Matters of Liveliness and Other Absurd Scenarios

By: Guy Ben-Ary, Gemma Ben-Ary, Kirsten Hudson, Boryana Rossa, Tanya Visocevic and Nathan Thompson

"The cyborg is a kind of disassembled and reassembled, postmodern collective and personal self." Donna Haraway [i]

Introduction

I believe art plays an important role in encouraging engagement with, and critical reflection on, a unique cultural moment where we are witnessing the unprecedented evolution of bio-technologies and various modes of liminal lives that defy traditional understandings of life. Interested in how art has the potential to initiate public debate on the challenges arising from the existence of these liminal lives, I create artworks designed to problematise current and emergent bio-technologies' influence on the shifting forces that govern and determine life, death and sentience. [1]

I am an artist and core researcher SymbioticA, the Centre of Excellence for Biological Arts at the University of Western Australia (UWA). Since 2001 the biological laboratory has been my art studio - where the creative process takes place - and tissue culture, tissue engineering, electrophysiology, microscopy and other biological techniques have been my artistic mediums. My research is inter-disciplinary and the production of artwork usually involves the collaborative effort of artists, scientists and engineers.

Image 1

[1] Throughout this paper, the word "I" denotes Guy Ben-Ary. However, this paper is a result of a collaborative writing effort between Guy Ben-Ary, Gemma Ben-Ary and Kirsten Hudson.

Boryana rossa participated in writing the text for the snowflake, tanya visocevic for the living screen and nathan thompson for cellf.

My research explores a number of fundamental themes that underpin the intersection of art and science; namely life and death, cybernetics, and artificial life. I consciously approach processes capable of transforming bodies or living biological material from artistic, philosophical and ethical perspectives, and I make use of new scientific and cybernetic technologies to create artworks that re-evaluate understandings of life and the human body. In my work, I use bio-technologies in a subversive way, attempting to problematize them by putting forward absurd and futuristic scenarios. Visual strategies are employed to help lure viewers into exploring the artworks in a manner that draws viewers into a dialogue about the future of these technologies, and encourages them to re-evaluate their own perceptions and beliefs. This paper examines the conceptual frameworks and methodologies that underpin my artistic practice with reference to major projects completed over the last decade: *MEART*, *Silent Barrage*, *The Living Screen*, *In-Potentia*, *Snowflake* and *cellF*.

Image 2+3

Liveliness

In 1999 I collaborated with the Tissue Culture and Art Project [2] on the development of a work entitled *The Stone Age of Biology* in which muscle cells and neurons were grown over miniaturised replicas of pre-historic stone tools[3]. This led me to the realisation that I could grow biological neural networks in-vitro, and monitor them via time-lapse photography in order to effectively visualise their growth over long periods of time. Observing the activity of the neurons as they grew, interacted, transformed, formed new connections, and reorganised themselves spontaneously into neural networks, caused me to wonder about the internal nature of the cells, and whether I might be able to influence, or interact with them in some way. My 'discovery' of electrophysiological techniques offered various interfaces and means to interact with the neural networks.

Image 4

Electrophysiology makes it possible to record and monitor the behaviour of neurons. More importantly, the electrophysiological interface gave me a glimpse into the state of the neural network and the way that individual neurons were interacting with each other. It also

[2] The 'Tissue Culture and Art Project' are Oron Catts and Ionat Zurr, and during the years of 1999-2003 I collaborated with them. (http://www.tca.uwa.edu.au)
[3] http://www.tca.uwa.edu.au/pastIndex.html

gave an impression of the ways that the neural networks respond to external events via stimulations. This moment in my research is crucial, as it marks a point whereby I shift focus to attempting to match bio-engineered neural networks to artistic, robotic bodies, in other words, matching a 'brain'[4] to a 'body'. For me, 'matchmaking' these 'brains' with the most appropriate robotic forms or 'bodies' originates from the urge to highlight the liveliness of these almost invisible neural networks and to manifest their erratic existence through movement and behaviour.

Terminology

It is important to note, that my use of the words 'brain' and 'body' are in the context of my artwork. I do not grow real brains in vitro, rather two dimensional neural networks that consist of around 50,000 neurons. Brains consist of an average number of 100 billion neurons interconnected via trillions of synapses, not factoring in the complexity of thought, intent, memory and 'personality'. Thus the 'brains' of my projects are essentially symbolic. However, I use real living neurons deliberately, as a way to force the viewer to consider future possibilities that neuro-engineering and stem-cell technologies present, and to begin to assess and critique technologies not commonly known outside of the scientific community. However simple or symbolic these brains may be, they do produce quantities of data, and they do respond to stimulation, and they are subject to a lifespan. The term 'brain' when used in this paper in relation to my work, refers only to biological neural networks grown and supported in-vitro.

Ethics

Oron Catts, co-founder and director of SymbioticA, claims that he feels a sense of unease whilst working with dissociated neurons, or 'bits of brains', more than with any other type of tissue. This sense of unease draws him back to the lab to try to understand exactly why such research provokes an instinctively unsettling feeling. I sympathise with this sentiment, and agree that when working with neurons, ethical questions are raised in regard to consciousness, intelligence and sentience. Questioning neurons' ability to feel pain is valid,

[4] I recognise the terminology of 'brain' is problematic and will clarify the use of this terminology in the following paragraph

whilst also understanding that the neural networks I create, currently only exist in a symbolic realm. Other ethical questions that drive my research are: what directions will current and emergent bio-technologies take us in the future, and what are our responsibilities to the liminal lives they create? What kind of ethical boundaries will need to be established around these living liminal entities? Following Catts and Ionat Zurr who state that "it is important to critique the use of neurons for computational devices and the possibility of the creation of a sentient computer,"[ii] I believe artworks using neurons have the potential to evoke or elicit responses in regards to shifting perceptions surrounding understandings of 'life'. By bringing possible scenarios to life, neural artworks confront the viewer, both instinctively as well as intellectually, by calling into question the liveliness of the differential categories of life and death, human and non-human.

Robotic Embodiment as a Strategy

The processes I use to bio-engineer the brains for my artwork are ,in some ways, very similar to the process of developing robotics, as they have the same three cornerstones; hardware, software and sensors. The bio-technologies that are used to bio-engineer the neural networks are:

Hardware: This could be better described in this practice as 'wetware'; neurons are grown and maintained in-vitro using tissue culture and tissue engineering techniques.

Software: Stem cell technologies, mainly Induced Pluripotent Stem cells (iPSc) which assist in reprogramming and converting cells to become stem cells, allowing them to be differentiated into any other cell type, such as neurons.

Sensors and interface: an electrophysiology system consisting of amplifiers connected to a specialised Petri dish, the Multi Electrode Array (MEA) hosting the living neural network. These dishes consist of a grid of electrodes that can record the electric signals that the neurons produce and at the same time send stimulations to the neurons – essentially a read-and-write interface to the brain.

Image 5

My original aim in embodying the brain with robotics was to highlight the liveliness of microscopic neural networks, and to manifest their erratic existence through movement and behaviour. Compelled to provide a manifestation for the brain by giving it a robotic body, the electrophysiological interface allowed me to establish a feedback loop between the robotics and the biological brain, and thus create an autonomous cybernetic entity. To me, the entities that I create represent the fears and hopes of humanity as we enter into an unknown future, as they illustrate, in a highly visceral manner, popular ideas surrounding around disembodied consciousness and intelligence. Mention of disembodied brains and discussions surrounding what constitutes 'consciousness' is found across diverse philosophical discourse such as Plato's allegory of the cave and René Descartes' evil demon. The relationship between material 'brain matter' and consciousness also enters discussions surrounding cybernetic theory, as well as frequently appearing in science-fiction stories. However, although the neural entities I create might instil in the viewer a sense that science-fiction is close to actualising the manufacture of intelligence or consciousness, in reality, the existence of these creatures is intended to be absurdly vicarious.

Image 6

MEART - The Semi-Living Artist

MEART – The Semi-Living Artist (originally titled *Fish and Chips*) was the first neural robotic entity I created in collaboration with Phil Gamblen, Dr Stuart Bunt, Oron Catts, Ionat Zurr and Iain Sweetman. In 2000, Phil Gamblen was an artist in residence at SymbioticA, and was developing artificial muscles as part of his research into bio-mechanical processes. Conversations with Gamblen led to the idea of providing a robotic form of embodiment to a bio-engineered neural network to create a brain-machine hybrid or a cyborg. As we became more interested in the manifestation of neural data via movement or robotic behaviour, we invited Dr Stuart Bunt, a neuro-scientist[5] at UWA to join the discussion, and it was he who confirmed the biotechnological feasibility of these ideas. Later, Oron Catts, Ionat Zurr and Iain

[5] Dr Bunt has a lab in the school of Anatomy & Human Biology, UWA and was then the scientific Director of SymbioticA.

Sweetman joined the three of us in developing a project we titled *Fish and Chips* that later on evolved to be *MEART - The Semi-Living Artist*[6].

Image 7

MEART - The Semi-Living Artist is an installation distributed between two locations in the world. Its brain of dissociated rat neurons in culture was grown on an MEA dish in Dr Steve Potter's laboratory[7], while the geographically detached robotic body resided wherever the work was exhibited, sometimes in different continents. The body consisted of pneumatically actuated, insect-like robotic arms capable of drawing on paper. These robotic arms were designed and constructed by Gamblen and inspired by natural and biological structures such as bone and muscle fibres. A camera located above the drawing captured the progress of drawings created by the neuron-controlled movement of the arms. The visual data was then sent back to the lab to instruct stimulation for the electrodes on the MEA that hosted the brain and the response to the stimulations was then sent back to the robotic arm. The geographical remoteness of the brain and body was overcome by the Internet, acting as an extended nervous system. Thus the brain and robotic body communicated with each other in real time for the duration of the artistic activity, providing a closed loop communication for the neurally-controlled semi-living artist.

Neuro-engineers usually make robots that perform utilitarian tasks such as navigating; however, *MEART* was given the very non-utilitarian purpose of being an artist. Assigning *MEART* a non-utilitarian task allowed us to engage viewers in discussions about the future use of neuro-engineering technologies, as well as to raise questions about the nature of future semi-living entities that may potentially be conscious, sentient, or creative. Throughout its public exhibitions *MEART* had a specific task - to draw portraits of viewers. *MEART* explores the cognitive dimensions of 'seeing' by converging what it sees into representation. Thus the optical element, the digital camera, instructs the mechanical element, the robotic arm, how to draw via the interpretation of the wet element, or neurons. Unlike human artists, there is no knowledge in the arm itself[iii].

[6] The collective who developed *Fish and Chips* and *MEART* was known as the SymbioticA Research Group.

[7] Dr Steve Potter is an Associate Professor in the Laboratory for neuro-engineering at Georgia Tech, Atlanta, USA. Potter and his then-PhD student, Douglas Bakkum, were our scientific collaborators and played a major part in the development of *MEART*.

Image 8

After exhibiting *MEART* and the portrait series a few times the work was developed further. Douglas Bakkum, a PhD student in Potter's lab at that time, who worked closely with the team on the development of *MEART*, suggested changing the task given to the neural networks. He observed that human portraits are of a complexity that the neurons may not be able to cope with, and that a simple geometric shape such as a square might be better. At the same time I was in conversation with Bulgarian artist, Boryana Rossa, who was writing a text juxtaposing *MEART* with Malevich's famous Suprematist artwork, *Black Square*:

Black Square is considered to be the beginning of a new and redefined art form. The Suprematist paintings are projects for, and instruments of, a new universe and a new system of the world. The Suprematist canvases were sign-projects, containing images of the technical organisms of the future Suprematist world. *MEART* is a real futuristic organism, an organism existing in reality, a realized project of the futurist's and Suprematist's dreams.[iv]

Following conversations with Bakkum and Rossa, the team decided to engage *MEART* to reproduce the *Black Square*. The visual properties of the work were a factor in this decision, as well as the conceptual value of the artwork, as a continuation and contribution to this significant work and its place in art history. A video camera, the sensory input and the 'eye' of *MEART*, was set up to observe a video recording of the painting, captured in the Tretyakovsky Museum, Moscow. By reducing the input to the neurons to a simpler shape, *MEART*'s task was made simpler, and it was able to cope with the data more efficiently. This allowed for an examination of the relationship between input and output, and the possibility of detecting behavioural patterns. This outcome satisfied many criteria, both scientific and artistic. *MEART* was a proof of concept, showing that it was possible to create a coherent feedback loop between the bio-engineered brains and a robotic body, and to use the artistic processes as a metaphor to raise questions about the potential of semi-living entities to be emergent or creative.

Image 9

Paul Vanouse describes *MEART* as presenting:

[A] collage of contradictions that are designed to create cognitive dissonance in its viewers, and it forces them to re-evaluate their own perceptions and beliefs. Its authoritative

complexity simultaneously convinces us of its technological re-engineering of cognitive processes, while also calling attention to just how far it has strayed from generally held conceptions of life, intelligence or creativity. *MEART* is the ultimate Cartesian dualism; a machine body completely removed from its brain and to complicate matters even further the brain has been reconstituted in vitro from its cellular components.[v]

This accurately describes our aims for *MEART* and underlines the way in which the artwork serves to assist the viewer in engaging in a critical reflection on notions of life and sentience.

Art and science collaboration

The mode of collaboration which was set up with Steve Potter and Douglas Bakkum was unique in that both the artists and the scientists were fully engaged in the development of the project, and explored the same questions from different perspectives. In an early e-mail, Potter writes "Your project is very exciting to me for a number of reasons. It is very similar to mine, in hardware and goals. It combines art and science, and I am very interested in both and their overlaps. It addresses an important aspect of my work that I have had a very hard time addressing: How should the lay public think about these things?"

Oron Catts, in an interview with Emma McCrae in 2006, described the collaboration between the artists and scientists in *MEART* as being a true collaboration; in other words, both parties engaged and explored possibilities, rather than exploiting the skills of the other for their own purposes.[vi] Whenever *MEART* was exhibited, there were always two parallel experiments being conducted. One side of the experimentation was the artistic, cultural exploration by the artists, and the other was a scientific experiment recording data and drawing conclusions in alignment with Potter's own research. The scientists tried to increase their understanding of the fundamental mechanisms that underpin the behaviour of embodied neural networks in-vitro.

One notable finding for the scientists was related to Potter's research into the way neurons behave when growing in vitro. Potter writes:

We noticed that a culture that was being used to control *MEART*, after days of receiving stimulation fed back via the internet from its video camera eye, began to calm down, showing less and less epileptiform activity. We found we could quell the barrages of activity in all of our cultured networks by sprinkling low-frequency pulses of electricity across the network, delivering via the substrate electrodes."[vii]

Interestingly, this discovery, made by the scientists while observing one of *MEART*'s cultures responding to specialised stimulations, was one of the focal points of a subsequent project with the same collaborators: *Silent Barrage*.

Silent Barrage

Image 10

In 2006, Gamblen and I were invited as research fellows to Dr Steve Potter's lab, one of the eight laboratories for neuro-engineering in the Coulter Department for Bio-Medical Engineering at Georgia Tech. This proved to be a pivotal development which provided a significant advancement in both the creative and technical aspects of our work. The outcomes of the research, alongside Steve Potter, Douglas Bakkum, Riley Zeller-Townson and Peter Gee[8], eventuated in the production of a major project and artwork entitled, *Silent Barrage*. Up until 2006, communication between the artists and the scientists in the Potter laboratory was based purely on email exchange, so it was a remarkable experience for us to finally access the lab, and become part of the scientific environment of our collaborators.

Silent Barrage is similar to *MEART* in its basic architecture; a cybernetic entity that is assembled from a bio-engineered brain that grows over an MEA interfaced to a robotic body. However it has a different narrative and set of aesthetics, and the development and creative process during *Silent Barrage* also differs from *MEART*. Being in Potter's lab allowed us, the artists, close proximity to the brain. We began to understand the brain better, and become acutely aware of its fragility and the complex process involved in growing and nurturing it. Moreover, we became familiar with the experiments being conducted by the scientists, and these interactions were creative triggers that led to the development of some of the essential narratives that underpin *Silent Barrage*.

During the residency in the Potter lab my aim was to focus on learning about the process of growing neural networks on to the Multi Electrode Array (MEA) interface. The phenomenological experience of making a brain in Potter's lab, coupled with experimentation

[8] When Douglas Bakkum graduated and left the Potter Lab, Riley Zeller-Townson took his place in the *Silent Barrage* team. Peter Gee, an engineer, also joined the team. Both were instrumental in the development of *Silent Barrage*. Dr Nathan Scott, an engineer, and Brett Murray, a programmer, also assisted in the production of the work.

with new ideas for robotic embodiment, being conducted at the time by Gamblen, led us to develop the aesthetics of *Silent Barrage*. We also realised how important the MEA dishes are to the scientists; each scientist had their own dishes, and each had developed a unique relationship with them. An email from Potter in 2001 sums up this unique relationship:

> [We were] a bit reluctant to 'anthropomorphise' them, and that naming them was my idea […] The name goes with each dish, which usually serves for several successive cultures, usually lasting several months, and in one case, for about two years. […] It is difficult not to feel the cultures are 'alive' since we use many of the same terms we use for living animals, say, like 'feeding', 'growing', 'keeping warm', and that the behaviour of the cultures is complex and dynamic, as is the structure. We go through hours if not days of 'mourning' if a workhorse culture dies from getting infected or other mishap. And the excitement of seeing a new culture fire great signals for the first time must be like seeing your baby take its first steps.

During this residency we observed that the scientists spent days upon days looking down the microscope, observing the cultures and using many different visualisation techniques to illustrate the events that continuously occur in the MEA dish. It became apparent that the dish was a microscopic arena for a neuronal performance. It was at this point that we decided to create a 'parallel magnified immersive space' within which the robotic body could perform. We tried to create a space evocative of the MEA so that viewers could walk through *Silent Barrage's* brain and thus experience its complexity and chaos.

Image 11

As the viewer approaches the space housing the robotic body of *Silent Barrage*, thirty two robotic components can be heard and seen, as they move vertically up and down the columns of PVC piping. At 2.4m in height, these columns tower above the viewer and are arranged in a grid-pattern across the gallery floor. As the robotic parts navigate the columns, they leave traces around their circumference with a pen pressed against sheets of paper wrapped around each column. These drawings are the robotic body's translation and representation of information received from the bio-engineered brain hosted on one of the MEA dishes in the Potter Lab. But the origin of the mark-making has another layer of complexity because the audience plays a crucial role; there is feedback between the audience and the neurons. The viewers are invited to step into this immersive space and move around the chaotic robotic objects, and through their presence in the space, the viewer communicates directly with the neurons. Cameras are located on the ceiling to capture the movement of the audience, and

this information is fed back to the brain as stimulations. In response, the neurons produce their own electric signals that are then fed back to the robotic objects to enact their kinetic choreography and mark-making activities, and draws further attention from the viewers. This process occurs in real time. The drawings on the poles are unique to each individual neural network, and more importantly, they trace and record the interaction between the viewer and the brain.

Image 12

The scientific research conducted in Potter's lab during the residency in 2006 inspired us, and became central to the development of *Silent Barrage*. The scientists were researching specialized stimulations in order to calm unwanted bursts, or barrages of activity, to try and enhance the functional plasticity in the cultured neural networks. In other words, they discovered that once the neurons formed a network over the MEA, they showed spontaneous epileptiform activity; a similar thing happens in the brain of a patient experiencing an epileptic seizure. These barrages of unwanted neural activity may originate due to the chaotic natures of the disembodied neurons and disturb the neural network with the processing of data. Potter and his research team managed to overcome this problem by sending specialised stimulations to the networks to calm them, and enhance their functional plasticity, increasing the possibility for learning.[viii] These experiments contributed to our vision of multiple robotic objects arranged in an immersive environment in which we ask the viewers to generate stimulations to the neurons by moving through this environment. Thus the viewers, in a symbolic and poetic way, are helping cure the dysfunctional brain from its epileptic properties by walking through the space and being among the poles. The viewers help to 'silence' the 'barrage'.

In-Potentia

In 2008 the media became saturated with news of the development of a new stem cell technology known as Induced Pluripotent Stem Cells (iPSc). The iPSc technology was pioneered by Professor Shinya Yamanaka who showed that the introduction of four specific genes could convert adult cells into pluripotent stem cells. Yamanaka was awarded the 2012 Nobel Prize, along with Sir John Gurdon, for the discovery that mature cells can be reprogrammed to become stem cells. In layman's terms, the iPSc method transforms adult

specialised cells into a form that is equivalent to stem cells, which are capable of becoming any other type of cell in the body (skin, liver, muscle, neuron, etc.). The process involves re-programming their 'software' (genome), and coaxing them back into their embryonic state. The discovery of this biological alchemy intrigued me. Questions regarding how we are able to deconstruct, manipulate and re-assemble the microscopic building blocks of life in completely new ways, as well as the increasing ethical dilemmas[9] and discourses associated with iPSc, gave me a new insight into how malleable and fragile our bodies really are.

Around this time, I also had a conversation with Boryana Rossa who criticised artists using the biological material of other species. She questioned the ethical aspect of this practice and asked why human material was not being used. I had to concede that *MEART* and *Silent Barrage* both relied on mouse and rat neurons grown over the MEA interface, a standard scientific practice, as human brain cells were (up until this point) out of the question, as there was no way to harvest brain cells without causing fatal harm. However, the discovery of iPSc technology appeared to offer a way to safely use human cellular material. By re-programming human skin cells using iPSc, it seemed that I would be able to create a brain from scratch; hacking into the skin cell's software, manipulating the genetic make-up of the cells and from there, craft the building blocks necessary for the creative process of 'brain-body' making. *In-potentia* was the first project I produced, in collaboration with Dr Kirsten Hudson, Mark Lawson and Dr Stuart Hodgetts, where I was able to experiment with the new technology of iPSc in order to create a human neural network/robotic body entity.

For *in-potentia*, as we were interested in problematizing iPSc technology, we selected human foreskin cells as a starting point to learn the iPSc technique, with the aim of reprogramming them into stem cells, and then into brain cells. We aimed to highlight the absurdity of the scenario; to reverse-engineer foreskin cells, and from this material, create a living 'brain', and so the project was affectionately given the working title of 'Project Dickhead'. By positing an absurd scenario (transforming foreskin cells into neurons), *in potēntia* not only challenges the belief that iPS helps resolve the ethical dilemmas surrounding human embryonic stem cell

[9] Initially, iPSc was hailed as the technology that would help resolve some of the ethical dilemmas associated with embryonic stem cell harvesting, but it is now clear that it merely transformed the ethical landscape of the field of stem cell research. Not only are there increasing concerns regarding the relative ease with which iPSc cell samples could potentially be taken from us, without our knowledge or consent, but more specifically, there are increasing concerns regarding the ethically loaded potential for iPSc technology to be used in the derivation of gametes; human reproductive cells, ie. sperm and oocytes

research, but also raises ethical concerns regarding the relative ease with which human cell samples can be obtained (such as the purchasing of foreskin cells from an online catalogue).

Image 13

It is important to note that foreskins obtained from circumcision procedures are frequently used by biochemical and micro-anatomical researchers to study the structure and proteins of human skin. In particular, foreskins legally obtained from newborns within a hospital environment have been found to be useful in the manufacturing of human skin for skin graft tissue, β-interferon-based drugs used in the treatment of Multiple Sclerosis as well as foreskin fibroblasts being used in much biomedical research. Moreover, human growth factors derived from newborns' foreskins are also used to make commercial anti-wrinkle skin cream. Therefore, not only is the purchasing (and selling foreskin cells) a legal enterprise, but it is also commercialised and internationally sanctioned; an accepted trafficking of human body parts, which while most of us know nothing about, we are still otherwise complicit. By transforming human foreskin cells into a functioning neural network, *in potēntia* not only raises awareness of the mythologies surrounding biotechnology – in this case, particularly iPSc and associated stem cell research – which are premised on notions of hope, authenticity and value, but also deliberately questions the commercialisation and commoditisation of the body at the hands of biomedicine.

Image 14

In creating *in potēntia*, we deliberately sought to resist the lab-based aesthetics of object-production. With this in mind, the brain of *in-potēntia* was encased within an incubator-like robotic body that was designed using an 18th Century aesthetic. The phallic, somewhat steampunk incubator was custom-made from hand-blown glass and polished timber panels, with aged brass fittings. This elaborate encasing concealed a bio-reactor that automated the process of feeding and clearing wastage from the living brain cells. There was also a DIY version of an MEA that converted the electrical activity from the brain into an unsettling sound-piece. In this work, unlike *MEART* and *Silent Barrage*, there was no feedback loop or interaction with the brain, and there was no expectation of 'body performance' other than simply keeping the 'brain' alive. Instead, we placed the brain on a pedestal, presenting it with the indifference of a museum specimen, or a piece of jewellery; something to be viewed, behind glass, feted, admired, and perhaps even feared.

Since the era of enlightenment, philosophers have attributed the human brain with a great deal of importance as the primary organ that determines life or death. Previously, ancient Egyptians and Greeks saw the heart as the primary organ that determined life, while early Christians and Hebrews believed life was indicated by the breath. However, when automated processes (breathing/circulation) were separated from sensation and volition (that was determined to be based in the brain), the move towards defining the brain as the pivotal organ of where life resides in the body began. Thus with Descarte's famous declaration "I think therefore I am", western philosophy established the anthropocentric belief that thinking is required before any living being can be granted human status. This distinctly modern philosophical paradigm placed the brain on a pedestal, and clearly marked the thinking brain as the primary signifier of individual existence or personhood within modern western culture. By literally placing a live, male 'brain' on a sculptural robotic pedestal that has been informed by the aesthetics of 18th century scientific paraphernalia, *in-potēntia* raises some interesting questions in regards to why we still seem to be ruled by an antiquated and distinctively modern historical form of personhood, and in turn, with *in-potēntia* we ask: what does it really mean to be alive and be human in the 21st century?[ix]

Image 15

Collaborative Re-Play: *The Living Screen and Snowflake*

As mentioned earlier, collaboration is an essential element of my art practice, and as a researcher in *SymbioticA,* all the projects in which I have been involved are in sympathy with the collaborative structure and philosophy fostered by *SymbioticA*. Rather than seeing art/science collaboration as one in which art is employed by science as a "legitimate tool to aid scientific research" to "communicate big ideas in an engaging and intuitive manner"[10], *SymbioticA* - instead positions the role of art as that which critically and openly challenges and critiques new scientific knowledge and application. Rather than seeing art as a tool that simply aids in the engaging visualisation of science knowledge, Catts asserts that artistic research should be 'valued for its own merits and its contribution to culture rather than be seen for its potential secondary outcomes of aiding or acting as a research and development

[10] . www.synergyexhibit.org

arms for other disciplines'[11]. The projects in which I have been engaged, thus emerge out of a rich, diverse, collaborative research community, which not only encourages a range of cross-disciplinary collaborative approaches that activate new forms of understanding and critical enquiry, but also encourages better understanding and articulation of cultural ideas around scientific knowledge and informed critique of the ethical and cultural issues surrounding life manipulation[12].

Due to the collaborative complexity of the projects in which I am involved, there have been times when two or three projects, often with varying theoretical, artistic and technological concerns, run parallel to each other. Although the projects discussed thus far have been primarily concerned with the construction of brain/body interfaces, I have also been involved in other projects, that whilst not focused on brain/body matching, have remained concerned with various modes of liminal lives and bio-material that defy traditional understandings of life, and/or problematizing the workings of biomedical technique/practice along with legitimating power structures surrounding socio-economic and bioethical apparatus'. Two such projects are *The Living Screen* (2005-2015) and *Snowflake* (2006/2015).

The Living Screen

The Living Screen is a collaborative project with Tanya Visosevic (an interdisciplinary artist, film critic/theorist and educator), that investigates the interface between biological arts (and related discourses) to film theory and cinema history. It explores the ways in which the nature of the spectator evolves and/or ruptures when the viewer interconnects with a screen that is alive. Originally initiated in 2005, *The Living Screen* shares the same artistic objectives of much contemporary cine-art: to deconstruct traditional cinematic forms that impose ideological constraints, and seeks to participate in the creation of new poetics made possible by fusing bio-technology into a living cinematic apparatus. Screens are grown or scavenged from different tissue sources, and Nano-Movies are projected over these living screens via the Bio-Projector that houses a digital projector, digital player, microscope and

[11] Oron Catts, *Through the Looking Glass*, www.anat.org.au/2010/07through-the-looking-glass-visualising-science-oron-catts/

[12] Oron Catts, Ionat Zurr, *White Paper – Biological Arts*, www.seadnetwork.wordpress.com/white-paper-abstracts/abstracts/biological-arts/

multiple optical lenses, and miniaturises the movie to 500 microns square in size. Viewers are invited to peep into the Bio-Projector, one at a time, to gaze at the mutation of the Nano-Movie and its inter-related living screen. The living screens react, transform and eventually die, contorting the projected nano-movie and intimately confronting the spectator by seducing them into thought surrounding issues such as actuality and virtuality, life and death.

Image 16

Over the last decade, *The Living Screen* project has been staged over ten times; each time making direct reference to cinema's heritage as a means to critically and aesthetically reflect upon the changing climate of the cinematic experience. Each time *The Living Screen* has been installed, each living screen has been symbolic and symbiotic in a different way, with the properties of these screens conceptually informing the content of the projected Nano-movies. For example, *The Screen Kiss* (2008) was produced for the living screen made from semen and was a remapping of Thomas Edison's *The Kiss (*1896), and its semen screen a reframing of Andy Warhol's *Blow Job* (1963). Whilst *The Barnum Butcher* was a film that referenced the story of Dr Eugene L. Doyen who recorded his operation separating conjoined twins Doodica and Radica Neik in 1902 and was projected onto a screen of living skin cells. Most recently, in NEUROPLASTIKA, the living screen was made from my own neurons (created from cells taken from a skin biopsy and reprogrammed into neurons using iPSc) with the Nano-Movie *Screen Thoughts: dreams of becoming a brain* created by Tanya Visosevic and soundtrack by Claire Panell.

Image 17 – Please insert Image of the living screen from Nervoplastika here

In discussing the possibility of using my own neurons for a new installation of *The Living Screen* for NEUROPLASTIKA, Visosevic was instantly aware of how this scenario puts forward Deleuze's notion that the 'screen is a brain'. She states:

For Deleuze, the brain is a screen and Thought is molecular... where the essence of cinema has thought as its higher purpose, nothing but thought and its functioning. What Deleuze does more than any other film theorist to date, is to open up the spectator to the transforming possibilities of cinema, the potentials of life affirming thoughts and new ways of being by figuring the brain as a screen[13].

[13]Visosevic, T. NEUROPLASTIKA: *The Living Screen*, 2015

Along with Deleuze's 'brain screen', when creating the Nano-Movie *Screen Thoughts: dreams of becoming a brain,* Visosevic was also conscious of Tom Gunning's idea of a 'cinema of attractions'. Rather than being a cinematic experience that evokes an involvement with narrative action or empathy with character psychology, Visosevic sought to create a Nano-Movie/living screen relationship as a site of confrontation where both the film form and its mode of exhibition addresses the viewer directly as a kind of 'death dream'. For NEUROPLASTIKA, this entailed a cinematic confrontation where the spectator is opened up to the transformative possibilities of cinema, the potential of life affirming 'thoughts' and the conundrum that comes from the awareness that whilst watching a living 'brain' screen and its neural activity, it is also in the process of dying.

Image 18

Snowflake

Cryonics is a field of research focused on the preservation of a body in liquid nitrogen, and presents certain hopes for those wishing to be cryogenically preserved in order to be 'awoken' in the future. The concept of cryonics was first introduced in 1962 by the founder of the Cryonics Institute, Robert Ettinger. In his books *The Prospect of Immortality* and *Man into Superman,* Ettinger places great hope in nano/bio-technologies to restore the tissues and ultimately revive frozen bodies, although it should be noted that science is yet to resolve issues surrounding how to repair vital tissues and in particular maintain the brain plasticity necessary for knowledge, memories and identity. Although, the concept of cryonics (and its social and cultural implications) has been widely explored in many science fiction texts it appears that our current times attempt to commercialize these yet-to-be-realised technologies via biomedical narratives of hope as well as fear.

Snowflake is an art object I created in collaboration with Boryana Rossa and Oleg Mavromatti that conceptually and materially examines the scenario regarding how biotechnologies can manipulate brain plasticity to create false memories, and the implications this has on the border that separates the physical and the psyche. In 2006 (when I was an artist-in-resident at the Steve Potter Lab in Georgia Tech principally for *MEART*), Rossa, Mavromatti and I initiated a project that was inspired (albeit differently to *MEART* and *Silent Barrage*) by how neural networks could produce and receive data and

stimulation. In *Snowflake* we decided to repeatedly stimulate neural networks grown from mouse neurons with the image of a snowflake, effectively trying to mold the network's plasticity, by bio-engineering the image of a snowflake into the networks' 'memory'. We then cryogenically preserved the snowflake "engraved" neural networks at -80°C, for an indefinite length of time.

Image 19

At the time of cryogenic preservation, none of us had yet to conceive of a definite outcome for these frozen neural networks that symbolically carried a memory of a snowflake. Nor were we able to take the neural networks with us once our residency was finished, as the frozen networks had to remain at -80 C. And so we had to leave the networks (artwork) behind, preserved and conserved in a freezer. However, 9 years later the freezer unit housing the frozen neural network broke down and the fragile material thawed and died.

When we were informed of the death of the networks, I was in the initial phase of thinking about works for NEUROPLASTIKA. The sudden death of these networks inspired Rossa, Mavromatti and myself to pay homage to the original project from 2006, however this time, rather than using mouse neurons, we decided to display in a liquid nitrogen container, a neural network made from my own neurons, which we stimulated with the same image of a snowflake before freezing them at -80 C. Assembled to evoke thoughts about the technological future, as well as where we are placed within the process of its creation, we ask in *Snowflake*, to what extent has cryonic technology changed the value of life? And what are the ethical and/or statutory considerations required to cope with external commercial interventions with memory and plasticity.

Image 20

cellF

Image 21

In 2012 I was awarded a Creative Australia Fellowship from Australia Council for the Arts to create a new project, a cybernetic self-portrait, entitled *cellF. cellF* started with the same 'new materialist' question, underpinned by the belief that artistic practice can act as a vector for

thought, that has informed all my projects: What is the potential for artworks using biological and/or robotic technologies to evoke responses in regards to shifting perceptions surrounding understandings of life, death, sentiency, and the materiality of the human body? However, for the first time, this project was also inspired by an ultimately narcissistic desire to re-embody myself. *cellF* is thus a progression of the past fifteen years of research conducted through various projects involving the process of developing robotic bodies whose aesthetics and function are informed by the specificity of each bio-engineered 'brain'. It also continues my interest in problematising bio-technologies and contextualising them within an artistic framework via the staging of absurd senarios. However, for the first time, the fellowship allowed me the time and space to develop my interest in exploring new and novel robotic self-embodiment strategies.

When conceptualising *cellF*, I was thus very conscious of dividing the project into two parts; the first, which posed enormous challenges regarding biological protocols, was to reprogram my own skin cells taken from a biopsy, transform them into neurons to create a functional neural network using iPSc technology, effectively creating my external brain independent from my body. The second part of the project was to develop a compatible robotic body to interface to my external 'brain'.

Image 22

In 2012 I had a biopsy taken from my arm, and cultivated the skin cells in vitro in the labs of SymbioticA at UWA, then froze them cryogenically and shipped them to Barcelona, where I collaborated with Dr Michael Edel.[14] In Barcelona, with the help of Edel, I reprogrammed the cells using iPSc and created stem cells, which began to differentiate and were pushed down the neuronal lineage until they became neural stem cells. These were frozen and shipped back to SymbioticA, where I, in collaboration with Dr Stuart Hodgetts[15] began to develop a protocol to fully differentiate them in an MEA dish[16]. Dr Douglas Bakkum[17] has also returned to collaborate again with me to assist with the decoding of the data received from the neurons.

[14] Head of the Laboratory for Pluripotency, University of Barcelona
[15] Director of the Spinal Cord Repair Lab, University of Western Australia
[16] Working with Edel and Hodgetts is another example of a close collaboration with scientists where both parties benefit from the research; the scientists are using the artistic cells for scientific purposes and this project has allowed them a unique opportunity to do so.
[17] Dr Bakkum is currently a group leader at the Department of Biosystems Science and Engineering, the ETH Zurich.

Dr Andrew Fitch[18] has custom-designed the synthesisers specifically for this project and in develop the interface hardware and other modules that are required to connect the MEA to the sound producing body. It was Andrew's skills and idea to keep cellF 100% analogue, or Wet-alogue, and eliminate the computers that were supposed to be part of cellF. Dr Darren Moore[19] has worked on the aesthetics and data mapping of the sound and Nathan Thompson joined the project as the designer of the sculptural object that houses the neurons and synthesisers (mini Biological lab) however he also played a major role in hacking and developing components that were needed for the project such as a tissue culture incubator and a class 2 sterile hood.

Image 23, 24

It is important to note that essentially, the brain/body entities I have been involved in creating over the last 15 years, have all emerged out of a desire to scramble habitual categories of thought – active versus passive, inert versus animate, political versus ontological, causality versus spontaneity, human versus non-human, forcing the viewer of those entities to think materially as well as ethically about our anthropocentric take on the world. Positioned at the intersection of art, science and society, I have spent many years 'messing around' with biological and cybernetic technologies as means to examine processes involved in the transformation of bodies or living biological material in order to re-evaluate our understanding of "life", sentiency, and the human body. Most importantly, the staging of absurd scenarios has been an attempt to critically question and examine how we interact, develop and maintain meaningful connections in a world where we are constantly barraged by information, technologies and idealisations.
Oron Catts in the catalogue text for *Silent Barrage* asks: "Can the pairing of cells and audience help make 'meaningful' connections?" This question of Catts is vital to my work as it points to my desire to match the most 'compatible' robotic body to a bio-engineered 'brain' in order to create the potential for new forms of interaction, or what could be called a kind of mediatic co-constitutional site of engagement. The liminal entities that I create thus function as sites of post-humanist performance that call into question the givenness of

[18] electrical engineer and an analogue synthesiser builder from Perth, owner of nonlinearcircuits
[19] experimental musician and lecturer at Lasalle College of the Arts in Singapore

the differential categories of human and non-human, subject and object, knower and known.

Therefore, in parallel to the biological work carried out in Barcelona and Perth, I also spent time considering the aesthetic aims of the *cellF* project; namely, what was the most compatible kind of interactive robotic body I could give myself? When thinking about what kind of body to design for myself, the idea of working within a humanist anthropocentric paradigm bored me. So whilst I desired a body that worked in synergy with my external brain, including a real time feedback loop and following the same hardware, software and sensors formula as other projects, the decision to create a sound-producing body was ultimately based on a long-standing passion for music, combined with my naïve childhood dream of being a rock star. With this in mind, essentially *cellF* has been designed to be a cybernetic musician; robotic sound-producing artwork or performative liminal entity that interacts with human musicians in a series of special one-off events. Human-made music is fed to the neurons as stimulations, and the neurons respond by controlling the analogue synthesisers, and together they perform live, improvised sound pieces.

Initial talks and brainstorming regarding the aesthetic and functional goals of *cellF*, were thus informed by a desire to contextualise the work from a musical perspective. In these conversations, Moore referred to several examples of significance. For example: the futurist, Russolo, in the early 1900's, wrote about the art of noise and was interested in expanding the sonic palette to include noise and noise-making machines; conceptually ahead of its time and not fully realised by others until the 1950's and 60's when synthesisers became more commonly used in music. John Cage's *4'33"*, 'silent piece', was also an important work in the conceptual development in the field of experimental sound-art; it emphasised the noise of the environment around the performance and the non-musical aspects around the music. David Tudor is also of significance, where in the 1990's, he combined the engineering of electronics with the inspiration of biology and developed a synthesiser that was controlled by an artificial computer coded 'brain', not made from biological matter, but closely resembling one in its activity and intention and used it to composed and play a series of works titled *Neural Synthesis Nos. 6-9.* In other words, Tudor's artificial neural network simulated the way real biological neural networks operate using a computer code and wired this to a synthesiser

to create sound. *CellF* builds on these precedents, and in particular takes Tudor's vision a step further from using an artificial neural network and making use of a real biological neural network to play electronic music.

Image 25

CellF has been designed to be a sound-producing 'body' comprised of an array of analogue modular synthesises. The aesthetics of the synthesiser, which are similar to that of an electrophysiological laboratory, fits my vision perfectly. Furthermore, there is a surprising similarity in the way neural networks and synthesisers work in that in both voltages are passed through the components to produce data or sound. There is also a practical consideration, the neural networks produce large and extremely complex data sets, and by its very nature, the analogue synthesiser is well suited to reflecting the complexity and quantity of information via sound. From these aesthetic, theoretical and functional positions, we moved to considering how the interactive element would be achieved. This included our desire for *cellF* to be:

- A stand-alone object in function and appearance.
- A physical, almost over-bearing presence both in a performative setting and a gallery space.
- Accessible and observed from all angles.
- Able to incorporate both music/sound production devices as well as house functioning lab tools for biological work such as tissue culture.
- Broken down into smaller parts, stacked and crated for shipping.
- Packed so that each piece/crate is able to fit through a standard size doorway.

Both in sound production process and neuronal cellular investigation, the amplification and alignment of signals in order to increase their facility is arguably the most important element in cellF. With this as a fertile bed of inspiration, the design took shape around the amplification chamber that blooms outwards from an endless internal loop. Informed by natural forms such as a floral stamen inversely curving, or a wasp's self-inflicting sting, we decided on a design that folds back and engulfs itself, shielded from intrusive irregular states while projecting its internal Lukasiewicz-like logic.

Aside from the complex brain - modular synthesizer interface that is at the heart of this project, other aspects have been equally as important for the success of the work as a whole. For example, the environment where the neurons are maintained needs to be controlled within tight tolerance. A constant 37degrees C at 5% CO2 is an optimum habitat to ensure the culture remains active and healthy. Although we looked for an 'off the shelf' incubator, none were of satisfactory size, so we decided to build our own with the help of Andrew Pelling from Pelling Labs[20].

Image 26

A sterile hood are also an essential element of *cellF*, both for worker safety and culture integrity. Sterile hoods offer an environment where cell culture work can be carried out without contamination. They come in various standard ratings and because we are working with human cells we are governed under the most stringent guidelines. As sterile hoods tend to be large, heavy and extremely expensive we were forced to build our own hood that complements *cellF's* aesthetic concerns as well as adhere to health and safety guidelines. In-cooperating the sterile hood to the final object allows me to maintain the cultures in sterile conditions (mainly feed them) in the gallery or performance spaces.

Finally, the analogue interface with my external brain was designed to be carried out at the mouth of the piece, what Nathan describes as 'the station of genesis but also its *sonitus ultimum*.' This encapsulating vessel positions and accelerates the non-binary values and with each pass, with each stimulation pulse, particles charge and axons grow. Interjecting and slicing this stream is the aerofoil control surface, a tactile plane situating the performer/observer at the very apex of wetware < > hardware collaboration, whilst laboratory procedures are carried out buffered by this internal flow path in a biologically sealed cavity. New cell cultures are prepared under the vibrationary influence of current active neurons at the interface, and an evolving dialogue of neuro-acoustic chatter infuses the protocol whilst synaptic memories pass along and through to future generations.

Image 27

Conclusion

[20] http://www.pellinglab.net/

Throughout my artistic career I have embraced an interdisciplinary position that involves in-depth collaboration and research with a variety of people in various disciplines. By engaging in an art-based methodology, I attempt to distil disciplinary knowledge and practices, allowing them to interact in synergy. The artworks presented in this paper, *MEART*, *Silent Barrage*, *in-potentia*, *The Living Screen*, *Snowflake* and *cellF*, all highlight my desire to create strongly subversive projects that problematize emerging biological innovations, materials and technologies, and critique them from a cultural perspective rather than a scientific one. In each, there has also been a deliberate attempt to set up absurd scenarios in order to problematise the very technologies, materials and practices I am using, in order to force viewers to look forward at possible future implications of technologies, as well as to look backwards in terms of how technologies have informed (and continue to influence) our belief in the givenness of categories. The discomfort I feel whilst working with dissociated neurons, or 'bits of brains' means that I am constantly confronted by ethical questions regarding past, present and future understandings of consciousness, intelligence and sentiency. This in turn had led me to an explorative art practice which is more about posing questions than providing answers. However, by 'messing around' with neuroscience, cybernetics and art (amongst other things) in order to match-make neural networks to compatible robotic bodies, ultimately, my aim is to critically question how modern western culture's institutionalisation and fetishisation of consciousness, which in turn (I hope) asks viewers to re-evaluate understandings of life, death, the human body, and sentience.

Image 28

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List of Images

Image 25 – cellF performing with Darren Moore
Image 26 – The class 2 sterile hood that is embedded into the cellF object.
Image 27 –cellF performance
Image 28 – Dish P9/07 – the neural network that performed in the word premier of cellF.
Image was take the following day in my Lab at UWA.