiralling flight paths in the wake of invisible macaques that are wandering on the island. In *Dreams of Mice* animated pulsing lights are displayed to the slowed down time of neurons firing in a dreaming mouse. *In Search of Chemozoa* takes the viewer on a cellular journey where we are immersed in the visual spectacle of cell dynamics, from within the body of the organism, and, from outside where we see the organism as a whole in its environment. In *Call of the Silent Cell,* we are taken on a journey through a winter forest, with the idea of an impending storm looming, but it gradually emerges that this is a cytokine storm inside the body; an over-reaction happening within our immune system. This allows the viewer to consider the symbiotic relationship between the ecology of our body and the natural world (presented as landscapes within these artefacts). All of these artworks create an animated aesthetic expression of biomedical research, where we have utilised a poetic evocation, to share some of the apparent relationships between ways of thinking about health at the microscopic level (from a cellular perspective) and from an environmental perspective.

[6] Written by myself and Paul Smith in 2020 for our solo exhibition *Restless Balance* press release in Arizona State University, Herberger Institute for Design and the Arts, USA. Accessible at: https://herbergerinstitute.asu.edu/news/asu-art-museum-announces-restless-balance-new-exhibition-boredomresearch [Accessed 23 February 2022]

1.3.2 Introduction to the Practice-Based Artefacts

Below is an introduction on each of the four practice-based artefacts that are included in the Volume I portfolio to provide a brief contextualisation of the core themes in relation to this thesis.

Artefact I. Dreams of Mice (2015)

Dreams of Mice is a collection of expressions of neural activity recorded in dreaming mice, rendered in real-time, using a three-dimensional game engine. Brain activity during sleep reveals that far from downtime, sleep is complex and beautiful. This artefact was developed from research exploring the interaction between environmental factors affecting sleep and human neurological disorders. *Dreams of Mice* considers the increased control, management and disruption of sleep behaviours. Boredomresearch collaborated with scientist, Dr. Vladyslav Vyazovskiy (investigating brain activity during waking and sleep) and scientist, Dr. Peter Oliver (researching the relationship between sleep and mental health) from the University of Oxford to produce this artefact to reveal the intriguing beauty of slumber in an aesthetic expression driven by the firing neurons of a dreaming mouse.

Figure 4: Dreams of Mice (2015)
Image credit: Boredomresearch

Figure 4: AfterGlow (2016)
Image credit: Boredomresearch

Artefact II. AfterGlow (2016)

An award-winning computational practice-based artefact, created in a three-dimensional game engine. *AfterGlow* presents a new expression of a malaria infection scenario, placing the audience in the mosquito's perspective. The infection is left in the wake of wandering macaques as they search the island for food, revealing the intimate relationship between disease and its environment.

The spectator is taken on a real-time journey through the eyes of an autonomous camera which traverses the island following the infection scenario; from clustering luminous spiralling cells of colour to black turbulent infectious spirals. Where the infection is most dense, we see a blizzard of disease, vividly expressing the complexity of this dangerous scenario. *AfterGlow* was developed in collaboration with Dr Paddy Brock, a mathematical modeller at the Institute of Biodiversity Animal Health and Comparative Medicine at the University of Glasgow.

Artefact III. In Search of Chemozoa (2020)

This practice-based artefact explores new perspectives in response to the first study of cancer across species, presenting a poetic rendering of an in-silico model organism, called *Chemozoa*. *In Search of Chemozoa* was created in collaboration with Arizona Cancer Evolution Center (ACE), at the Biodesign Institute, USA. The artefact responds to mythical creatures documented in scientific literature to reveal tensions and interconnections between human and planetary health. The multi-channel moving image installation combines computer animation, filmed environments and scientific speculation to weave a poetic narrative that introduces new ideas emerging from cancer research.

Myself and Smith were artists-in-residence at the Arizona Cancer and Evolution Center in 2018 where we witnessed the beauty of the *Placozoa* being studied by Dr. Angelo Fortunato who is developing novel model organisms to understand cancer across species. It was this simple multicellular organism that inspired our imaginary *Chemozoa*, a fictional organism that exhibits all the hallmarks of cancer from birth, in consequence it can only survive in toxic environments that act as an analogue for chemotherapy.

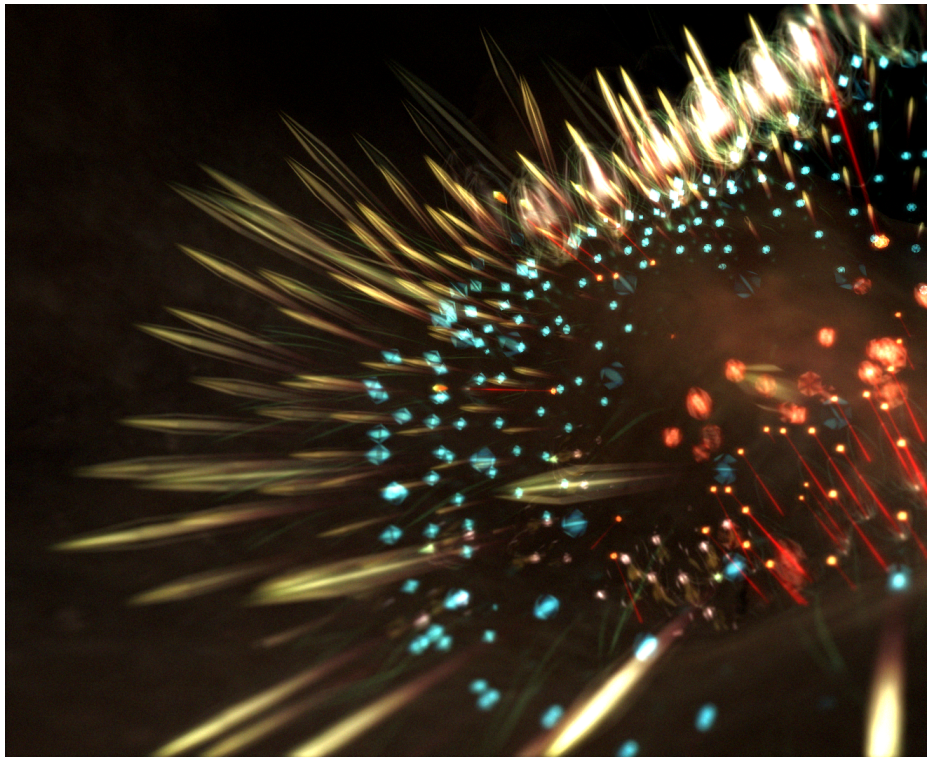


Figure 6: In Search of Chemozoa (2020)
Image credit: Boredomresearch

Figure 7: Call of the Silent Cell (2021)
Image credit: Boredomresearch

Artefact IV. Call of the Silent Cell (2021)

An experimental film of cellular behaviour centred on the interplay between the gut microbiome, the immune system and wider concerns regarding the symbiosis of human and environmental health. The beautiful patterns of nature, as we might experience on a walk in the woods, can also be found in our bodies. *Call of the Silent Cell* gives you the opportunity to briefly enter this magical world as a storm breaks, revealing we are not as separate from nature as we think.

In the film you journey with an old man who wanders through a forest, meditating on the fragility of his body and the environment. A storm arrives, *"not of breath and air but of cells and their signals,"*[7] revealing a disturbance in the body, an immune system in overdrive. The old man emerges from the storm, gaining a new wisdom that his bodily health is deeply intertwined with the life of the forest.

The film reflects on the latest insights revealed by single cell analysis and was produced in collaboration with Human Cell Atlas members, Dr. Marcin Pekalski and Dr. Melanie Dunstan, based at the Wellcome Centre for Human Genetics at the University of Oxford.

[7] A line from the film's narration, written by Isley and Smith, Boredomresearch in 2021.

Chapter II

RESEARCH AND PRACTICE METHODOLOGY

2.1 Research Methodology

2.1.1 Practice-Based Research Process

The methodology used here for my artistic expressions is practice-based research, where the concepts are explored through making and practice itself is embedded in the research process (Candy and Edmonds 2011). Visual cultural artefacts have been produced as final renditions of my investigative and exploratory interdisciplinary process which express the scientific computational models and research.

> *"Thus, the research is dependent upon the creation of an artefact and it is difficult, if not impossible, to understand its significance without direct experience of the artefact itself."* (Candy and Edmonds 2011, p.36)

Alongside this thesis, Volume II consists of a portfolio of my four practice-based projects to enable an understanding of how my practice-led research has been applied in the final visual expressions. The four artefacts within this portfolio have been extensively exhibited in international exhibitions in galleries, museums and/or festivals.

> "*Practice-led research is intrinsically experiential and comes to the fore when the researcher creates new artistic forms for performance and exhibition*." (Haseman 2006, p.100)

Exhibiting the work in multiple contexts allows for a diverse audience to respond and engage with the final moving image pieces. This research unfolds through *"making"* (Haseman 2006) and *"for the research to be considered a 'contribution' and even 'innovation' in a field, it must have been shared with an appropriate community of practice"* (Lawson 2012, p.2). The practice-based research here has been applied to the wider community, both within an art and science academic arena and within a public exhibition context. The work progresses and adapts with each exhibition. As different venues can provide new challenges, with differing space and equipment requirements. Artistic directors and exhibition curators may frame the artworks differently depending on their thematic exhibition contextualisation. Art which is driven by computational technology can be in a state of flux where adaptations are made for each exhibition. This continual 'making' process allows for other new opportunities for exploration, reflection and evaluation and the role of the artefact is viewed as central to this research process (Candy and Edmonds 2018, p.66).

2.1.2 Art and Science Interdisciplinary Research Process

David Abram, an ecologist and philosopher who has written extensively on the connections with phenomenology, ecology and environmental issues describes how science consistently overlooks our ordinary, everyday experience of the world. Abram (1996) critiques how our direct experience is necessarily subjective and relative to our own context.

> *"Despite all the mechanical artifacts that now surround us, the world in which we find ourselves before we set out to calculate and measure it is not an inert or mechanical object but a living field, an open and dynamic landscape subject to its own moods and metamorphoses"* (Abram 1996, p.47).

It is my belief that the majority of scientists do not overlook subjective experiences; it is just that the context of the science world has enforced this way of communicating the research. It is therefore vital that artists can be the catalyst to embody this heightened sensual appreciation of science that has been gained by years of scientific study. An art and science interdisciplinary process, establishes a microcosm, where artistic and scientific creativity can become one, allowing artists to explore new ideas of balance and stability in a world increasingly destabilised by human activity.

The art and science interdisciplinary process that has been undertaken for this body of research, commenced with establishing collaborative science partners that are adaptive to the process being exploratory, allowing for the concepts of the final practice-based artefacts to materialise from the collaborative process. This is instrumental in forming a successful interdisciplinary collaboration where the science partner is responsive to the potentials that emerge from the process of this interdisciplinary collaboration. It is important that the science partner is not in the mindset that the artist is working in the service of science. For example, where the artist creates an image that beautifies or illustrates the science research and is disseminated through the standard science communication channel. If the art concept is still flexible and not prescriptive, before the interdisciplinary process commences, this enables the artistic concept to emerge from the collaborative process. This can be challenging from an arts curatorial standpoint as many funders have the desire to know specific outcomes even from the early stages of a project's development. However, leaving an openness at the beginning of the project to what will be conceived through this interdisciplinary process allows for a true art and science collaboration to unfold. The artistic research and computational model then emerge from the artist's perceptions during the interdisciplinary process, leading to a genuine aesthetic-emotional response. As Monica

Bello (Creative Capital 2022)[8] Curator and Head of Arts at the European Organisation for Nuclear Research (CERN) in describing their art and science program mentions how their aim is not to look for a single outcome from an artist-in-residence. Bello (Creative Capital 2022) believes that the outcome needs to grow with the system that is created when the artist is in residence at the science institution. She describes the sublime feeling for an artist when they first arrive at CERN, this huge iconic institution, where the scientists are investigating big questions about the construct of the universe. She further describes how the artists feel like they have no tools in this context and how they have to build meaning through the experience of being in this environment. Bello sees her role as nurturing this valuable arts and science environment to enable new perspectives with ecological views to be created and allow the scientists to escape from their discipline. Voss (2016) discusses Bill Fontana who was a CERN artist-in-residence in 2013 and how CERN provided an environment away from the egos the artist encounters in the art world, where he felt he "was free". A new environment to conduct your practice can be very liberating where it allows an artist to also perceive their practice from a different standpoint.

This interdisciplinary process goes beyond just asking a scientist for some specific data or resources, it is not just coming up with a design or solution that will act as an illustration or representation of the science. It is a method to find the truth and heart of the science, not the science that is mediated by a political, institutional or media framework but in the context of providing an *aesthetic model* (see Chapter II, Section 2.2.2, p.44 on the aesthetic model). This is achieved by being with the scientist and being immersed in their daily environment and amongst their tools and material. Truth comes not just from reading written communication on the science but primarily from first-hand perception of the science and this takes time for an artist to observe, hear and become aware of the intricacy of the scientific research. It is only when you see the scientist working naturally in their environment, when it is not staged for a public tour, that you can experience the true sensual awareness of the scientific process that is happening. This enables an authentic collaboration where you can open up a channel of dialogue which reveals transparencies that are beneficial to both the artist and scientist. As Anna Dumitriu, a British contemporary artist, renowned for her art and science interdisciplinary practice, states:

> *"When artists engage at a deep level with an area of research they have the possibility to explore and critically*

[8] Monica Bello Director of Arts@CERN stated this in the online panel discussion 'Creative Capital Event - Ecologies of Meaning in Art, Science & Technology Collaborations' on the19th January 2022. Access recording at: https://www.youtube.com/watch?v=6AoDY86uTjc

> *interrogate that field in a number of interesting ways, bringing together aesthetic sensibilities such as beauty or disgust with intellectual complexity."* (Dumitriu 2018, p.83)

A genuine collaboration reveals not only the beauty and poetics of the science but the flaws, problems and messiness of the science. To start a process of critical interrogation the scientist needs to be comfortable with your presence and have complete trust in the potentials of what may emerge from the interdisciplinary process. When the artist engages with the science material at a *deep level* this can reveal new connections that may have been abandoned or disregarded as being significant to the scientific concerns and the scientist needs to be open to present these as options for consideration. This openness allows the artists to bring a broad range of issues to the surface, allowing for dynamic interconnections of different scientific material to be seen from the artist's subjective perspective. This can lead to what Boredomresearch refers to as a 'fictional frontier' where idea or hypothesis generation is more a consequence of imaginative thinking. Imagining things that have yet to be proven, or where the evidence is incomplete. That leads to the artists designing their own speculative fiction that is underpinned by scientific research. We see it as our role to help form those missing links between the kind of science that happens with privileged individuals behind closed doors and other ways of thinking about human or other expressions of human culture that are often impacted by science. We enter a laboratory with our own ideas and areas of interest which then blend, combine and grow during the collaborative process; fed by the imagination and creative thinking of our partnered scientists (Isley and Smith, 2021a).

Applying Forbes (2015) art and science interdisciplinary methodological framework (see Chapter III, Artistic Review, Section 3.1.1. p.49), the *augmentation* process which has been incorporated in my practice-based research is to allow the scientific research to become more compelling rather than just a pragmatic output. One of the *provocation* methods in which I have implemented in my work is *"exploring meaning and implications, not just functionality"* (Forbes 2015, p.334). In regards to *generation* as I see the interdisciplinary process as being exploratory, many questions are raised during the collaboration, enabling new connections to be made that can be through other interdisciplinary project partners. When artists are in residence in science laboratories, they often explore unpublished research that as Forbes (2015, p.334) writes "*is not easily accessible,*" this provides artists with the opportunity to reflect on scientific study that may be in its infancy and can benefit from a creative input into the early-stage design. Discourses which materialise during residencies and periods of collaborative inquiry has enabled "*reflection-in-action"* where an artist

can allow the research to drive the development of the project where it becomes a fluid process of working.

To gain a perception of my collaborative scientist's practice, part of the process is spent interviewing them, visiting their laboratories and meeting them in their research departments to gain an intimate impression of their methodology. This is not a process to become an expert in their field but to form an appreciation of the significant elements of their day-to-day research concerns and unearth what personally drives their scientific research. This enables an artist to truly experience all the nuances of the scientific experiments and fieldwork which is being conducted. This process sometimes reveals areas of scientific focus which are not yet published and areas of concerns which have been discarded due to funding constraints or being difficult to evidence; of which these can be the most stimulating, providing a different angle on more mainstream concerns. This interdisciplinary process can enable artists to gain scientific insight into current concerns such as: technological advancement, climate crisis, planetary health and the effect of the Anthropocene and then address and embed these scientific concerns in experiential artefacts which can be relatable to a diverse audience.

Every collaboration entails a new scientific understanding, involving a new body of practice-based research to be conducted for each project, that entails conducting detailed interviews with scientists on the core scientific principles for each project, as Wilson (2002) describes artists becoming *"knowledgeable commentators"* on the scientific research. It is this collaborative process, with Boredomresearch bridging art and science, that has enabled production of artworks which are multi-layered, enabling effective *"knowledge sharing"* between the disciplines as stated by Forbes (2015).

Art and science interdisciplinary practice also allows scientific research areas which may still be in their infancy to be encapsulated in an artistic artefact which is then rapidly scrutinised in the eye of the public in a gallery or museum. Artists through their interdisciplinary process can notice aspects that have been ignored by scientists (Malina 2011)[9] and *"find very specific areas which do not fit into the usual boundaries of scientific research"* (Piirma 2014, p.25) and also have the ability to *"translate in ways familiar to the indigenous people on the other bank ideas or experiences that have no equivalent"* (Malina 2011, p.6). Science research primarily focuses on finding pragmatic solutions and not on creating subjective experiences. In our daily life we access

[9] Featured in Malina's Leonardo Quarterly Review (Vol. I, No.3, p.6-8) in 2011 that is primarily an editorial on Levy-Leblond's 'Science is not Art' publication. Here, Malina argues that art and science collaboration is like a network of rivers where many boundaries are fuzzy, unlike Levy-Leblond who argues that the disciplines are very different and should be kept as 'two different banks of a river'.

and filter the world through our senses rather than scientific instruments (Malina 2011) the output from interdisciplinary practice enables science to be perceived through the senses.

2.1.3 Evaluation Process

All of the practice-based artefacts presented in this thesis have been exhibited internationally in a broad spectrum of art and cultural institutions. This wide dissemination allows for *"engaging ways to visualize that data, and subjecting it to unprecedented kinds of analysis"* (Wilson 2010, p.182). During the process of devising my artistic concept for an interdisciplinary project, consideration is made in regards to how the artistic endeavour will enable the embedded scientific research to provide a valuable aesthetic experience for my practice, the scientist and finally to a public audience. This audience can be diverse, consisting of viewers that have a pre-existing insight of the science research (i.e. scientists, artists and interdisciplinary practitioners) and the general public which can consist of viewers that are laypersons to the science. Due to the nature of the work bridging art and science, the audience usually consists of artists and scientists that are interested in interdisciplinary methods and implementers (i.e., funders, commissioners, governors) that have a direct interested in the scientific or artistic research for gaining insight for future collaborative programmes.

Once the practice-based artefacts have been exhibited and reviewed a *"reflection-on-action"* can emerge where you can consider the audience engagement and participation with the artwork (Haseman 2006, pp.99-100). In the case of this practice-based portfolio the *reflection-on-action* which has happened has been conducted through: receiving feedback from exhibition audiences, curators and critics; interviewing the collaborative scientists; evaluations conducted by the commissioners or producers and writing co-authored public presentations[10] with the collaborative scientists. All of these evaluation processes are considered within my Analysis - Chapter IV.

[10] Boredomresearch and Dr. Paddy Brock gave a joint presentation on AfterGlow at London Art Science Evening Rendezvous (LASER), London at the University of Westminster (2015).

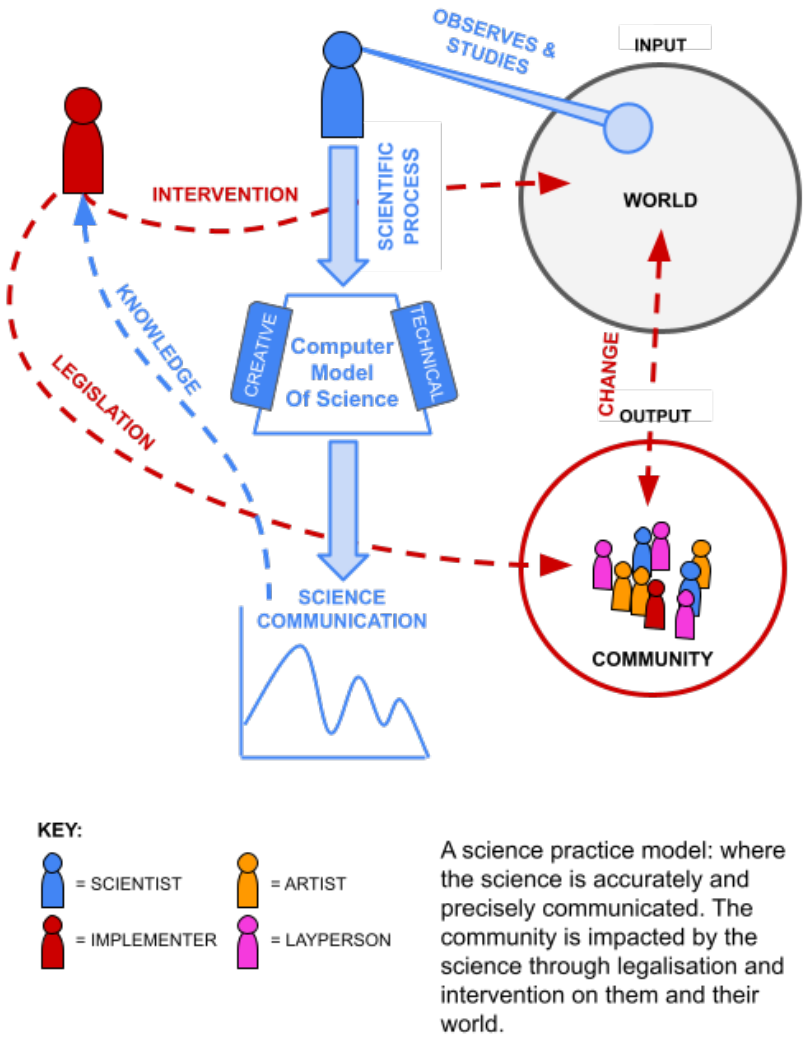
2.2 Practice Methodology

2.2.1 Scientific and Artistic Models

Hinterwalder (2017) when describing the difference between a computer-based scientific model and other models such as 'physical models', 'material models' and 'phenomenological models', uses an example Ian Hacking presents to illustrate two different model types:

> *"Some nineteenth-century physicists made similar hold-in-your-hand models of the inner constitution of nature, models built with pulleys, springs, string and sealing wax. Most generally, however, a model in physics is something you hold in your head rather than your hands. Even so, there is an odd mix of the pictorial and the mathematical."* (Hinterwalder 2017, p.108)

Hinterwalder (2017) concludes from Hacking's illustration that both model types, the physical and mathematical model, stand in close relationship with each other and are held in the scientist's *"mind's eye."* A computer-based model, which I refer to as a *computational model*, also can become a tool to execute algorithmically and procedurally the mathematical principles that are in the 'mind' of the scientist. As Hacking describes, a computational model could be a combination of both a physical model and a mathematical model. A scientific computational model often considers elements that are physical entities, where the primary content has been provided from scientific fieldwork



Schema 1: The Scientific Model (2022)

Image credit: Vicky Isley

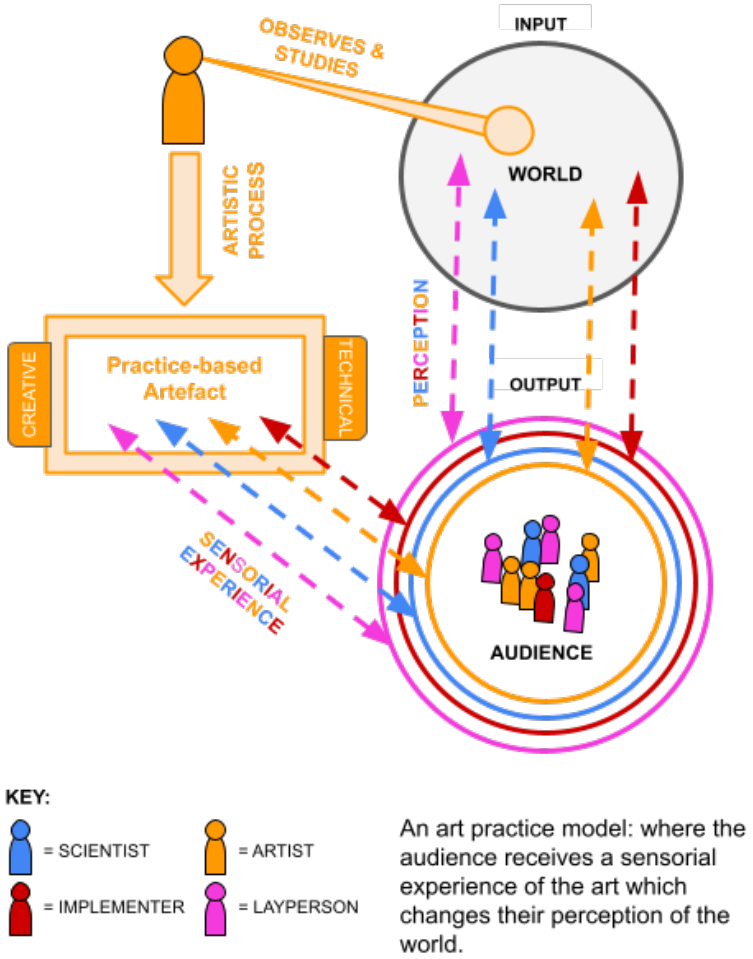
and research material. These computational models are often dynamic and consider spatial and temporal parameters; however, the tangibility of these computational models lies within the virtual realm, usually on a computer in a science research laboratory. The output from these scientific computational models are often decoded and simplified for illustration purposes to communicate to a non-specialist audience.

The *scientific model* (see Schema 1) depicts the flow of a scientist's practice (graphically displayed in blue), where the production of a computer-based model of science is produced which is both a creative and technical process. A non-specialist audience will not usually have the opportunity to see the scientific computational models running live and they will not experience the computer code that is underpinning these models. These components of scientific research are invisible and often only perceived by an audience through a visual representation or description of the model within a scientific paper used for science communication. In Schema 1 the output of the science computational model is depicted as a graph, here this diagram has been simplified, the graph is the icon for all science communication i.e., written and visual representations. This scientific model (Schema 1) shows how science can provide change to a community of people. However, through this scientific methodology the community of people are not receiving any first-hand experiential perception of the science. Science is being disseminated through the standard scientific communication tools. Governance will utilise the knowledge from scientific research to enable legislation and intervention to happen on the people and their environment (see the red graphics in Schema 1 which symbolise the implementer's actions in this scientific model). Obviously, Schema 1 is a very simplified diagram depicting scientific research processes but it clearly shows how science practice (depicted in blue) flows in a linear path. We can see that the community is receiving input from this scientific research, delivered by the implementer, which is primarily focused towards solutions, for example legislations, interventions and new technologies. However, this objective scientific process does not provide the community with a sensorial experience of the science.

Hinterwalder (2017) examines computer artist, Frieder Nake's discussion in regards to computer graphic software in which Nake characterises a drawing on a computer as:

> *"It exists as a visible complex of lines on the computer screen and to this extent is analogous to the drawing on paper; but also indeed, even above all it exists as an invisible model in the computer memory."* (Hinterwalder 2017, p.58).

Hinterwalder (2017) continues to describe this combination, between the output that we perceive on the screen and the invisible model in the computer, using the mathematical term of 'bijective', where each component diverges with each other, both the visible surface and the part that is invisible below the surface, to have a double existence. This is



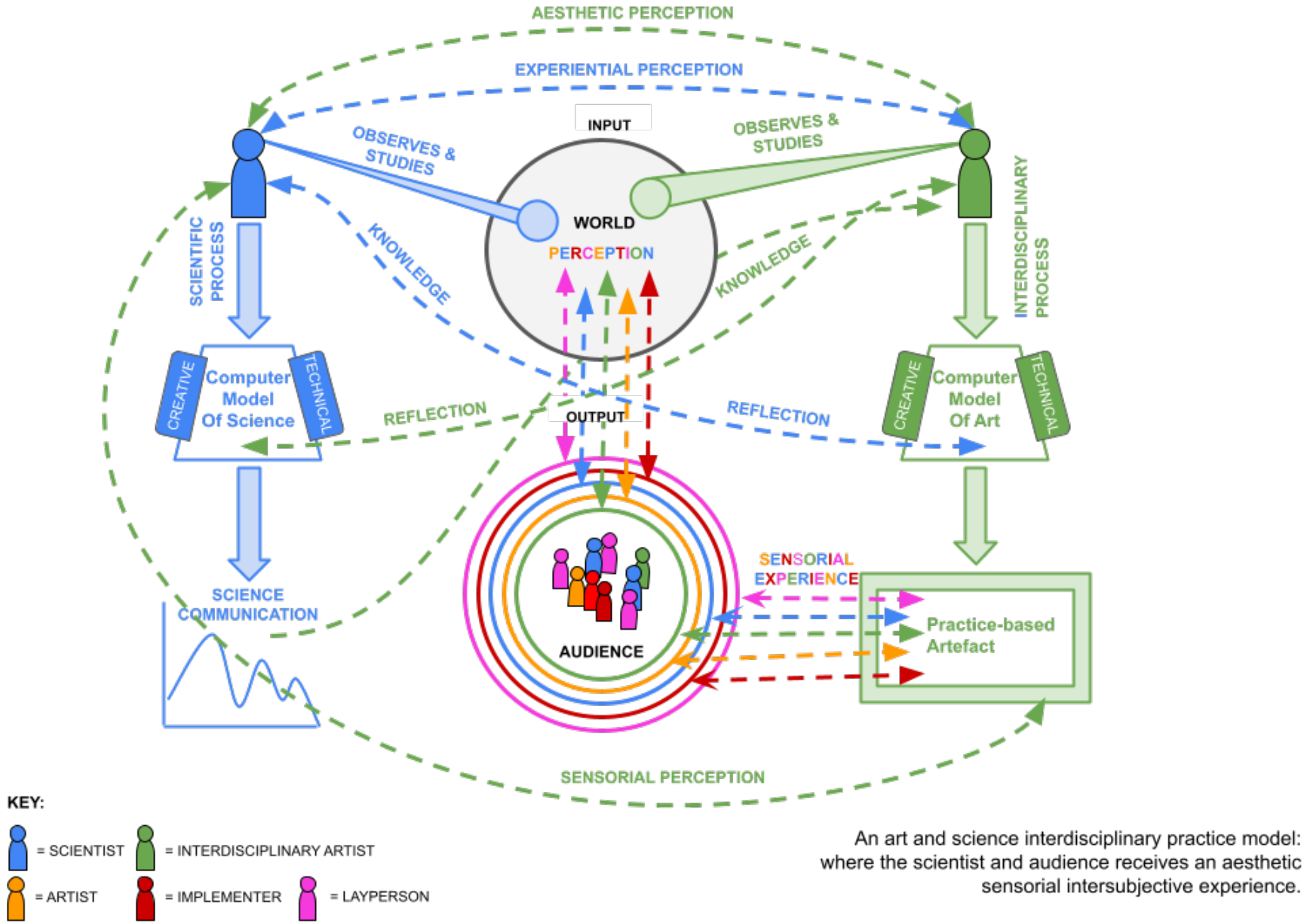
Schema 2: The Artistic Model (2022)

Image credit: Vicky Isley

comparable to an artistic practice, whether your chosen specialism is to paint, film or sculpt, each practitioner will have an invisible expression in their mind that is influencing their final practice-based artefact. Similar to a scientific practice the artistic practice (see Schema 2) is still highly technical, where the practitioner has mastered their chosen specialist medium (i.e. ink, clay, wood, film, animation) to enable the culmination of their processes and techniques to form a creative artefact. Like the scientist, the artist also studies and observes the world to make perceptions, so they can express them in their practice-based artefact. The final artistic artefact becomes a tangible entity of all the concepts, ideas and expressions that are perceived in the mind of the artist. When you compare these two diagrams of scientific and artistic practice (Schemas 1 and 2), it is evident how the output from these processes is different. The artistic practice clearly has an audience output, which is a sensorial experience, providing an insight which changes how the viewer perceives the world. The artistic methodology where the artist's mind's eye is rendered in a physical artefact, enables a materiality of the artist's perceptions of the world. The artistic practice, from concept to the final production of the practice-based artefact, becomes an *artistic model*, where an audience can directly experience the artist's vision.

2.2.2 Aesthetic Model

Boredomresearch's practice is consistent with the artistic model (Schema 2), our methodology is exactly the same, however in our practice we introduce an art and science interdisciplinary approach. In our practice, aesthetic visual expressions are produced, by initially creating an artistic computational model, using computer-based processes similar to rendering a scientific simulation or visualisation. Comparable to the scientific model (Schema 1), Boredomresearch's practice also has an invisible underpinning computational model. This computer-based art model becomes a vehicle for the scientist to respond and reflect upon during the interdisciplinary process. Unlike the scientist's computational models, the artistic computational model is perceived by an audience, where the mechanics and behaviour of the models are revealed within the final practice-based artefact. This enables an audience to perceive hidden computational models through a sensorial experience. In our practice a computational model is created through our artistic concepts and ideas, combined with the insight gained from the scientific computational models and our perception of the scientist's research. Our artistic computational models are also combined with other aesthetic components in the form of computer graphic imaging techniques including: animation, three-dimensional assets, film and special effects. These different interdisciplinary processes, our perceptions of the scientific computational model and research and our aesthetic computational model and artistic elements, blend to create a new model - the *aesthetic model* (see Schema 3). In this interdisciplinary practice the artistic computational model is an integral part of the process as this is where the rules, mechanisms and behaviour of a particular scientific phenomenon are expressed through code. In the aesthetic model (see Schema 3), the aesthetics become the interface between the perceptions of the scientist (graphically depicted in blue) and the artist (depicted in green), and between the scientific computational model (in blue) and the artistic computational model (in green). In the aesthetic model (see Schema 3) the dotted lines depict the artist, scientist and audience perceptions, as inputs and outputs, from and to each individual or community. The blue dotted line symbolises the scientist's perceptions and the green dotted line symbolises the artist's perceptions. This diagram has been simplified for this illustration but you can evidently see through this interdisciplinary



Schema 3: The Aesthetic Model (2022) Image credit: Vicky Isley

practice, that there are many lines that connect the artist and scientist practices. There is a dynamic flow between the two different practices which is not present in the separate scientific (Schema 1) and artistic (Schema 2) models. In the aesthetic model both the art and science computational models are perceived by the other practitioner, where both the artist and scientist are reflecting on each other's practice and gaining new insight and knowledge. Another clear difference in the aesthetic model which is not found in the scientific practice model (Schema 1) is that the science research is now enabling an audience to perceptually experience the science through the insight gained from the artistic expression. As the artistic expression directly takes input from the scientific computational model this allows an audience to experientially perceive elements of the science models through the final practice-based artefact.

"Science is largely conducted through data analysis and not through empirically sensing the world, and, because there are no obvious ways to represent probabilistic, fleeting or otherwise unintuitive data, this necessitates the attention of the artistic sensibility that is skilled at thinking about issues of representation."
(Forbes 2015, p.330)

Chapter III

ART AND THEORETICAL REVIEW

3.1 Artistic Review

3.1.1 Interdisciplinary Collaborations from an Arts Perspective

Since, British scientist and novelist Charles Percy Snow's Redes Lecture in 1959,[11] highlighting the potential detrimental notion of a diversion of two disciplines, science and humanities, there has been much scholarly discourse reflecting upon how successful artists and scientists are polymathic and are transcending disciplinary boundaries (Root-Bernstein et al. 2011). Farra (2018) critiques how artists can create valuable interdisciplinary actions focusing on global environmental concerns, promoting the importance of gaining knowledge through polymathic approaches which *"seeks to push boundaries"* and are *"forging new processes and ways of looking"* (Anthony 2012). Contemporary artist and scholar Victoria Vesna (2001) critiques Snow's notion of two cultures proposing a third culture, in which artists become *in-between* mediators of the art and science interdisciplinary practice-

[11] The Redes Lecture was delivered by C.P. Snow in May 1959 and subsequently published as The *Two Cultures and the Scientific Revolution*. Available at: http://s-f-walker.org.uk/pubsebooks/2cultures/Rede-lecture-2-cultures.pdf [Accessed 2 May 2019]

based process, where artists are not only *"forced to articulate the reasoning and meaning informing the art we produce"* but create a *"room for an active dialogue with both humanists and scientists."* It is this art mediation, that is bridging and synthesising the different disciplines, which Vesna (2001) concludes *"creates a triangle and promises the emergence of a third culture."*

Angus Graeme Forbes (2015), a practice-based researcher and scholar in computational media explores the advantages of art and science interdisciplinary discourse and practice, providing a framework to articulate the importance of media art in this collaborative process, describing the fluid areas of the interdisciplinary process, through establishing the following terms: *augmentation*, *generation*, *provocation* and *mediation* and describing each method having "*downstream implications"* that can lead to the implementation of the next process. The *augmentation* and *generation* processes involve a reflective exploration, where the artists become *augmenters*; seeking out new knowledge from the interdisciplinary methods by *provocation* of new research questions. This results in the *generation* of new concepts and ideas and finally the artists become *mediators* and *commentators* through the implementation of cultural artefacts, that can consequently have further impact for the scientist's research and practice. Forbes (2015) highlights how much can be gained from art and science interdisciplinary collaborations, where the collaborative process which is artist driven, leads to new methods of execution and the artists can take on roles such as: leaders, communicators, visionaries or a challenger whilst working in this domain. This leads to a new way to explore culture, society and human experience that integrates *synesthetic experience* with analytical exploration (Root-Bernstein et al. 2011), where the artistic expressions allow the science to be experienced through the senses. In the aesthetic model (see Schema 3, Chapter II, Section 2.2.2) the framework that Forbes describes from augmentation to mediation, is implemented in the experiential pathways that are mapped between scientist and artist in this diagram (depicted in the dotted lines). These pathways become a fluid process, where connections are made between the artist's and scientist's observations and perceptions. For example, when the artist observes the scientist's computational model they will be augmenting and provoking new questions on the content and behaviour of these scientific models.

Yuri Mikhailovich Lotman (2011) a Soviet structuralist, semiotician and cultural historian critiques the importance of play where one can model a situation in their consciousness, allowing for a change of situation or reaction *"develops an emotional structure necessary for practical activity,"* theorising how art is one method in which play-type models are implemented which do not conform to a logical model structure.

> "*A scientist creates a model based on a hypothesis, whereas an artist creates a hypothesis based on a model. He models*

an uncomprehended (or not completely comprehended) object." (Lotman 2011, p.266)

Aesthetic expressions often incorporate elements of perception that go beyond what is comprehended in that moment of time, where the underpinning scientific models or principles are perceived differently for each viewer. Merleau-Ponty (2012) describes how our mind can perceive the back of an object even though we do not see it. This is due to our perception being formed by numerous observations of that object, enabling the object to become translucent through our previous multiple perceptions intersecting to create the full depth of the object. If the aesthetics of the art transfixes the viewer, their mind can start to imagine beyond that which is being transmitted in the moving images. This allows the spectator to develop their own response to the mechanisms and dynamics revealed in the artwork.

The dynamic computational elements within this body of practice-based research enables a fluid temporal quality to unfold in the artefacts where different shifting states are revealed in the visual expressions. Complex information is embedded within the artworks, enabling the artefacts to be similar to biological systems, where in the real-time artworks, even the author cannot predict the future direction of these artistic expressions of science. Lotman (2011) describes that art transforms *"an abstract idea into a reality,"* enabling abstract properties within the scientific research to be sensed and experienced in a more tangible form. For example, an artwork with an animation that is changing depending on data fluctuations, the variations of the data can instantly be perceived in a visual form, where patterns and disturbances that are responding to the embedded data become visible. This level of aesthetic generation enables the data to be performed and multi-layered. As Lotman (2011) describes this type of modelling process where an idea is performed rather than just being a *"materialised idea"* creates *"a system of multi-layered probabilistic intersections"* and *"carries information that cannot be transmitted by any other means."* Computational artworks that take inspiration from biological systems to generate new life-like complex worlds can transform and shift between different states and behaviours, where one artefact can encompass elements from different scientific models and/or principles, creating a multi-layered outcome. Contemporary artists such as Jon McCormack (Australia), Laurent Mignonneau and Christa Sommer (Austria), Rafael Lozano-Hemmer (Mexico), Lise Autogena and Joshua Portway (UK) and interactive art studio group Invisible Flock (UK) are just a few of the practitioners utilising technology to incorporate elements inspired by biological systems, providing aesthetic expressions of dynamics and mechanisms in the natural world. Similar to my practice, the computational processes of the work produced by these artists are often hidden, instead a visual expression of the underpinning mechanisms and processes is conveyed. Using the language of moving image, the

artworks become relatable to a broad audience, including those that would not usually engage with complex scientific notions. The real-time component of these artworks creates a temporal and interactive experience of the embedded scientific research, allowing audiences to *"develop a sustained interaction"* with the work *"a relationship with it that brings them back time and time again"* (Candy and Edmonds 2011, p.39). These 'living' computational artworks are not just representations of science. The artists do not perceive themselves as scientific illustrators. Their primary interest lies in expressing the science through consideration of the aesthetics and psychological qualities that are embodied within the artefact.

> "*ArtScience is a new way to explore culture, society and human experience that integrates synesthetic experience with analytical exploration. It is knowing, analyzing, experiencing and feeling simultaneously."* (Root-Bernstein et al. 2011, p.192)

All of the artists mentioned above are crossing and bridging disciplines and through this process creating innovative and multi-layered approaches to scientific research. Using the medium of aesthetics, artists can provide materiality to scientific concerns and principles. Enabling a visual interpretation of the data as a physical entity which allows for a sensual awareness of the science.

3.1.2 Aesthetic Landscapes Revealing Invisible Elements of Science

Art that emerges from art and science collaborations not only provides a public window into the reality of scientific data and processes, a reality that has become normalised by the scientific community, but through art practice we can experience the awe, complexity and sublimeness of science that often is created behind closed laboratory doors.

World-wide advanced scientific institutions such as the European Organisation for Nuclear Research (CERN) in Geneva (CH), SETI Institute in California (US) and the Arizona Cancer Evolution Center (ACE) at the Biodesign Institute (US) have established interdisciplinary art and science programmes, embedding artists in their science laboratories and research groups through fellowships and artist-in-residence programmes. There are many other international scientific research institutions that recognise an urgent need to engage audiences with issues, insights and implications arising from their activity. However, there remains no clear artistic research methodology for translating the complex activity of cutting-edge scientific research into cultural artefacts; allowing a non-expert audience to engage meaningfully in a way that also allows scientists to benefit from a cultural perspective on their activity. Therefore, we are finding that contemporary artists are driving this interdisciplinary development where they are becoming innovators in the field to guide science

institutions with the best methodologies of cross-disciplinary practice. Arthur Clay (2021) discusses the significance of artists working cross-disciplinary across art and science collaborative partnerships, where their artwork can provide a deeper understanding of challenges and the possible-future impacts of our interactions with other life:

> *"..by creating works in which science still plays an important role, but in which the focus is placed on adapting design fictions that guide the viewer to perceive the artwork as being embedded in a social–cultural dialogue whose content reflect the problems of today and possible solutions of tomorrow."* (Clay 2021, p.5)

This has certainly been the primary focus for designers and curators[12] of art and science collaborative programmes where attention is not focused on the artists purely describing or illustrating the science but on the process that emerges from the art interventions that happen within a residency context.

Two contemporary British artists that have been collaborating with scientists for over fifteen years are Ruth Jarman and Joe Gerhardt, collectively known as Semiconductor. The artist collective produces moving image artworks that present a new perspective on the material nature of our physical world through the lenses of science and technology (Bello 2018). They have collaborated with many cutting-edge scientific institutions through artistic residencies at The National Aeronautics and Space Administration (NASA) in 2005 and The European Organisation for Nuclear Research (CERN) in 2015. The artist duo is renowned for their large-scale multi-channel moving image installations that incorporate computer generated imagery, animation, audio and film. All of these elements provide another dimension of science which *"invite us to consider the philosophical problems of our mediated understandings of science and of nature"* (Bello 2018).

Semiconductor's practice often embeds the scientific data into their artworks, directly incorporating the scientific imagery and audio files into their final artefacts. As seen in their *Brilliant Noise* (2006) artwork where they created a time-lapse from raw satellite imagery before it has been cleaned or processed (see Figure 8).[13] Unlike the scientists who see flaws in the imagery as interference or confusion, Semiconductor embraces the errors and noise which are an ordinary part

[12] This includes Arthur Clay with his BioArt exhibition program in Seoul, S.Korea and Ariane Koek when developing the Collide@CERN Ars Electronica residency program and with Monica Bello who is continuing curating this program at CERN.

[13] The artists describe in their interview with Richard Bright in the Interalia Magazine (2019) how they worked with the raw data as it is first captured by the technology rather than when it has been processed to remove the noisy signals or had scientific interpretations applied to it in the form of colour or turned into mosaics for public consumption.

Figure 8: *Brilliant Noise* by Semiconductor (2006)

Figure 9: HALO by Semiconductor (2018)
Images credit: Semiconductor

of the scientific capturing process as a way to remind us of the presence of a human observer (Bright 2019). This allows the artworks to have a more authentic quality, where the rawness of the science that they incorporate reveals a truth that is not present in the cleaned up scientific rendered imagery. Hinterwalder (2014) critiques how this artistic methodology allows art to depart from the scientists' everyday work practice, who routinely eliminate the noise in their work, as unwanted artefacts. The scientists do not see this noise in the original scientific imagery as having anything to do with the studied phenomena, they readily remove the noise where it could not be avoided in the original scientific collection process.

Often these highly technical art and science collaborations involve producing custom built tools and software to incorporate the scientific data and/or imagery. Both Semiconductor's and Boredomresearch's practice involves producing new tools and software to create different visual and acoustic components that combine computer graphics, animation and effects. Through this process of building our own tools it allows the artists to produce a new methodology of embedding the science within the art, involving combining realities by superimposing a layer of modelled and unmodelled data (Hinterwalter 2014). This allows the artists to create fictional landscapes that are a combination of modelled scientific data with imaginary

modelled worlds of aesthetic value. This results in artworks that have a visual complexity that goes beyond the scientific intention. In Semiconductor's installation, HALO (2018), you step into a large cylinder of 10 metres diameter, that is engulfed with projected points of light and strings where hammers hit and then build up resonance (see Figure 9). The epicness of this installation alludes to the architectural sublimeness of the Large Hadron Collider at CERN[14] where Semiconductor conducted the research for this project. Gerhardt and Jarman were privileged to work closely with the scientists at CERN during their artist residency in 2015 which enabled them to access the original raw scientific particle physics data. Using this data, the artists seek to convey the signature of the technology, the mark of the architecture of the experiment, or the presence of man's voice (Semiconductor 2018). In HALO the viewer is confronted with the data, before it has been processed for scientific consumption, through a tactile visual and acoustic experience. The original CERN scientific data that the artists were investigating is outputted as 'event displays', graphic visual mapping of the particle physics which is conveyed through different coloured lines and blocks. This visual display method allows physicists to see subatomic particles which would be too tiny to see with the eye and to analyse and interpret the visual complexity of these systems (O'Luanaigh 2015).

> *"Semiconductor points to alternative image worlds. In cases where the hitherto unseen is effectively invisible, this sometimes requires a transformation in scale or another shift in the realms of human perception."* (Hinterwaldner 2014, p.16)

There is a strong element of similarity between Semiconductor and Boredomresearch's practice, where both duo collectives are interested in creating exploratory landscapes of the unseen. These artworks that are framed as landscapes, bring the importance of philosophical and environmental concerns to our understanding of natural systems. Both artist collectives share the desire to shift the viewer's perspective by incorporating different scales, conveying the invisible, nano and microscopic. Semiconductor's interdisciplinary collaborations tend to be in the fields of geology and physics, where their collaborators include astrophysicists and seismologists. This allows for their research to explore the material nature of the physical world, as Gerhardt states in a HOLO magazine interview *"we're interested in the external world: in touching, seeing, hearing things beyond ourselves"* (West 2014). This differs from Boredomresearch's interdisciplinary research which has

[14] The world's largest particle collider, underneath the border between France and Switzerland, built by the European Organisation for Nuclear Research (CERN).

HALO is an Audemars Piguet Art commission that was developed by research conducted by Semiconductor when they were artists-in-residence at CERN in 2015 as part of the ongoing Arts@CERN programme which is curated by Mónica Bello.

been exploring our external natural world but combined with research on our internal world, exploring human health in the scientific fields of: immunology, sleep physiology, epidemiology and oncology. The visual aesthetic expressions that form this body of research is distinctly different from Semiconductor's art as we explore scientific research centred on the human body, to express the interconnections between the health of both our internal and external environments. The body of practice presented here embodies elements of research on cellular behaviour and mechanisms within the body so an audience can respond to the aesthetic expressions empathetically as they can perceive them from their own standpoint.

3.2 Scientific Review

3.2.1 Scientific Creativity

Science is an evolving process, one that is not fixed or immutable (Heinich 2018). As Garfinkel (1967 cited by Heinich 2018) states where the scientific practice has become 'artful', requiring improvisation and the crafting of rational accountable objects. This artful scientific approach, is often highly creative and experimental, for example scientists that are working with new model organisms, are devising innovative methods of maintaining and nurturing the organisms within a laboratory context. This creative improvisational process is often shared with the scientific community as there are many science laboratories that are collaborating on initiatives that involve consortiums collectively working together to achieve breakthroughs in science. However, it is difficult for non-experts to gain an appreciation of the nuts and bolts of these new innovative scientific techniques and processes especially when the science is in its infancy. The security protocol to access a science laboratory is very strict, a hurdle that limits the number of researchers and collaborators that are granted access permission, increasing the boundary of experiencing the science first-hand and in context. This creates a stronger barrier between the science expert and the public, which can lead to the general citizen becoming distant from the scientific process. This is a pity as the public can gain immensely

from the wonderful curiosity that is felt when viewing a scientist at work and vice versa scientists benefit greatly from experiencing the public's reaction of awe to their techniques and processes. As scientists are repeatedly exposed to their research over many years, they can become desensitised to the wonder of their work but for a first-time visitor, this can knock you back (May 2021, p.156).

Science practice has become innovative in devising techniques and tools to analyse scientific experimentation, including practical methods to produce ground-breaking visualisations for not only scientific research purposes but which have been exhibited in specialised digital art galleries (Lynch 2019). These 'specialised' art galleries tend to focus on imagery or illustrations that have been conducted during the scientific inquiry i.e. microscopic imagery or data visualisations. Ede (2000, p. 186-88) discusses how scientists use 'aesthetic' judgement in the selection process of their imagery, however the images are painstakingly uninvested with subjective emotion. In comparison she states that an artist brings a trained aesthetic with a sense to arrange, distort and finetune, creating artworks which will convey to their viewers a unique take on the world. Lynch (2019) discusses scientific 'rendering' practices and how scientists consider aesthetics, describing science laboratories using different methods for transforming tissue into graphic displays and utilsing techniques such as staining and chemical labelling to analyse samples. These visual 'renderings' enable the scientific research to be analysed more efficiently and findings to be presented more conclusively. I experienced this first hand in my collaboration with the Human Cell Atlas scientists, at the University of Oxford in 2021, where they are conducting single cell analysis, using fluorescent markers to analyse human immune cells. Using markers on a complex mixture of cells they can identify individual cells and then interpret the distribution of these cells for example where they might be clustering and the patterns of their distribution. This form of rendering of the science provides a tangible visual tool to enable elements of the science to become more visually perceivable. This scientific form of representation is not that different from artistic practice, where artists invent new methods of rendering science research, where focused visual elements can be extracted or highlighted. However, as Ede (2000, p. 65) discusses these scientific visualisation methods are devoid of individual interpretation or passion and are not art.

Lynch (2019) does not consider scientific renderings as necessarily 'high art' and critiques how they are not aesthetically appealing in a conventional sense, with the scrutiny of artefacts by scientists being *"treated with dismay, as sources of interference that mar the aesthetics of an image and potentially confuse its naturalistic interpretation."* Interpretation is the key component here where it is crucial that the scientists can evidence their research through the imaging processes that they are conducting, in day-to-day science this very much

outweighs the aesthetic focus of the visual artefact. This raises the question if scientists are already exhibiting their scientific research in public exhibitions, even if they are 'specialised' galleries, how can they benefit from collaborating with artists? Lynch (2019) interviewed scientists about engaging with the arts, reasons that were given included *"to cultivate public understanding, to interest potential donors and government agencies, and to reveal non-obvious features of objects of study."* The latter rationale connects with my research practice where it is the more oblique components of the scientific research that are often more compelling to pursue. It is these non-obvious features that can lead to pertinent questions being raised that go beyond the surface of the science that is being conducted. But what is quite apparent from these scientists' interview accounts is that emotional connections to science are not included as reasons to engage with arts. This aesthetic emotion should be at the forefront, allowing audiences to perceive science from their own unique perspectives and this is where art makes its valuable contribution.

3.2.2 Phenomenology on the Nature of Experience and Relation to Interdisciplinarity

As the body of practice in this thesis embodies sensual awareness of science it is relevant to reflect on Phenomenology which entails the philosophical study of experience. Abram (1996) provides an eloquent account of how this discipline emerged, inaugurated by Edmund Husserl in the 1900s as a method to turn towards the world as it is experienced:

> *"Unlike the mathematics-based sciences, phenomenology would seek not to explain the world, but to describe as closely as possible the way the world makes itself evident to awareness, the way things first arise in our direct, sensorial experience"* (Abram 1996, p.35).

As Abram (1996) describes, this scientific study was devised by Husserl to study the subjective realm in isolation from the mechanical world of material facts that was being constructed by the objective sciences. Husserl originally considered perception as a phenomenon of the mind. However, at the time he was heavily criticised for exploring the field in this way, as it was perceived to be solipsistic. Considering experience as being primarily perception of one's own mind conjured up it being a solitary experience rather than recognising the reality of other experiences. Husserl did eventually recognise that there are different experiential fields: the one of our minds and the one of our body and through our bodily experience we can also collectively experience through others (Abram 1996). Allowing experience to be relative to our situation and circumstances, to enable experiences to be *"profoundly ambiguous and indeterminate*" and where *"the life-world is thus the world as we organically experience it in its enigmatic multiplicity and open-endedness, prior to conceptually freezing it into a static space of facts"* (Abram 1996, p.40). Husserl pleaded that science must acknowledge that their discipline is rooted in the same world that we all engage in our everyday lives and it should not be forgotten that this stems from our directly felt and lived experience (Abram 1996). In a series of notes written in 1934 by Husserl he describes a set of phenomenological thoughts into the contemporary understanding of space. Considering all bodies, including our own being relative to the ground of the earth (Abram 1996).

> *"While contemporary science maintains that 'in reality' the earth is in motion (around its own axis, and around the sun), Husserl maintains that the very concepts of 'motion' and 'rest' derive all their meaning from our primary, bodily experience of being in motion or at rest relative to the 'absolute' rest of the 'earth-basis'."* (Abram 1996, p.42).

Husserl's thoughts were radical for their time, suggesting that there was a profound instability in the scientific worldview, materialising from the conflict between our *"intellectual convictions and the most basic conviction of our senses, between our mental concepts and our bodily percepts"* (Abram 1996, p.42). Husserl wasn't rejecting the field of

objective science; his aim was to illustrate how scientific practice remains supported by our lived sensations.

Abram (1996) in discussing how the field of science is perceived as an objective construct which is *"utterly independent of awareness or subjectivity,"* states how objectivity explored from a phenomenological standpoint, strives to achieve greater consensus among a plurality of subjects, rather than as an attempt to avoid subjectivity altogether.

> *"The 'real world' in which we find ourselves, then-the very world our sciences strive to fathom-is not a sheer 'object,' not a fixed and finished " datum" from which all subjects and subjective qualities could be pared away, but is rather an intertwined matrix of sensations and perceptions, a collective field of experience lived through from many different angles."* (Abram 1996, p.39)

Abram (1996) describes how the real world, our lived experienced world, is not a fixed entity in which we can strip away all of its subjective qualities; he states how our collective experience affects the interweaving of our individual phenomenal fields into a single phenomenal world or 'reality'. In this argument Abram (1996) posits Husserl's phenomenological theory in regards to his notion of 'intersubjectivity', which creates a new interpretation of the scientific 'objective world' as defined here:

> *"For the conventional contrast between 'subjective' and 'objective' realities could now be reframed as a contrast within the subjective field of experience itself - as the felt contrast within the subjective and intersubjective phenomena."* (Abram 1996, p.38)

In my *aesthetic model* (see Chapter II, Section 2.2.2, p.44), interdisciplinary practice provides an experiential perspective on the scientific method which combines an artistic aesthetic awareness of the science alongside the intersubjective phenomenological perspective. The act of an artist being positioned within a scientific institution, can rapidly create a valuable subjective "*knowledge-sharing*" (Forbes 2015) process. This encourages the artists' collaborative scientists and their science community to experience a heightened subjective perception of their scientific research; where the artist has enabled further awareness of the sensorial aspects of the science to surface. Ede (2000, p.47) states artists work may display a poignant desire for inner meaning but each individual expression is different, as is the individual response of their viewers. This can be liberating for the scientist where they can experience a new personal perspective on their research. In an interdisciplinary process both the scientist and the artist are sensing the science. The scientist naturally sensorially perceives their scientific subject material, but often does not contextualise or use the language of these sensorial experiences in the public realm. Ede (2000, p.54) discusses scientists communication approach where the rational language they rely on is better understood by the decision-makers.

Throughout the process of an art and science interdisciplinary collaboration, the artist shares their development sketches and computational models with the scientist which empowers the scientist to articulate their science from a more aesthetic perspective. In response the artist can perceive the sensations of the scientific material embedded in their work from the scientist's perspective. This art and science intersubjectivity is then expressed to an audience through the practice-based artefact that enables viewers of the art to then sense individually themselves and collectively sensorially elements of the scientific research.

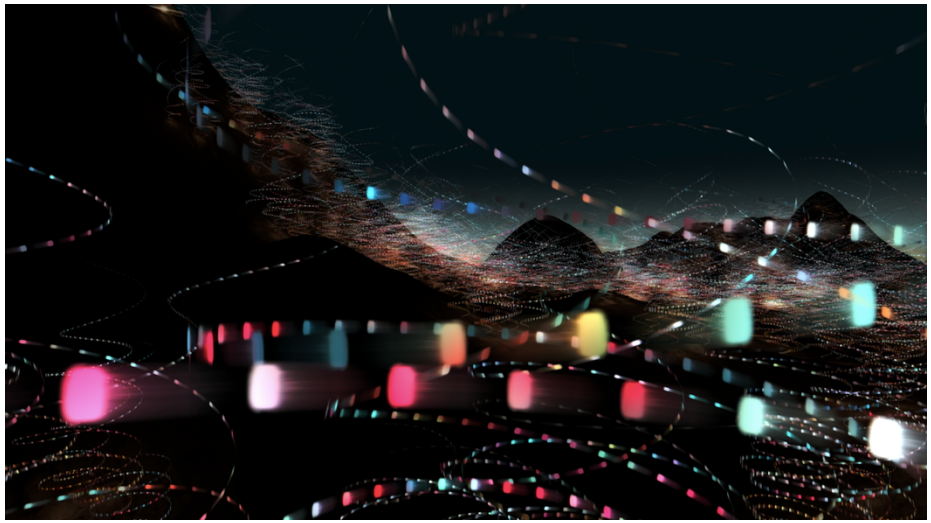


Figure 10: A still from AfterGlow showing the colourful benign spirals - evocative of mosquito flight paths (2016) Image credit: Boredomresearch

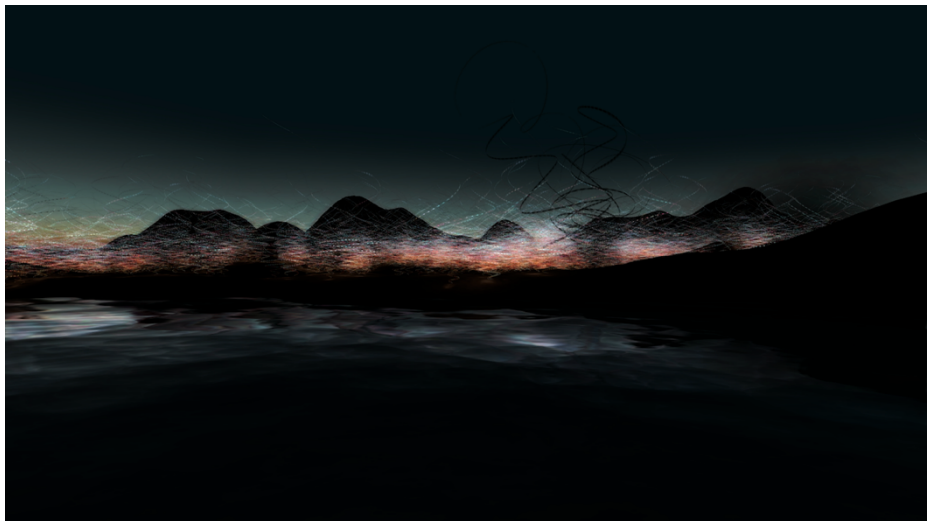


Figure 11: A still from AfterGlow showing the island terrain from a distance with a black turbulent infectious spiral to the right of the centre (2016)
Image credit: Boredomresearch

Chapter IV

ANALYSIS

4.1 Expressing Oblique Scientific Data Reveals Hidden Processes

This analysis section (from sections 4.1.1 to 4.1.3) presents a critique on the artefacts *Dreams of Mice* and *AfterGlow* which both embed complex scientific data into the visual expressions. Through the processes incorporated in the production of these artefacts this text reflects on two of my research questions: *Can expressing oblique scientific research, through the creation of a visual aesthetic artefact, reveal hidden processes? Can we maintain the integrity of the art through these interdisciplinary projects?* In these sections I reflect on how the process of scientific data gradually unfolds in these two artefacts and whether this reveals new shifting states and dynamics. This reflective text has been supported with interview excerpts from the core three collaborative scientists involved in this body of research: Dr. Paddy Brock, Dr. Peter Oliver and Dr. Vladyslav Vyazovskiy.

4.1.1 Expressing Complex Scientific Computational Processes

AfterGlow, is a three-dimensional expression of a malaria transmission scenario which is set in the landscape of Banggi Island in Northern Sabah Malaysia (see Figure 10 and 11). The aim of the project was to show the beauty of data complexity, where "*patterns reveal themselves*" (Evers and Nack 2016, p.779). Visual aesthetics emerge from the data gradually, where the fluid automated camera provides different resolutions of viewing the infection patterns in the landscape; enabling a visual expression of the different movements and behaviours of a malaria transmission model from susceptible, exposed, infectious and recovered (SEIR) states (see Figure 13). It was my aim to map these spatially and sensitively within a three-dimensional game engine (see Figure 12). Enabling the different stages of the model to be observed from a landscape perspective, where patterns and movement from a complex infection transmission scenario could be made visible.

> *"Scientists try as hard as possible to make their mathematical models as close to reality as possible, but how often are they prevented from doing so by constraints of the model set--up, limitations of computer power etc. Is the distance that these uncontrollable constraints take the model away from a true representation of the real world further than the distance an artistic perspective would?"*
> (Brock 2014)

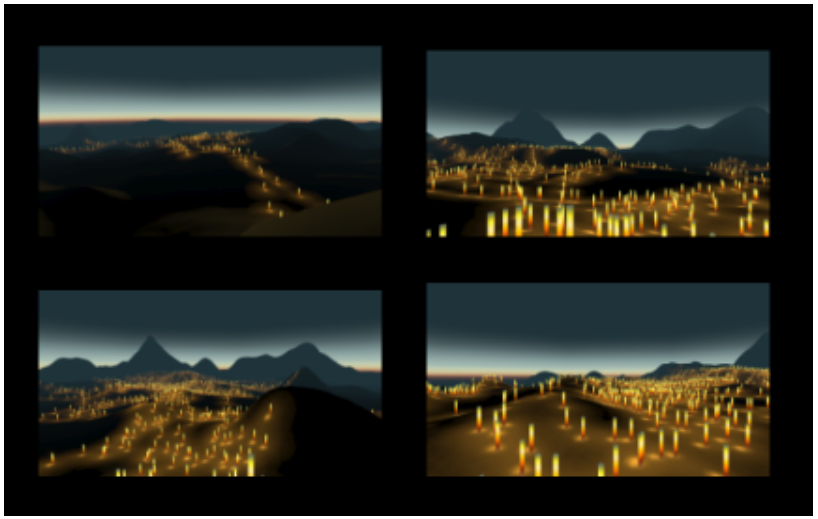


Figure 12: Boredomresearch development sketches of lighting tests on the terrain in Blender game engine (2015) Image credit: Boredomresearch

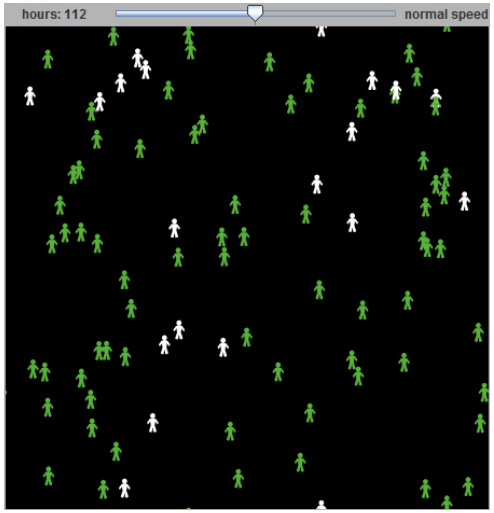


Figure 13: The scientists SEIR (Susceptible, Exposed, Infectious & Recovered) Model (2014) Image credit: Dr Paddy Brock

In both art and science disciplines, each practitioner works within the limitations of computing hardware, making careful considerations and economies that aim to respect the integrity of the desired outcome (Isley and Smith 2017). This leads to both artist and scientist creating models that are fictional landscapes. However, the scientist is always going to be considering this from an objective standpoint. Boredomresearch found some scientific conventions in the methods of epidemiology visualisation challenging, especially from a visual arts perspective. Both myself and Smith found it difficult to justify the use of a single-coloured line to signify the deaths of millions of individuals. In many cases a mathematical description will not even represent individuals, instead a proportion of a population may be fit, unwell or dead. Often these scientific models run invisibly in the depths of the computer only displaying a visual representation once all calculations have been made. Ultimately, it seems, these representations are devoid of individuals, space and time; qualities that we as artists felt were essential to form a deep appreciation of the subject under study (Isley and Smith 2017). At the start of our collaboration Brock expressed an interest in models of disease transmission that are spatially sensitive. At the time this was still relatively new in the field of epidemiology, that formerly favours the above-described shapeless representations; devoid of individuals (Isley and Smith 2017). Then and very much now with modelling the recent

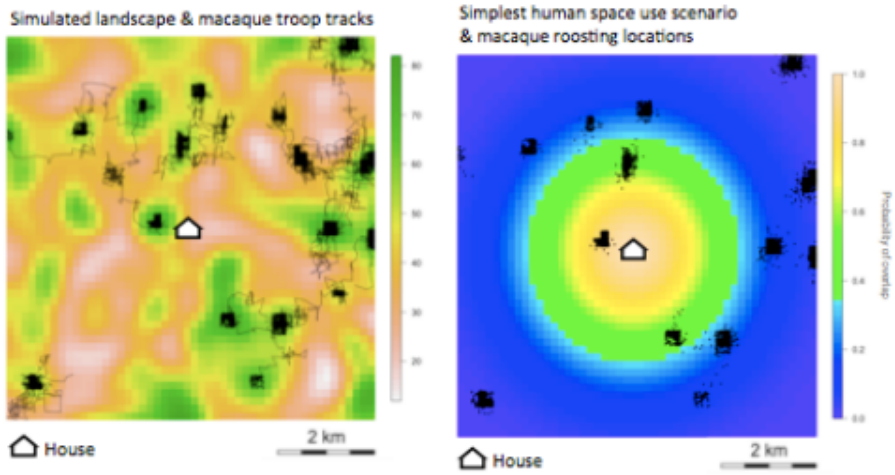


Figure 14: Scientific spatial mapping on Banggi Island of macaque movement and roosting locations on the island (2015) Image credit: Dr Paddy Brock

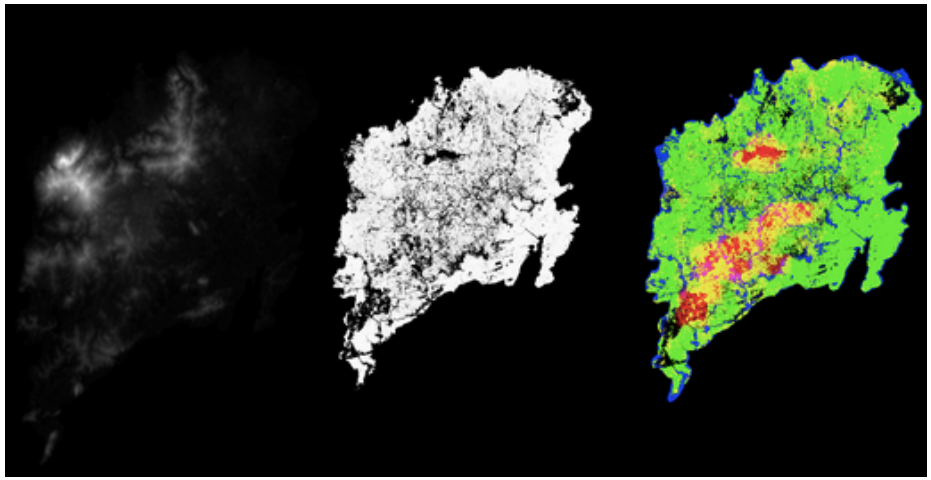


Figure 15: AfterGlow's different maps used to express (from left to right): the height of the terrain, forest cover and water sources on the island (2015) Image credit: Boredomresearch

Covid-19 pandemic, modelling in epidemiology has moved towards spatial representations of infection dynamics, considering the ways in which people and vectors move through, inhabit and are influenced by the physical landscape. During the development stage of our project from 2015 to 2016, these extensive spatial models were still in their infancy in the field of epidemiology. As stated on the London School of Hygiene and Tropical Medicine, *MonkeyBar* science project website (2019) *"often spatial epidemiologic research does not fully incorporate the geographic perspective."* The *MonkeyBar* project documentation highlighted the importance of capturing scientific spatially sensitive data i.e. from radio collars on monkeys and collecting land maps of human population and forest coverage was vital to understand the relationship of the infection within its environment (see figure 14). Dr. Paddy Brock (2015) describes the value of exploring the infection transmission scenario from a spatial perspective in an Animate Projects interview:

> *"boredomresearch's interest in landscape from an artistic perspective links to a hot topic in research epidemiology, which centres around how transmission models can be related to spatial variation"* (Animate Projects 2015).

This presented new potentials for our *AfterGlow* project where we could utilise recently collected scientific fieldwork data, cartographic resources (see figure 15) and mathematical models to enable subtle qualities of an infection transmission scenario to be seen temporally and spatially from a human and landscape perspective. The human perspective is experienced through the cinematography in *AfterGlow,* where the camera moves fluidly through the terrain from a first-person perspective. The landscape perspective is perceived through the silhouetted three-dimensional island terrain that gradually fills with colourful spirals of benign infection (see figure 10), lighting up the land to reveal its form and shape.

> *"Works of art are not only characterized by an extremely large capacity for and economical storage of very complex information, but they also can increase the amount of information stored in them. This unique characteristic of works of art makes them similar to biological systems and gives them an extremely special place among everything created by the mankind."* (Lotman 2011, p.268)

As Lotman (2011) describes above an artwork has the capacity to hold a large amount of complex information, where it is similar to a biological system. In our artistic visual expressions, we can incorporate many layers of complex scientific data in one artefact, where the complexity of this information can be more easily comprehended through the visual sensorial experience. The scientific data embedded in *AfterGlow*, allows viewers to gain an insight into the behaviour of complex dynamic systems significant to human health.

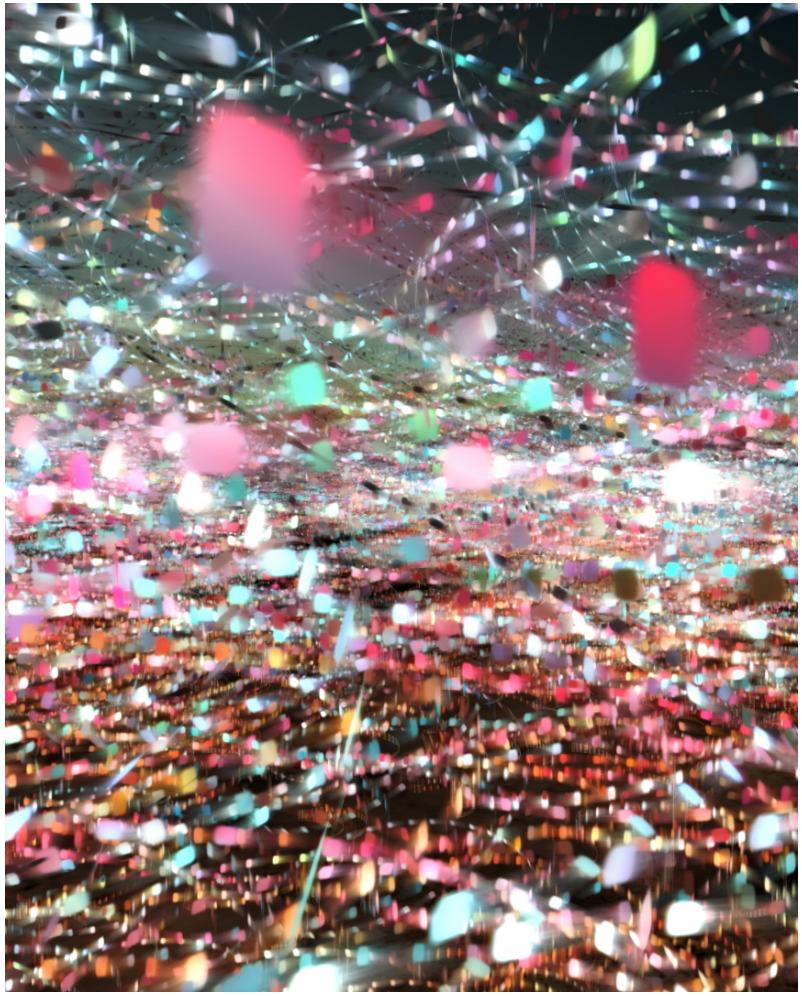


Figure 16: A visual blizzard of mosquito trails in AfterGlow (2016)
Image credit: Boredomresearch

4.1.2 Revealing the Unknowns of Scientific Practice

During the research stage of the *AfterGlow* interdisciplinary project, it became apparent that there were some unknowns about the mosquitoes and the infection reservoirs and therefore these were less contextualised in the scientific research. For example, there is very little known about the movement of the *Plasmodium knowlesi* parasite vector the *Anopheles balabacensis* mosquito. The macaques, the primary disease reservoir, are even more elusive; disappearing rapidly into the remaining rainforest on the island. From an artistic context these unknowns are compelling, as they allow us to apply a speculative approach. In *AfterGlow* we embedded these different hidden layers of bodily forms within an aesthetic expression creating a new interdisciplinary contribution that pushes the boundaries of the 'scientifically justifiable' as described by Brock (2015) in the Animate Projects interview:

> *"The project has been liberating, being released from the usual restraints of a scientific approach: exploring the grey area that lies outside 'scientifically justifiable' helps us to define its boundaries."* (Animate Projects 2015)

By making visible the complex scientific unknowns of the mosquitoes and the macaques' movement and behaviour in a three-dimensional

landscape, *AfterGlow* enables viewers to see the interrelationships of these bodies, within their environment from both an internal and external perspective and through time and space. The aesthetic concept for *AfterGlow* came from viewing night-time satellite images, where populations become visible through the intensity of light. In these images you instantly see the density of humans around water sources, coastlines and rivers as they become vivid hotspots of light. It was our aesthetic objective to use light as the primary source to display the hotspots of infection in the landscape (see figure 12). In the artwork light animations reveal the contours of a black landscape, performing an intricate dance choreographed by the underlying infection transmission scenario. This is described in a statement by Tessa Jackson (OBE) at the Lumen Prize Award Ceremony (2016)[15]:

> *"A compelling short film where flight trails and foraging macaques are rendered into glowing shapes and patterns of wonder and beauty. It is a memorable example of artists employing digital media to its full potential."* (Animate Projects 2016)

Similarly, to science models of infection transmission scenarios (see Figure 13) *AfterGlow* runs through the different SEIR states. However, the data component of *AfterGlow* is not explicit, the audience is not exposed to the computational model and the underlying data maps (see Figure 15) are not visible. Just like the science models these data layers are integral to the artistic expression and without these mechanisms the visual components would not be seen. Unlike scientific computer simulations, *AfterGlow* does not provide an output display which states the population number of the macaques and mosquitoes. Instead of a two-dimensional graphical output the infection scenario is experienced from a first-person perspective with the camera continually at a human height when it traverses the three-dimensional landscape. This first-person perspective allows for an audience to appreciate the density, scale and texture of the infection transmission scenario. When many macaques are bitten by the vector, the camera will move through a blizzard like cloud of mosquito trails allowing a spectator to experience the volume and complexity of the disease (see Figure 16). This embodied experience of the infection can only be perceived through the sensorial expression of the models within the artwork.

[15] Tessa Jackson was on the Lumen Prize jury and selected *AfterGlow* to win the moving image award in 2016. She read this statement at the Lumen Prize award ceremony in Hackney House London (29 September 2016) when she presented Isley and Smith with the award. There is a short article which highlights this achievement on Animate Projects, Silent Signal exhibition website at: https://www.silentsignal.org/afterglow-wins-the-lumen-prize-moving-image-award/ [Accessed on 14 July 2019]

The highly abstract mathematical models of disease transmission primarily used in epidemiological research have a significantly limited ability to express the complexity of most real-world infection transmission scenarios. It is currently recognised that features significant for future interventions may not currently be comprehensible within the limitations of current modelling strategies. In an Animate Projects interview Brock (2015) states that in the field of epidemiology they are constantly trying to find ways of incorporating space into their models and how it is very difficult to make a model entirely spatially explicit. Further describing how the landscape component of the project has been one of the most productive areas of the arts and science collaborative discourse. Brock in the Animate Projects (2015) interview highlights the reflection-in-action approach of this project as being *"really really interesting"* allowing him to consider our "*approaches in terms of current trends in epidemiology and how space is being incorporated into these models."* Brock (2016) also discusses the benefits of the collaborative process in an article he wrote for the Cambridge Journals Blog, here he highlights the importance of *"T-shaped scientists, who are experts in their field and have the skills to work across many others"* he continues to reflect on *AfterGlow* describing how it taught him:

> *"..that the transition to constructive dialogue need not take the length of a career. With our models as a central focus for discussion, the desire to achieve mutual understanding as our shared mission, and the support of progressive institutions, we made the journey to T during the course of a single project."* (Brock 2016)

The *reflection-in-action* stage of this interdisciplinary collaboration led to a deeper understanding of the working methodologies of each other's practice, I gained an appreciation of the limitations of Brock's scientific models in regards to the constraints, such as ensuring they function efficiently and are generalisable and how art could be a vehicle to overcome these limitations. As Candy and Edmonds (2018) describe the research questions which arise from practice-led research, enlightens and enhances practice, that leads to as Forbes (2015) states artists supporting effective *"knowledge-sharing"* and taking on roles as commentators or mediators of the science. In this *generation* of research questions where artists are seeking new methods of executing the data, there are many challenges, as Vesna (2001) warns us of artists who are *"bridging and synthesizing many worlds"* they can easily conform to the academic structures that are already present in the other disciplines' infrastructure. She further questions how do we practice *"without losing the intuitive, 'wild' aspect of artistic practice, which taps into the silent, the unknown, the mysterious."* Brock (2015) comments in the aforementioned Animate Projects interview that he was concerned at the beginning that the project *"might look like data visualisation"* and *"a very flashy video-based version of a model which was not dissimilar to the kind of thing*

we would make for scientific purposes." It is easy to be seduced by the scientific data and whilst researching and experimenting with the scientific models, one can find themselves drifting towards complete accuracy and precision with the data. Therefore, it can be a challenge to hold onto the integrity of the art, for me it was essential that the final creation, not only was authentic and true to the data but also was a new creative sensorial expression of the science. Manovich (2002) questions how new media artists can represent data in new ways, representing the *"ambiguity, the otherness, the multi-dimensionality of our experience"* concluding that we should not forget *"that art has the unique license to portray human subjectivity – including its fundamental new dimension of being 'immersed in data'"* (Manovich 2002, p.11). The aesthetic emotion in *AfterGlow* allows the viewer to be perceiving the scientific data through a bodily experience where *"by withdrawing from the objective world"* (Merleau-Ponty 2012, Part 1: B, para.2) our senses can become completely immersed in the experiential qualities of the scientific data. This practice-based project enabled me to create an aesthetic expression of disease transmission, underpinned by spatially sensitive disease models, displaying disease transmission dynamics from a landscape perspective incorporating animal behaviour, data representations of land use and forest cover. On *reflection-on-action* Brock (2015) states that by myself and Smith exploring the unknown scientific processes, this enabled the science to be explored in a totally different way, *"in a new perspective."* This project not only allowed me to create a novel approach to the ongoing research in the relationship between land use change and zoonotic disease transmission, centred on a zoonotic form of malaria significant to human health, it also allowed me to create a sensorial experience in real-time of the scientific data. Therefore, two insights were provided through this practice-based research where the scientist gained from viewing their research from a new perspective and an audience gained from experiencing the final aesthetic expression.

4.1.3 Making Visible Neurons Firing Through Light

Existing visualisations of neural activity are highly abstract in nature and primarily limited to use in data analysis solely from an expert perspective. Normally consisting of two-dimensional plots of amplitude over time these existing representations, while allowing for accurate analysis and comparison of discrete features, remain limited in the expressive communication of subtle biological signatures. The novel approach taken here uses real-time, three-dimensional animation tools to create a highly visual expression of small-scale neural activity.

In *Dreams of Mice* eleven lights are animated in the centre of the artwork, each representing a neuron in a mouse's brain, named Ron,[16] where the nanowire implant has made a connection, taken from a recording on the 19th October 2014 at 2:48am. The animating lights illuminate depending on the strength of the neural signal, they are at their brightest when the activity is most active. The speed of the neuron recording had to be slowed down to become perceptible. It was Boredomresearch's aim to have the lights nestled in a neural-like branch structure to feel like they were contained, taking inspiration

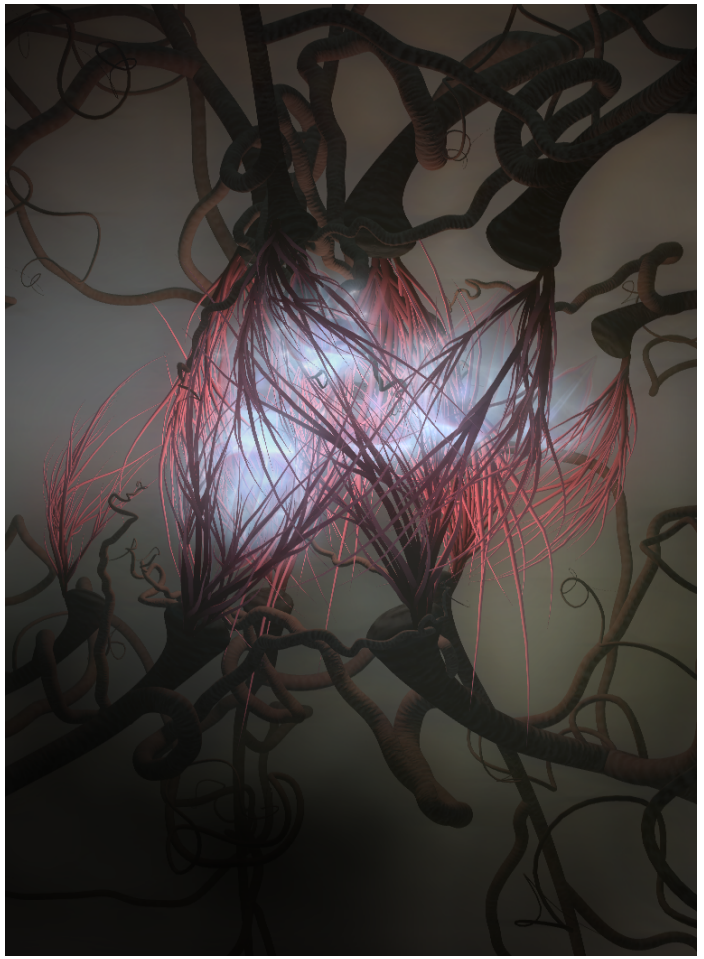


Figure 17: The pink neural-like branch structure around the animating lights (2015) Image credit: Boredomresearch

[16] Vyazovskiy provided the raw data from a recording of a mouse's dream called Ron. The surgeon who operated on this mouse, installing the implant, named the mouse after Ronald Weasley, a character in Harry Potter. The impulses of Ron's recorded dream provide the input signal for the visual and acoustic component of our artwork *Dreams of Mice.*

from the real mice nests in the laboratory and the concept of being inside a brain. Both myself and Smith created this neural-like branch structure around the animating lights (see Figure 17). A recording of the mouse in the wheel is used for the rotational timing of the neural-like branching structure (see Figure 18), when the mouse is awake in the recording, the pink hair light fibres will close in and the branch structure will start rotating, mapped to the mouse's wheel recordings when he is active.

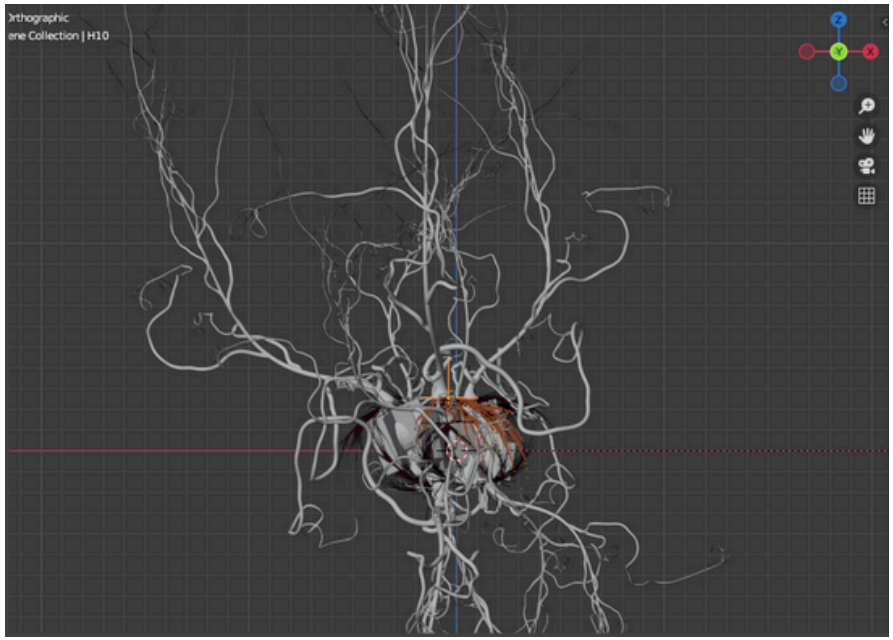


Figure 18: Blender 3D model of neural-like branch structure (2015) Image credit: Boredomresearch

This allows the artwork to have a continual steady movement but the piece is more active when the mouse Ron is asleep. This was a significant element of the project with the aim for the dream sequence to be more active than the awake period to provide a sense of the importance of the neurons firing whilst the mouse is sleeping. It is not necessary for an audience to understand the different active and inactive components of the artwork, but it was our goal for the viewer to feel the flutters, pulses and subtle patterns in the light and to have a sensorial experience of the biological data that is underpinning the artwork. This differs from the scientific aim of their neuron data representation, where the scientists' methodology is to find the most accurate and efficient technique to display the information. However, when viewing the original scientific neuron data that had been collected from sleeping mice, it first appears like a noisy wave in audio editing software, with the raw data lacking any emotional response. Discussing the data with Dr. Vladyslav Vyazovskiy, the scientist, enabled me to gain an appreciation of the different patterns and oscillations in the neural activity represented as a wave form. In the neuron recording that was provided by Vyazovskiy (see Figure 19) the different colours represent different neural activity from the neocortex, the outer brain layer of the mouse Ron whilst sleeping. This scientific data was then prepared by Boredomresearch to enable the spike timings and amplitudes to be mapped to an animation system (see Figure 20).

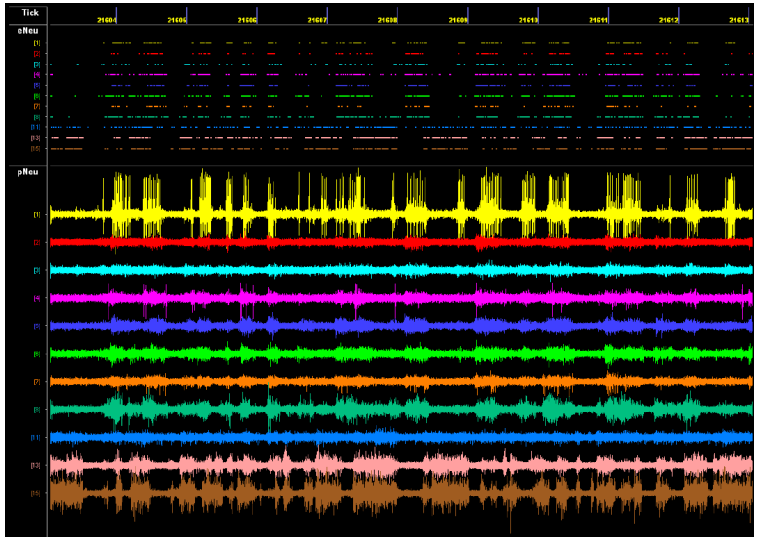


Figure 19: Original scientific data of Ron's neuron firing (2015)
Image credit: Vladyslav Vyazovskiy

1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
3.00E+01	1.10E+01	1.00E+01	1.50E+01	4.00E+00	3.10E+01	6.00E+00
2.92E+02	3.40E+01	2.90E+01	1.70E+01	7.00E+00	3.80E+01	3.00E+02
3.29E+02	3.90E+01	5.70E+01	2.10E+01	1.40E+01	4.00E+01	3.09E+02
3.36E+02	4.30E+01	6.20E+01	2.80E+01	2.40E+01	4.40E+01	3.22E+02
3.51E+02	2.59E+02	3.10E+02	3.40E+01	2.90E+01	5.70E+01	3.36E+02
3.67E+02	2.65E+02	3.93E+02	3.70E+01	2.83E+02	6.20E+01	3.43E+02
3.81E+02	2.92E+02	4.05E+02	4.10E+01	3.15E+02	6.40E+01	3.45E+02
4.19E+02	2.95E+02	4.28E+02	2.22E+02	3.18E+02	1.33E+02	3.50E+02
4.29E+02	2.99E+02	5.08E+02	2.34E+02	3.26E+02	2.45E+02	3.60E+02
4.85E+02	3.14E+02	5.12E+02	2.43E+02	3.31E+02	2.80E+02	3.68E+02
5.00E+02	3.25E+02	5.52E+02	2.56E+02	3.36E+02	2.94E+02	3.75E+02
5.27E+02	3.34E+02	5.66E+02	2.66E+02	3.48E+02	3.01E+02	3.91E+02

Figure 20: Boredomresearch prepared the above science data of neuron spike timings and amplitude to input into our animation system where increases in light could be mapped to the amplitude of the neuron signal (2015) Image credit: Boredomresearch

During our reflection-in-action stage, Vyazovskiy disclosed his ideas about what might be happening during sleep, highlighting significant points where many neurons fire simultaneously or inhibit one another. Scanning the mouse recordings, he discussed the spikes in the waveforms and how during sleep neural activity does not stop but continues in a more subtle and structured fashion; with brief bursts of neural activity and then alternating with moments of silence. The thought of observing a mice's dream, felt like it would be a compelling and magical experience, but when first presented with Vyazovskiy neural recordings of sleeping mice, it felt like an anti-climax. We were looking hard to see the patterns and nuances that were being described by Vyazovskiy and the data just appeared cold and lifeless. However, his description of the behaviour of the shifting activity in the scientific model, which he described as: "*brief bursting*", "*vivid*" and "*subtle*" accentuated the important elements in his data, allowing me to gain a sensibility of how the raw data could be transformed into a sensorial expression. Through the artwork we embody the scientist's expert interpretation and his subjective language of the data by mapping the neuron signals to an animated, pulsing light form, making visible the evocative nature of a fragile dream. By translating the scientist's intimate experiential qualities of the data, into a new aesthetic expression of the biological patterns and behaviours, we can enable these elements to be sensorially perceived by a non-expert audience.

The experience of seeing the mice in their cosy nests in the laboratory with invasive technology protruding from their small heads provided an emotional connection to the model organisms undergoing scientific study. The psychological response I felt during my time in the biological medical laboratory pushed the research concept of this artefact to be a subtle response in opposition to the invasive technology which was being deployed. Boredomresearch's aim was for the artwork to be presented in the style of a landscape painting that pays tribute to an organism that has given his life to science (see Figure 21).

Figure 21: Dreams of Mice in Digital Intersections Exhibition, Italy (2018)

The final artefact, *Dreams of Mice* (see Figure 22), introduces a primarily aesthetic expression of high-resolution neural activity creating a cultural artefact that fills a gap between the data visualisations valuable to science and those that can be experienced by a non-expert audience where *"The content of art as a modelling system is the world of reality, translated to the language of our consciousness"* (Lotman 2011, p.250). This value of art Lotman discusses in his theories, distinguishing art from other modelling systems.

Employing reflection-on-action after the project was completed and had been exhibited, I asked the scientist Vyazovskiy to respond to the following question: Do you think the artwork provides a new perspective or insight to your data? The scientist responded with the following statement written to me in a letter:

> *"In the last years, new and creative approaches to visualise the brain has greatly advanced the field of neuroscience. Novel neuroanatomical methodologies now allow precise 3-d reconstruction of neuronal processes and synaptic connections across the brain, while functional imaging techniques allow to see neurons "in action". However, it is currently not possible, or at least not practical, to combine both aspects - the topology of brain networks at microscopic resolution, and their dynamics and function - together in the same preparation. It would be fair to say that 'Dreams of Mice' could also be named 'A dream of neuroscientists'. If we were able to attain, with our future recording and imaging*

> *technologies, this level of detail with respect to how neurons communicate with each other deep inside the brain in real life, we would get closer to solving the mysteries of the brain and sleep."* (Vyazovskiy 2019)[17]

This powerful comment expresses Lotman's theory on how *"a work of art simultaneously adapts the consumer to itself, preparing him for the reception of a new portion of not yet transmitted information"* (Lotman 2011, p.268). Not one that is substantiated by science but one where the artwork becomes visionary, as Candy (2007) expresses pushing the boundaries of existing frameworks in order to discover new forms of expression.

The scientific research embedded in *Dreams of Mice* was the ideal practice to explore *hidden* scientific processes. As the neural and behavioural data, the scientists are collecting in the laboratory, is not accessible to the general public but it is very relatable to human behavioural disorders and how sleep is affecting our wellbeing. This interdisciplinary collaboration allowed me to express a mouse's dream, a magical space that we can only imagine; creating a sensual visual and acoustic expression to depict an evocative form to this ethereal material.

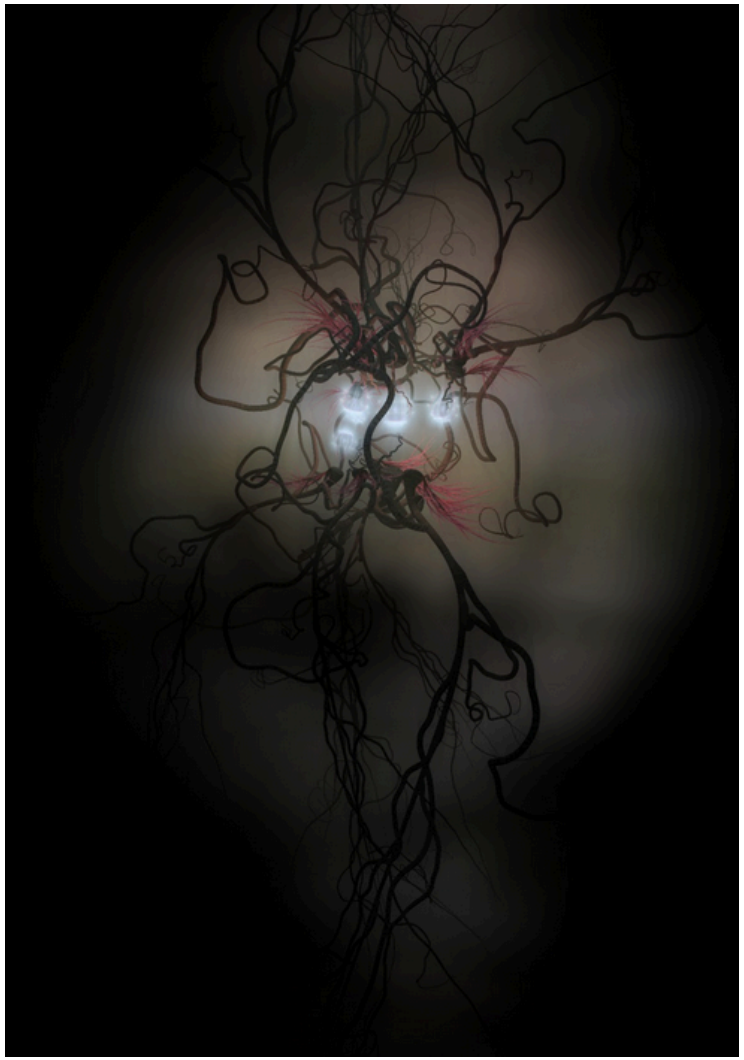


Figure 22: Full portrait frame from Dreams of Mice (2015)
Image credit: Boredomresearch

[17] Written by Vladyslav Vyazovskiy in a letter to Vicky Isley as an impact statement for the Research Excellence Framework exercise for Bournemouth University on 30 November 2020.

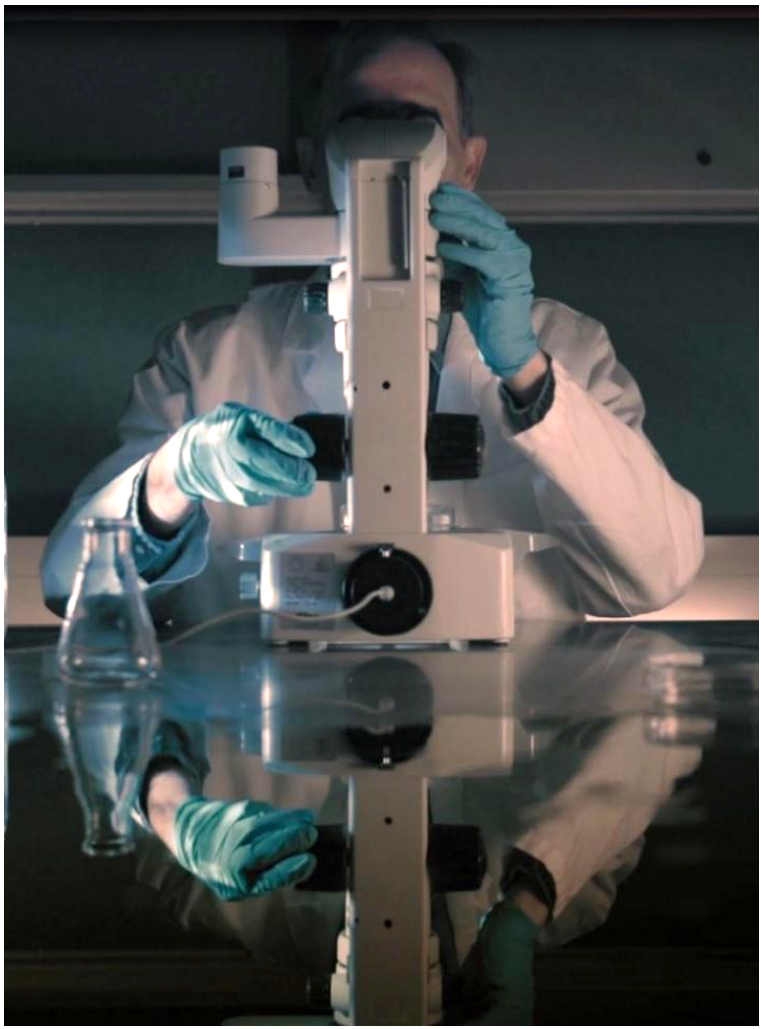


Figure 23: A still from *In Search of Chemozoa* where we captured the absorption of Fortunato experiencing the hidden world of the Placozoa through a microscope (2020)
Image credit: Boredomresearch

4.2 Expressing the Sensibilities of Science

This section presents an analysis of the artefact *In Search of Chemozoa* in response to my research question: *Can we create an interdisciplinary model that addresses the scientists' sensibilities?* This critique is primarily addressing excerpts taken from an interview conducted with my science collaborator Dr. Angelo Fortunato at the Biodesign Institute, Arizona (2019). This text reflects on the scientist's sensorial perspective of his scientific process and materiality of his work and considers the theory of phenomenology in relation to practice-based research.

As explored earlier in my phenomenology section (see Chapter III, Section 3.2.2), scientists do not overlook subjectivity, the field of science can perceive the objective world intersubjectively. However, the practice of science, as seen in my model (Schema 2) has ingrained a process that the science needs to be communicated objectively, with precision and accuracy. Science communication supports this theory where the language used in the dissemination of science is still biased towards objectivity, even though a large proportion of scientific practice has been achieved through methods that involve subjectivity. Scientists are still living, breathing and bleeding humans that see, touch, feel and smell the material that they are intimately researching. When observing a scientist in practice, as an artist, I experience the scientist experiencing (see Figure 23).

When I converse with a scientist, they often describe their sensorial encounters, moments of pinnacle influence that are gained from sensorial feedback from their subject matter. The scientist is continually perceiving their subject matter within experiments whether it is in a wet laboratory or a computational laboratory the detailed process of daily examination involves an intimate engagement of the science research that goes beyond objectivity.

> *"If you are patient enough these animals will tell you something. If you just wait they will suggest to you something - it's always like that. In fact most of the time we see stuff that you wouldn't have thought about doing before, as an experiment, before you started working with these animals…So we need to listen and in this case watch and they will communicate something."* (Fortunato, 2019)[18]

The above excerpt is from my interview with our collaborative scientist Dr. Angelo Fortunato at the Arizona Cancer Evolution Center (ACE), Biodesign Institute (USA). Fortunato's research at ACE was primarily responsible for developing new model organisms to study cancer, such as: comb jellies, sea sponges and placozoa. The primary reason

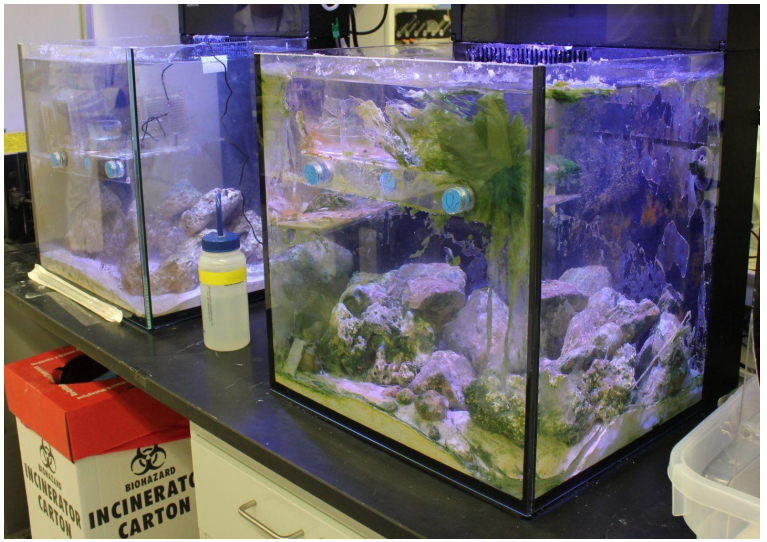


Figure 24: The *Placozoa* tanks at the Biodesign Institute (2018)

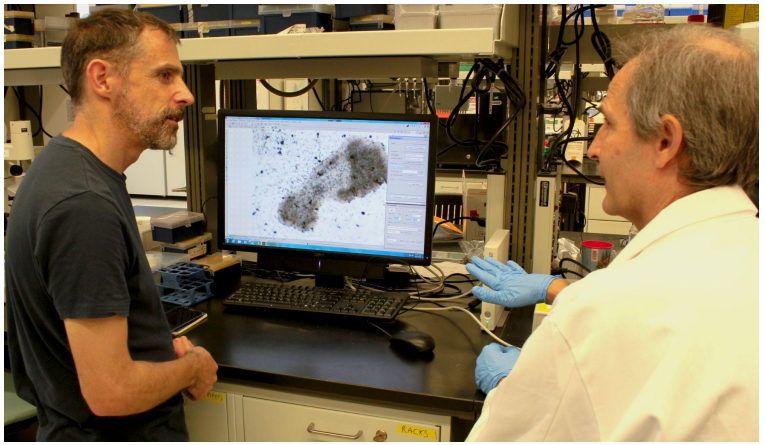


Figure 25: Smith discussing the *Placozoa* microscopy imagery with Fortunato during our artist residency (2018) Images credit: Vicky Isley

[18] A citation from my audio interview with Angelo Fortunato at the Biodesign Institute, Arizona in 2019; which included questions on his science background, methodology and the context of his practice. Excerpts of this interview recording were used in our documentary 'For we are but a single cell' (2020).

Fortunato is studying these organisms is that there have been no reports of cancer in any of these species. By observing and experimenting on these novel model organisms he can try to understand cancer across species in particular humans. It is apparent when interviewing him that they are more than just a subject matter, he has an intimate appreciation of these life-forms he is working with and his response in interview is an emotive response:

> *"If you are in the lab and you are considering these animals like any object that you need to have an answer for your experiment. Usually it doesn't work, you miss something and you get a weird result that you cannot reproduce. Because you are missing something about the animals. If you love the animals you enjoy and the experiment is the only real last step of the process."* (Fortunato, 2019)

Fortunato nurtures these animals to enable them to be healthy for experiments. This means having an intimate knowledge of what makes them happy and also ensuring their environment is the ideal ecology for them to be healthy (see Figure 24). This level of intimacy allows the organisms to go beyond being a mere object, or experiment, where the scientist has a sensorial awareness of their subject matter.

One of the methods Fortunato uses to analyse the behaviour of his model organism, the *Placozoa*,[19] is by creating hand-drawn plots of their movement patterns on acetate which is fixed to their tank. This drawing method is very time consuming and could be achieved in a fraction of the time through a mechanical process, such as digital camera tracking. However, this labour-intensive analogue process allows the scientist to study the movement more intimately on a daily basis. Every hand-drawn dot makes a physical connection with the scientist of that particular moment of time and where the body was in relation to its environment. The scientist's analysis of the subject matter is not only looking in from the outside, but they also see the body from the inside, with the help of the microscope (see Figure 25). This allows for an experience that goes beyond what we would perceive from just looking at an object from one angle. As Merleau-Ponty (2012) describes this way of seeing, where we rediscover the origin of an object, where it becomes a moment where you enter into the universe where the beings show themselves. This is the point in which the body of the scientist withdraws from the objective world, where the scientist unites their body with the perceived studied organism and their world. This can be illustrated further by Fortunato exploring the organism under the microscope, where he perceives

[19] The Placozoa (*Trichoplax adhaerens)* is the simplest multicellular organism. Fortunato is studying Placozoa as there have been no reports of cancer in this organism.

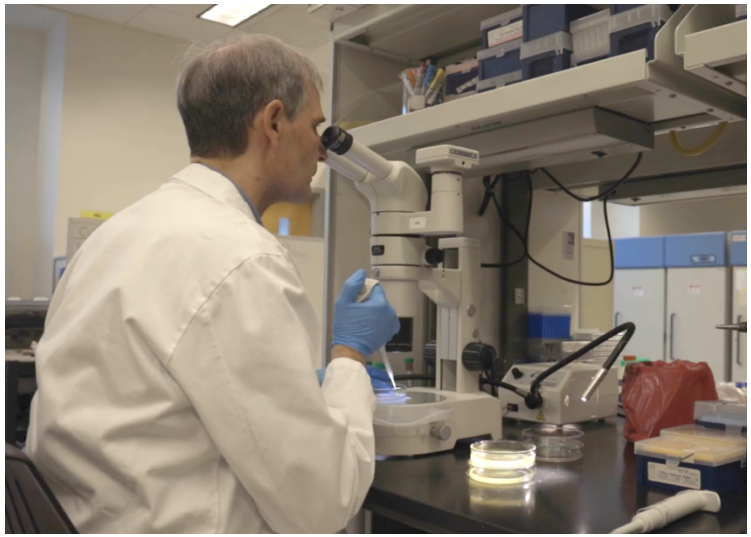


Figure 26: Observing Fortunato at work examining the Placozoa. A still taken from boredomresearch documentary 'For We Are But A Single Cell' (2020) Images credit: boredomresearch

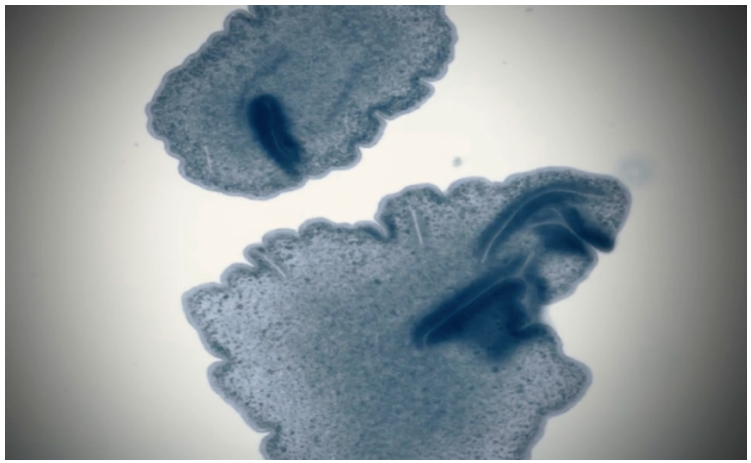


Figure 27: Placozoa under a microscope in 2019. A still taken from boredomresearch documentary 'For We Are But A Single Cell' (2020) Images credit: boredomresearch

the subject as well as the subject's world. The microscope enables the scientist to experience all the bodily matter where it is not hidden. It provides a tool where you can zoom into the subject on a petri-dish and the scientist's gaze can inhabit this hidden world (see Figure 26). During that observational moment, through the microscope, the body of the scientist is experiencing the organism's world. Fortunato describes this as a sensorial experience, that touches upon the profound:

> *"If you think of the Placozoa we assume that these animals are 500 million years old or even more. And when you are looking at these animals under the microscope it's an incredible feeling for me, to know the past, you have a real time machine. When you start to work with the microscope you feel to be part of what you are looking at. You are inside these petri dishes."* (Fortunato, 2019)

It was this personal experience of observing the model organism, *Placozoa*, under the microscope (see Figure 27), that inspired the artistic concept of the *Chemozoa,* boredomresearch's speculative fictional organism. Our computer-generated *Chemozoa* are designed as small simple multi-celled organisms (see Figure 29) that experience the same disease process, cancer, that touches so many lives.

With the dynamics of cancer programmed into their cells the *Chemozoa* are designed to survive in toxic environments that act as an analogue for chemotherapy. The artificial physiology of the *Chemozoa* does not differentiate between healthy and unhealthy cells and therefore no clear distinction can be made between cancer and body. As such the *Chemozoan* escaped the existential crisis of experiencing an internal conflict between healthy and unhealthy, self and other characteristics of cancer.

The film narrative of *In Search of Chemozoa* was scripted by myself and Smith to enable the different research components from the two cancer research laboratories (computational modelling and psychology) to be combined. The script purposely excludes scientific language but instead adopts a suggestive poetic voice to capture some of the rich emotional value that both underlies and motivates the scientific research. The narrative is based on the struggle of the *Chemozoan* which affect their own chemotherapeutic treatment by feeding on toxic algae but also focuses on their action of feeding, helping to balance their own environment (see Figure 28 which depicts the toxic algae, the larger red glowing crystal-like forms inside a Chemozoa).

The final film addresses the importance of health as a holistic part of a wider perceptual awareness of the interrelatedness and symbiosis that is not just confined to looking inside an organism's body

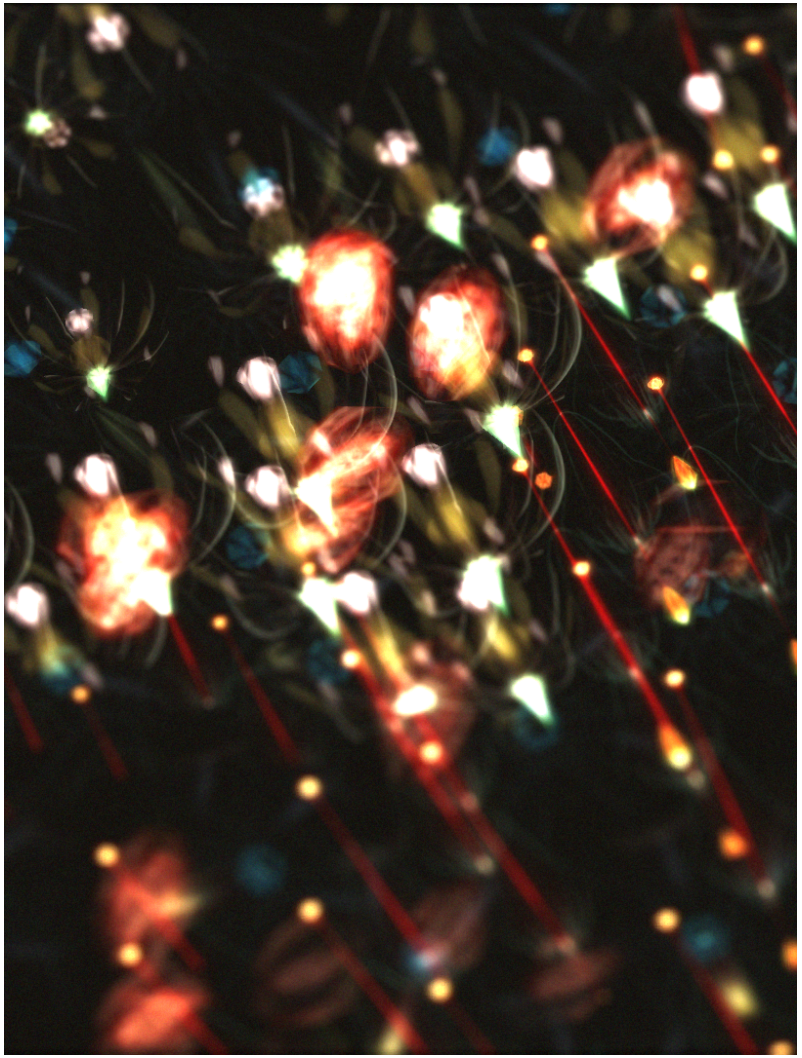


Figure 28: A still from *In Search of Chemozoa* where the camera is inside a *Chemozoa* so the viewer can experience the cellular bodily environment and the toxic algae that is circling inside the organism (2020) Image credit: Boredomresearch

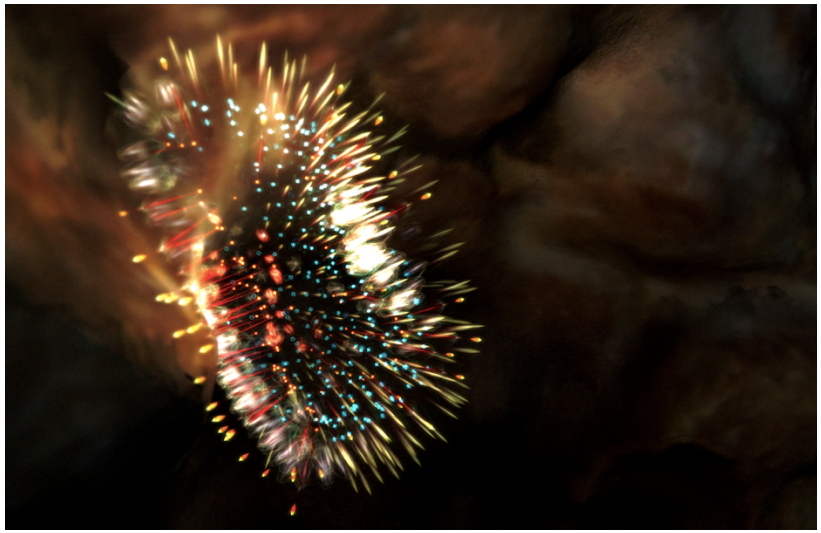


Figure 29: A still from *In Search of Chemozoa* depicting the whole fictional organism (2020) Image credit: Boredomresearch

Figure 30: A still from *In Search of Chemozoa* depicting the external seascape environment (2020) Image credit: Boredomresearch

but also, how it is subject to the health of the environment outside the body (see Figure 30). Sabin (2022) succinctly describes this relationship between body and environment in the *Chemozoa* artwork:

> *"This is a story about adapting to and living via toxicity through embodied knowledge of the environment. The analogy of chemotherapy is thus extended to encompass notions of environmental health, from one 'chemical regime' to another."* (Sabin 2022, p.248)

This creates new value in the consideration of health from both a natural and biomedical perspective. Nature is used as a point of inspiration in a biomedical context. Biomedical insight into health is used to better understand our connection with nature outside the body. *In Search of Chemozoa* allows us to reflect on our own relationship with conflict, foregrounding the benefits of balance in the management of singular identities made of conflicting parts. A philosophy that extends beyond the health of the individual to encompass the health of our societies and our sustaining natural environment.

"The rules that govern life and ecosystems are the same whether that is inside the human body or outside…This powerful film inspires people to think about how we are all part of the same natural world."

Dr. Marcin Pekalski[20] (Wellcome Sanger Institute, 2021)

Figure 31: A still from *Call of the Silent Cell* natural forest environment (2021) Image credit: Boredomresearch

4.3 Art Reveals Sensual Awareness of Challenges on our Environment

This section presents an analysis of the artefact *Call of the Silent Cell* in response to the question: *How can sensual aesthetics in art address challenges of both our bodily and environmental health?* This section addresses how Boredomresearch has made connections between elements of complex single cell analysis research in immunology, for the purpose of human health and combined with the interrelationship of environmental health. The research and development process for *Call of the Silent Cell,* responds to our science collaborator, Dr. Marcin Pekalski's research on immunological dysbiosis[21].

From our anthropic position, often concerns of the health of our own body seem to be prioritised before the health of our natural environment, such as the forest in *Call of the Silent Cell* (see Figure 31). It is integral that this gap between the onus we place on our own body from the concerns we have with our environment is reduced, where we can appreciate that the interrelationship between these two ecosystems, the body and its environment, are integral to each other. It is surprising that we are still having to argue the significance of the symbiosis of our

[20] Our science partner, Dr. Marcin Pekalski's response to the artefact *Call of the Silent Cell* in a Wellcome Sanger Institute interview in 2021.

[21] ScienceDirect defines dysbiosis as *"a reduction in microbial diversity and a combination of the loss of beneficial bacteria."* Accessible at: https://www.sciencedirect.com/topics/medicine-and-dentistry/dysbiosis [Accessed 24 February 2022].

natural environment and the human body. This was eloquently exposed by Hippocrates in his theories in the publication *Air, Water, Places*:

> *"Their voices are rough and hoarse owing to the state of the air, which in such a situation is generally impure and unwholesome, for they have not the northern winds to purify it; and these winds they have are of a very humid character, such being the nature of the evening breezes."* (Hippocrates 5th or 4th Century B.C.E)[22]

This is just one of many arguments Hippocrates poses in regards to the integral implications of air, water and our environment on human health. We do not have to go back centuries to realise the instrumental consequences of the Anthropocene on our human and natural environments and how these can lead to diseases. The Coronavirus disease pandemic is just one illustration of a global event where we are experiencing the consequences of what happens when we start tampering with our natural ecosystem. In this case leading to a zoonotic virus spillover event into the human population on an epic scale. If this symbiosis between human and natural environmental health is so integral, how is it that the majority of scientific research is still conducted in silos? Human and natural health research is still conducted in separate scientific research departments. Voss (2016) states when discussing C.P. Snow's antagonistic 'two cultures' of art and science that there are powerful structural factors, both educational and political that continue to separate the disciplines into distinct communities, including: *"educational streams forcing specialisation for both, with the sciences demanding a long and difficult training period of narrowing focus and enculturation of workers"* (Voss 2016, p.206). This specialisation goes even further as it is also happening within the separate disciplines, for example in the science field it can become difficult for researchers working in the field of human health to collaborate with for example a nature conservation scientist. This is where artists can be catalysts to bridge these silos in the science world and make connections between different focused departments to enable interconnectivity.

Here my examination will use a particular case-study, the practice-based artefact, *Call of the Silent Cell* to analyse the significant implications of creating a visual aesthetic expression that reunites the disparities between human and environmental health concerns. This artwork takes the immune system as its primary focus. A bodily ecosystem that is an extremely complex and dynamic system, which constantly has to adapt to our shifting internal and external environment. For example, our internal bodily environment can be rapidly lost, as in

[22] In Britannica it states that Airs, Water, and Places was originally written in the 5th or 4th Century BCE. Accessible at: https://www.britannica.com/topic/Air-Waters-and-Places [Accessed 23 February 2022]. The exact date is still unknown.

the case of cancer, where cells establish a counter environment that can literally destroy the body as a whole. Through our collaboration with Dr. Marcin Pekalski, an immunologist at the University of Oxford, our discourse revealed dynamics on the body as an environment, which contains an intricate ecology of microbial life.

> *"The human body can be thought of as an environment, a landscape that harbours whole ecosystems of life. Our bodies are home to communities of microbes - trillions of bacteria, fungi and viruses reside on our skin and in our guts. These environments within and outside our bodies intertwine, influencing each other from the moment we are born."* (Wellcome Sanger Institute 2021)

This microbial flora until recently has been invisible to us and therefore largely ignored. The population of microbes in and on the human body was mostly considered to be vast and largely unknowable (Blaser 2014). Only very recently has the curious scientific gaze been equipped with the technology that allows us to perceive this hidden world.

> *"Moody and dark, Call of the Silent Cell highlights the importance of the human body consisting not only of human-cells but also being an extended natural ecosystem that evolved with microbes (microbial flora). Changes to natural ecosystems and to human nutrition drive changes in the composition of our microbial flora (dysbiosis) and can induce (among other diseases) autoimmune reactions."* (Pekalski 2021)[23]

The microbial flora inside our bodies is central to our existence, where it can affect our mood, behaviour and health. We usually think of our body as one entity but yet our body is a whole ecology of cells and microbes that contains a diversity comparable to our external natural world. In the *Call of the Silent Cell* film the viewer is transported into the body during a storm of cellular behaviour known as a 'cytokine storm.'[24]

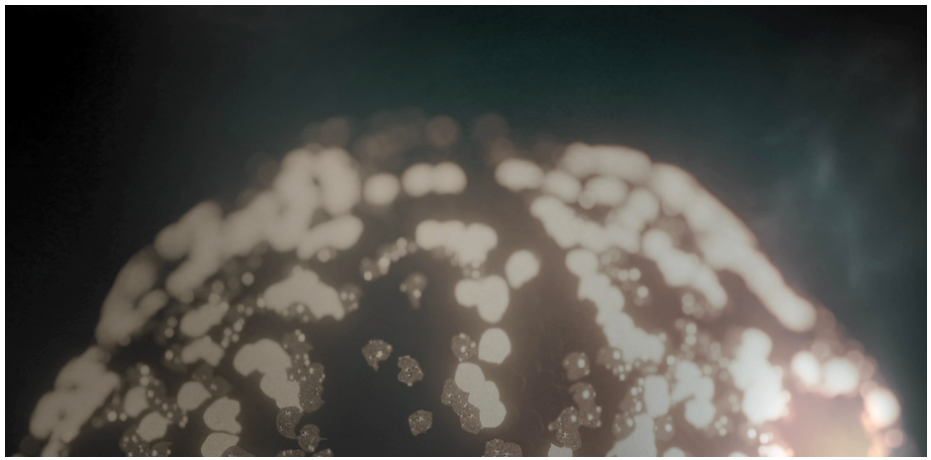


Figure 32: A still from *Call of the Silent Cell* depicting a detail of the 3D cytokine storm sequence (2021) Image credit: Boredomresearch

[23] Dr. Marcin Pekalski's feedback on *Call of the Silent Cell* in an email correspondence to Boredomresearch in 2021.

[24] Cytokines are substances that are made in our cells and signal to the immune system. For example, they may indicate an infection is under way so that your immune system can launch a response.

A cytokine storm can occur when something goes wrong and your body releases too many signals. This can cause the immune system to overreact and damage otherwise healthy cells. In *Call of the Silent Cell,* you see an animation of bright cells that are responding to signals of infection, where waves of light flow repeatedly over the same area (see Figure 32). This happens because we have changed the rules of the simulation to work like a broken immune system. The artwork explores how human changes to their environment lead to a depletion of biodiversity and how this in turn leads to a similar loss of diversity in the human gut ecology that is a driving force behind many autoimmune responses. Drawing links between ideas that happen at the level of the cell in the human body and the effect humans are having on external environments that in turn impact the health of the planet and subsequently impact on our human health. As Pekalski describes in an interview for a Wellcome Sanger Institute (2021) article *"This powerful film inspires people to think about how we are all part of the same natural world."* Through art, audiences can step out of the objective world and consider complex scientific research through a sensorial expressive lens which raises awareness of the interconnectivity of our body and our 'more-than-human'[25] world.

Figure 34: A still from *Call of the Silent Cell* where the camera is moving through the gastrointestinal tract where you can view the dynamic behaviour of the animating bright cells (2021)
Image credit: Boredomresearch

[25] Coined by David Abram (1996) in his publication *'The Spell of the Sensuous: Perception and Language In A More-Than-Human World'* as a way of referring to earthly nature.

> *"And since the genesis of the objective body is but a moment in the constitution of the object, the body, by withdrawing from the objective world, will carry with it the intentional threads that unite it to its surroundings and that, in the end, will reveal to us the perceiving subject as well as the perceived world"* (Merleau-Ponty 2012, Part One: The Body, Part B, para.2).

Merleau-Ponty's theories originally published in 1945 present philosophical arguments that our bodily and external worlds are interconnected and when you really see an object you are mentally and bodily inhabiting its world. He argued how objective science can make us lose contact with perceptual experience. *Call of the Silent Cell* considers the body not as *"one unitary being but a forest braced against a storm."*[26] In the film the storm is an animated expression of a cytokine storm happening in the body, where the body's immune system goes into overdrive causing inflammation and damage (Wellcome Sanger Institute 2021).[27] This visual expression enables a poetic materiality of this cellular landscape where we can aesthetically experience this complex system. The viewer is taken on a sensorial journey through the gastrointestinal tract where they can perceive this dynamic environment (see Figure 34). The film also reflects on camouflage and mimicry, Pekalski uses these concepts to describe how gut bacteria 'hide' from the human immune system to escape destruction (see Figure 35) or how gut bacteria trick the immune system to be accepted as self (Wellcome Sanger Institute 2021). These concepts allowed for the boundaries of the different environments to be blurred in the film. The fluid cinematography purposely allows for the body to be perceived as a landscape and the landscape to become body.

Figure 35: A still from *Call of the Silent Cell* depicting the hidden peppered moths that act as a metaphor for the camouflage that is happening in our bodies (2021) Image credit: Boredomresearch

[26] This is a line from the narrator's script myself and Smith wrote for *Call of the Silent Cell.*

[27] A Wellcome Sanger Institute blog article (2021) where boredomresearch and Dr. Marcin Pekalski was interviewed on the *Call of the Silent Cell* project. Online at: https://sangerinstitute.blog/2021/11/03/a-cellular-landscape/ [Accessed on 14 February 2022]

> *"The setting is amazing and it is scientifically 100% true as you reveal the truth that many scientists are blind to: we are vulnerable to changes in the established ecosystem. What is especially important when you are exploring the human body at the level of single cells. I think the fact that microbiome-immune interaction is a foundation of the most common diseases we deal with, is extremely important to tell (to general public). The single cell level narrative here works very well when combined/portrayed in the context of its ecosystem. Much more important than looking at cells out of context"* (Pekalski 2021)[28].

This aesthetic expression has been created to share some of the apparent relationships between ways of thinking about health at the level of the cell and more available ways of thinking about natural imbalance brought about through human modification of natural environments.

> *"Ones own body is in the world just as the heart is in the organism: it continuously breathes life into the visible spectacle, animates it and nourishes it from within, and forms a system with it."*(Merleau-Ponty 2012, Part Two: The Perceived World, para.1).

Art is the perfect medium to reunite the objective sciences with our experiencing body, where we can visually express our sensorial perception of science. In art there is no limit to how we interpret the world. We do not have to conform to real physics. In computer animation artworks, we can fly through objects and we can be transported into the human body. This enables our gaze to withdraw from the objective world, where we enter an imaginative space. Creating a phenomenon that allows for our sensing self to be transported into a perceptual experience of a bodily landscape. This interdisciplinary process has enabled me to have as Abram (1996) describes a 'lived experience' of the scientist's world.

Figure 36: The *Call of the Silent Cell* script being created in Boredomresearch's studio from interview excerpts with Pekalski (2021) Image credit: Boredomresearch

[28] An excerpt taken from an email from Dr. Marcin Pekalski after viewing an early development sketch of Boredomresearch's *Call of the Silent Cell* film in 2021.

This has been steered through Boredomresearch augmenting, generating and provoking an interdisciplinary reflective discourse with the scientist on his practice. As seen in Figure 36 which depicts the working process of developing the film script from interview excerpts with the scientist. Abram (1996) posits Merleau-Ponty's argument that the meaning of scientific knowledge is dependent upon our lived experience of the world:

> *"The whole universe of science is built upon the world as directly experienced, and if we want to subject science itself to rigorous scrutiny and arrive at a precise assessment of its meaning and scope, we must begin by reawakening the basic experience of the world of which science is a second-order expression."* Merleau-Ponty (1945 cited by Abram 1996, p.36).

The world that Merleau-Ponty refers to is the natural world, he is describing how our knowledge of science would be meaningless without a basic understanding and experience of this world. The artefact *Call of the Silent Cell*, brings a perception of our experience of scientific research and combines it with our sensorial lived experience of the external world. This is demonstrated in my aesthetic model (see Chapter II, Section 2.2.2, Schema 3, p.46) where we can see that the artist is perceiving the science practice and the output from the observations of the scientist's perception of the world. In *Call of the Silent Cell* the environment is set in an external world, the forest, in winter when the trees are sparse and bare (see Figure 37). The artists perceived this environment when we were filming the content for the artwork; we experienced the smell, sound, feel of this forest landscape.

Figure 37: Still from *Call of the Silent Cell* film in the winter forest environment Image credit: Boredomresearch

We also combined this world experience with our perceptions of the science research to intertwine the concept of our bodily and environmental health. The narrative of the film emphasises this symbiosis, between the life of the forest and our bodily health as demonstrated in the line in the film *"I see now, a forest, hidden by its trees. As my body is veiled beneath its skin."* This line is narrated in the

film when there is a medley of different bodily and environment images from leaves to macro shots of hands, allowing the viewer to perceive these individual components as a collective experience where the body and landscape elements become one singular reality.

Figure 38: Studio image, mapping the interdisciplinary research, for Call of the Silent Cell's narrative and structure (2021) Image credit: Boredomresearch

4.4 The Value of Aesthetic Expressions within Interdisciplinary Research

This section responds to the following question: *What is the value of aesthetic expressions of science?* This is a reflection on how the practice-based artefacts critiqued in the above sections have enabled new knowledge in the field of art and science interdisciplinary practice. How the artefacts have been embedded in programmes world-wide, being utilised as best practice methodologies of bridging art and science. The following text provides a reflection on how this research can be used as a model for artists that are emerging in the field of art and science interdisciplinary practice.

The process myself and Smith adopted within the film *Call of the Silent Cell* was produced predominantly through our research collaborating with immunologists (see Figure 38). The Human Cell Atlas (HCA) science that was underpinning the art and science interdisciplinary process, is focused on mapping the cellular landscape of the human body through single cell analysis. We envisaged this science research as providing us with a perspective that allowed us to see ourselves more as we see the natural world around us, consisting of complex interacting parts. Boredomresearch was interested in how we could create a visual expression to encapsulate the symbiosis of these two entwined environments: the landscape of which we are an individual part and the landscape that forms our individual selves. To gain a full

picture of the two landscapes, both in the body and nature, it was integral for the artists to have discourse with a scientist that was immersed in research exploring the ecology of our natural landscape. Mark Blaxter was the scientist of our choice, the lead for the *Tree of Life* Programme at the Wellcome Sanger Institute, he brings together a network of genome scientists, biologists, conservationists and bioinformaticians to investigate the process of evolution through genomics (Wellcome Sanger Institute 2022). Blaxter was in a privileged position to understand the worlds that span these two extreme environments on a molecular level. Surprisingly, there was some resistance that arose from the Wellcome Sanger Institute HCA team, where we had to justify why we wanted to interview a scientist that wasn't researching 'human' health. The essentiality of this meeting was obvious to us but large-scale science institutions have a need to be protective as they consider their reputations especially within the context of their governmental and funding criteria. When an artist is commissioned for an art and science interdisciplinary project especially if the commissioner is a reputable science institution, often the artist also becomes an ambassador for the science research project, to a point where this can be a contractual obligation. Therefore, artists can be groomed by the scientific institutions for what they say and do in a public arena during the research, development and production stages of the practice-based research. To retain the integrity of the art it is instrumental that as artists we develop an open and honest relationship with the producer or curator that is leading the interdisciplinary project. At times during these projects, I have conversed with the project leads about particular approaches that Boredomresearch want to undertake that are instrumental for the visual expression of the science that could be perceived as sensitive in a scientific context. As Bello states in a Creative Capital (2022) panel discussion, it is vital that artists continue to inspire change and transformation where they can be mirrors and echo what is happening in the society and if necessary, go against it with their humble tools.[29] As artists that transport ourselves into different scientific contexts such as moving from artificial life, conservation, human health, ecology etc we are in an advantaged position to make connections between the different specialisms. But this is only an advantage if we can express these connections within the final artefact. We can only express truth if we have freedom to channel our intuition that comes from the *lived experience* of immersing ourselves in scientific methodologies and approaches. Xavier Cortada an interdisciplinary artist, whose practice is focused on environmental issues, discusses the importance of truth in interdisciplinary research in the Creative Capital (2022) discussion:

[29] Monica Bello stated in the panel discussion:*Creative Capital Event - Ecologies of Meaning in Art, Science & Technology Collaborations* on the 19 January 2022. Online at: https://www.youtube.com/watch?v=6AoDY86uTjc [Accessed on 14 February 2022].

> *"We need to value the interaction between artists and scientists. We both try to understand our world through truth. Finding truth. Both of us are disruptors. Aiming to disprove what happened before. I don't believe that either artists and scientists accept our world, as we can imagine it differently"* (Creative Capital 2022).[30]

Xavier continues in this discussion to argue that the interaction between art and science forces us to speak out of our silos (Creative Capital 2022). This interdisciplinary voice enables us to reimagine our futures through an expressive medium. Here, the body of practice-based research is a model for artists that are emerging in the field of art and science interdisciplinary practice to appreciate how sensual awareness of scientific processes can be embedded within artefacts to bring a new sensorial language to the scientific field, an expressive voice that is not usually heard in the objective scientific world. Pekalski (2021) reflects on the importance of the *Call of the Silent Cell* narrative, enabling people to understand the science intuitively, where he feels we *"really have achieved a scientific objective combined with magical poetic narrative."* Through this collaboration we created a fiction of cellular behaviour within a computer-generated visual expression (see Figures 39 and 40), using the language of the moving image to amplify and celebrate the as

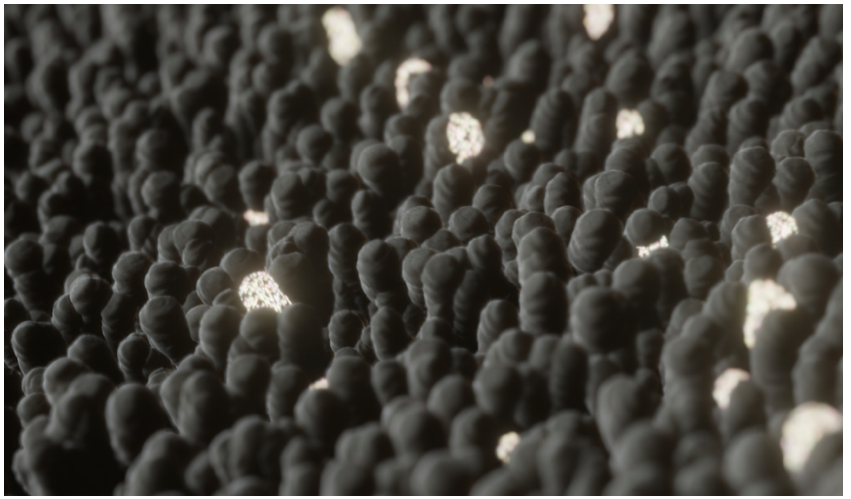


Figure 39: Still from *Call of the Silent Cell* film depicting the intestinal villi, revealing a stormy sea of infection (2021) Image credit: Boredomresearch

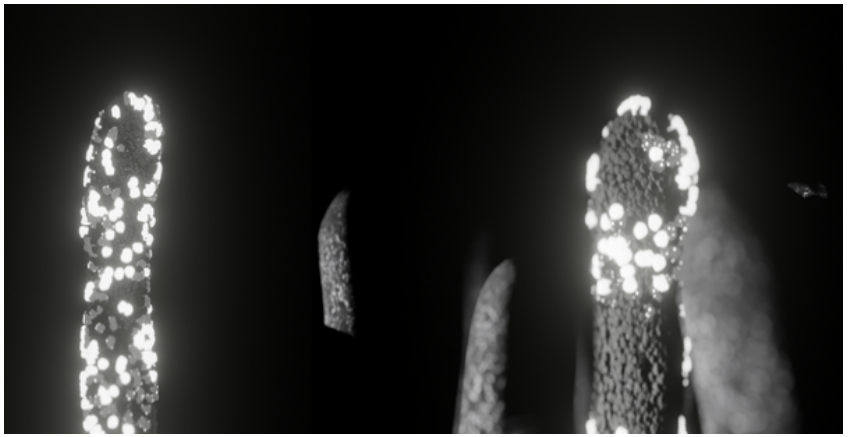


Figure 40: Test renders of cell signalling simulation in *Call of the Silent Cell* (2021) Image credit: Boredomresearch

[30] Xavier Cortada presented this theory in the same panel as stated in footnote 29.

yet unproven possibilities hidden in the hinterland of scientific speculation. It is integral for the next generation of artists to be emboldened by this body of interdisciplinary practice and to be confident to initiate new collaborative projects in this field. As demonstrated in my aesthetic model (see Chapter II, Section 2.2.2, p.44) the practice of both artists and scientists is similar; they both observe and study the world and both create computational models before dissemination of their research. However, the practices are radically different in regards to how artists communicate their research. As Ede (2000, p.22) states artists turning to science, force a human perspective into those chilly disorientating environments, placing human concerns and imaginative perspectives at the centre of their work. In my aesthetic model (see Schema 3, p.46) there is no scientific implementer, as the interdisciplinary research is usually funded through an arts organisation, so there is more freedom to approach the project from a non-governed perspective.

Once the science institutions realise the potential of how an artist can augment new knowledge and connections this will enable a more fluid integration of art within scientific arenas. In an ideal world we will have a future where it is standard practice for an artist to be in residence within science institutions and a funding stream to enable these fruitful interdisciplinary collaborations to flourish. Already we are seeing how Boredomresearch's body of interdisciplinary practice has enhanced the

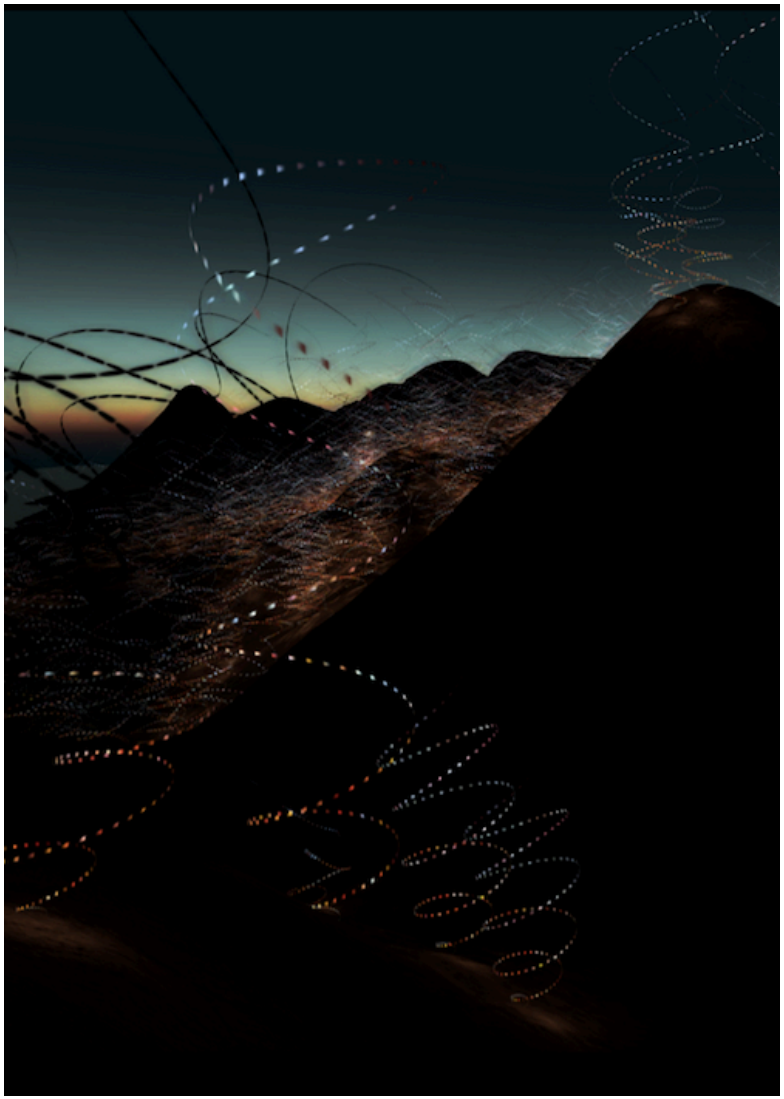


Figure 41: A still from AfterGlow (2016) depicting different states of the infection transmission scenario Image credit: Boredomresearch

development of new programmes. For example, Animate Projects, London have developed new initiatives informed by the research findings from the *AfterGlow* project (see Figure 41). In 2017, Animate Projects was invited by the British Council to facilitate a project entitled *Artience* in Daejeon,[31] Korea for the UK/Korea 2017-18 *Creative Futures programme*. Animate Projects incorporated both *AfterGlow* and methodologies from this interdisciplinary process in the *Artience* programme to inform best practice for art and science collaborations, highlighting how *"The UK has excellence and expertise in the convergence of art and science through years of experience"* (British Council 2017).

These practice-based artefacts and the discourse on the importance of interdisciplinary practice has allowed for a global audience and academics in the field of art and science to perceive the value of this research in addressing complex human and environmental concerns. This has been achieved through exhibiting the practice-based artefacts in many international public exhibitions (see Volume II - Practice-Based Portfolio, exhibition section for each artefact) including cultural art institutions in: Mexico, Arizona, California, Colombia, Seoul, Singapore, Shanghai, Amsterdam, London, Berlin and many more. The dissemination of the interdisciplinary methodology of this body of research has been presented in international symposiums and conferences. For example, Boredomresearch's keynote for Creative Futures and Radical Futures Symposium at the University of Brighton (2021) where *In Search of Chemozoa* was used as a case-study to discuss the advantages of artists collaborating with scientists and the role of interdisciplinary practice in addressing complex scientific research.

This section has provided a reflection on how my execution and practice of producing aesthetic expressions has created value by: combining separate scientific silos of research to come together through the production of an artistic artefact; evidencing how artistic interdisciplinary practice is integral for inspiring change and transformation; highlighting how this interdisciplinary practice has been utilised in international programmes and exhibitions as best practice in this field and demonstrating the value of interdisciplinary practice to provide a new sensorial language to the scientific field.

[31] Daejeon is a city in Korea addressing the importance of developing an arts and culture programme in the Silicon Valley.

Chapter V

CONCLUSION

Even though many scientists recognise an urgent need to engage audiences with their scientific concerns, insights and implications there still remains no clear methodology for translating the complex activity of cutting-edge scientific research into cultural artefacts. As Ede (2000, p.55) states *"the science world has recognised that it can be misunderstood by the public and has highlighted the need for positive initiatives to enhance the public understanding of science."*

Throughout this body of research, it has become evident that artists and scientists share similar processes in their practice (as shown in Chapter II, Section 2.2.1). They both apply their experienced perceptions of observing and studying the world through their creative and technical practice. This allows both practitioners to have unique perceptions through their intent observation and absorption of their subject matter. Both art and science practitioners employ technology, such as computation or a mastered artistic medium, to communicate the complexity of our world. They both create visual renderings to share the significance of their underlying process. However, in artistic practice, there is a greater acceptance of differences between interpretations, while in science, a singularity of meaning is enforced by strict protocols

which aim to ensure immutable translation. Individuals lacking the necessary key to unlock this value remain outside its field of influence. Much science communication fails to recognise the value of art in providing polysemous expressions with which the growing disconnection between experts and lay people can be overcome (Isley and Smith 2021b, p.167). This is why it is crucial for artists to act as ambassadors, to augment interdisciplinary art and science projects, providing the missing methodology to create cultural artefacts imbued with scientific insight for audiences to gain from an experiential perspective of the science.

This thesis outlines the epistemic framework, the aesthetic model, that has led to the creation of four original practice-based artefacts and a unique interdisciplinary process, providing an original contribution to knowledge in the following ways:

- The creation of an original interdisciplinary methodology that has provided the scientists with a new perspective on their work. These art and science collaborations, have enabled scientific partners to be receptive to new ideas and approaches, bringing a new sensorial language and expressive voice that is not usually heard in the objective scientific world. The aesthetic model has provided new insight and knowledge for scientists and pushed boundaries beyond what is 'scientifically justifiable.'

- Framing science from an aesthetic landscape context has been crucial in forming new innovative connections within different scientific fields. This framing has enabled the science to break from silos and consider the interrelationship between the health of the ecology of our body and our environment. Science studies generally focus on specialist areas, often ignoring the wider picture. Through making these artworks, scientists have been able to consider their biomedical research in the context of wider ecological concerns.

- The creation of four original aesthetic expressions has provided non-experts with unique visceral experiences not present in scientific visualisations and communication methods. The practice-based artefacts enable an audience to gain a sensual perception of science, that is usually hidden, through visual expressions that use aesthetic language and do not alienate the viewer.

This body of research shows how interdisciplinary practice can liberate an audience to sensorially perceive the science which is embedded in art

from their unique perspectives[32]. The aesthetic model (Schema 3, p.46) shows how there are no boundaries to how an audience interprets science. Scientists have recognised the validity of this collaborative approach where there can be multiple interpretations to their research, where a uniquely individual sensuous description maybe as true a version of reality as a peer-reviewed set of averages (Ede 2005, p.194). Through expressing the science through an artistic process, individuals are not limited to experiencing the underpinning science through objective communication. As presented in this research, the scientific model (see Schema 1, p.42), requires an external implementer, whereas the aesthetic model affords an individual subjective experience of the science. This highlights how through the process of the aesthetic model an audience can have agency over their perceptions of the embedded science. The aesthetic model has led to the materialisation of practice-based artefacts, that are new aesthetic expressions addressing scientists' sensibilities. Where the four artworks contained in this study provide a new experiential and temporal expression of the underpinning science research.

The aesthetic model is a formation of the process of collocation between the artists and scientists that has already had meaningful impact in the world, evidenced in the below:

- Students and academics, in the field of art and science, have gained knowledge from this interdisciplinary collaborative process. For example, Lucy Sabin has written a chapter on *In Search of Chemozoa* in the Routledge Handbook of the Digital Environmental Humanities (2022).

- Science institutions have utilised the research to show best practice within the interdisciplinary field and to secure funding for future interdisciplinary projects. This has enabled Arizona Cancer Evolution Center to use the *In Search of Chemozoa* project as a case study to receive further funding to set up their new Cancer Art Program.

- The practice-based artefacts in this portfolio have been screened internationally, with three of the artefacts receiving awards including: *Call of the Silent Cell* receiving Best Film and Best Artist Film Awards in Southampton Film Week (2022); *In Search of Chemozoa* receiving the Best Film Award at Sigma Xi STEM Art and Film Festival (2021) and AfterGlow won the moving image Lumen Prize award (2016) that celebrates the very best art created with technology.

[32] Shown in Schema 3, p.46 - depicting the audience and their perception of the world.

My aesthetic model (see Schema 3, p.46) has been produced through this body of research, where the interdisciplinary art and science processes have enabled a valuable combination of perceptions from both the artist and scientist. This cross-disciplinary convergence has allowed a diverse audience to sensorially experience visual aesthetic artefacts that embed oblique scientific research. The above outputs have enabled complex scientific research to be presented to an audience so they can gain a unique visual experience of the underlying scientific research. As evidenced in the Analysis Chapter IV (Section 4.1.2), my interdisciplinary practice has maintained the integrity of the art, ensuring that aesthetic sensorial expressions of the science were produced rather than the art being produced for illustration purposes or in the act of implementing a standard scientific imaging or visualisation method.

Lotman (2011) describes how artists have the ability to transform an abstract idea into reality, where artistic models can become *"a unique combination of scientific and playtype models, which simultaneously organize both the intellect and behaviour."* He highlights how this form of modeling creates a *multi-layered* and *performed* response, where an audience can experience elements that cannot be *"transmitted by any other means."* The interdisciplinary approach here has applied a provocation methodology by *"questioning assumptions and introducing alternative perspectives and interpretations"* (Forbes 2015, p.334), allowing scientists to gain a new aesthetic appreciation of the materiality of their research. This study has enabled me to augment, provoke and become a mediator[33] of the science. Exploring the unknowns, discarded theories and societal consequences of the scientific research has resulted in novel aesthetic expressions that are deeply poetic and philosophical, where *"The sentiment of beauty is not only able to trace cultural values but, as a corollary, also changes to the existing epistemic framework"* (Heinrich 2016, p.78). As Vyazovskiy (2019) stated in his reflection on *Dreams of Mice,* the art can sit outside of what is currently possible in the science community, becoming "*a dream of neuroscientists."*

[33] These different roles which artists play in interdisciplinary projects have been summarised in Chapter III, Section 3.1.1, p.49 on Forbes (2015) framework.

CHAPTER VI

INTRODUCTION TO PORTFOLIO: VOLUME II

Alongside this thesis is Volume II: Portfolio of Practice-Based Artefacts, as a hardcopy and an online version (see link below). This contains my practice-based research, supplementary descriptive text and audio-visual documentation on the four practice-based artefacts: *Dreams of Mice*, *AfterGlow*, *In Search of Chemozoa* and *Call of the Silent Cell* that are analysed in Chapter IV. The portfolio on each artefact contains:

- **Context:** a brief summary of how the interdisciplinary collaboration and project was established;
- **Description:** a short descriptive text, providing an outline of the core project concepts and how the project relates to the central research themes discussed in Volume I;
- **Methodology and Approach:** a reflection on my contribution to the project research and development methods and how these were new approaches.
- **Research Development:** a pictorial and video-based overview of some core developments during production.
- **Exhibitions & Awards:** an overview of the exhibitions, awards and screenings of the artefact;
- **Final Artefact:** a weblink to the final artefact, all films contain audio (please listen through headphones for best experience);
- **Supplementary Material:** links to online project specific supplementary material including: conference papers, video documentaries, interviews and artist presentations.

Please click here to access the online portfolio.

Please note it is best to view the online portfolio as the hard copy submitted is just for reference and does not have the video embedded.

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