Connor, K., Fannin, M., Kent, J., & Toye, A. M. (2021). Blood Culture: Reimag(in)ing Life at a Cellular Scale. *Interdisciplinary Science Reviews*, *46*(4), 655-676. https://doi.org/10.1080/03080188.2020.1855377

Blood Culture: Reimag(in)ing Life at a Cellular Scale

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Additional information

Funding

This work was supported by NHS Blood and Transplant R&D and National Institute of Health (NIHR) to support the Blood and Transplant Research Unit (NIHR BTRU) in Red Cell Products at the University of Bristol in Partnership with NHSBT, and the University of the West of England (IS-BTU-1214-10032); a BBSRC/EPSRC grant (BB/L01386X/1); a University of Bristol Brigstow Institute Seed Corn Grant; and Public Engagement Funding from the University of Bristol BioDesign Institute. This manuscript presents independent writing funded in part by the National Institute for Health Research (NIHR). The views expressed are those of the authors and not necessarily those of the NHS, the NIHR, or the Department of Health and Social Care.

Disclosure statement

No potential conflicts of interest were reported by the authors.

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Word count (including notes and references): 8,991

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Abstract

This paper reflects on collaboration between an artist, a scientist and two social scientists involved in research on cultured red blood cells. Cell culture is part of a suite of methods used by bioscientists to study cellular processes outside of the living organism. The production of laboratory-grown blood is at the cutting-edge of cell culture and regenerative medicine, with hopes for significant therapeutic benefit in the future, particularly for patients with rare blood types or with conditions that require frequent blood transfusions. We reflect on our collaboration and on artistic experimentation with spatial dimensions of cells and scaffolds used in red blood cell culture, highlighting our efforts to generate knowledge that cuts across our respective disciplinary locations. We situate our work together in the context of the increasing molecularization of the body in science and medicine, and on the efforts to 'open up' scientific practice to multiple publics.

Keywords

blood, tissue culture, synthetic biology, art, body, scale, biotechnology, tissue economy

In this paper we build on previous discussions of interdisciplinary projects that explore how art, science, and social science can enrich understanding of new biotechnologies. The interdisciplinary work we embarked on started with a shared interest in red blood cells, as objects, as living entities, as therapies and even as potential commodities or resources. Our aims in this essay are threefold – first to discuss the development of new techniques to culture

red blood cells on an industrial scale for therapeutic use, second to present the artistic work that resulted from an artistic residency in the research laboratory where the objects of scientific study are red blood cells (erythrocytes), and thirdly to reflect on and theorise the interdisciplinary dialogue and co-construction of meaning that has shaped our collaboration which Calvert and Schyfter (2016) call 'emergent critique'. Our collaboration involved bringing together conceptual perspectives on the corporeal geographies of contemporary science and empirical research on transfusion recipients' views of a new blood technology. The rationale for our work together was to explore how geographical concepts such as *scale* and attention to *bodily interiors* informed scientific, social scientific and artistic practice.

We reflect on how bodily geographies and scales are at work in the scientific laboratory-based research to create marketable and industrially produced quantities of cultured red blood cells. Central to this analysis is the 'imag(in)ing' of scale – from the 'macro' scale of the population and the market to the 'molecular' scale, to draw on Nikolas Rose's (2001) use of the term, of the sub-cellular and the genomic. For Rose, the 'molecularisation' of science and medicine has involved an intensification of scientific efforts to modify life at the level of the gene, as well as an ever-closer relationship between the production of knowledge in scientific laboratories and the production of therapies by emerging life science industries. Across these scales, blood flows: within and across bodily boundaries through practices of donation and transfusion, through laboratory processes that transform cells into potential therapies, and across healthcare systems and national boundaries through national and global scale 'tissue economies' (Waldby and Mitchell 2006). We analyse the corporeal topographies that shape these flows. Located within the research laboratory, microscopic and other means of imaging are used to observe the processes of extracting haemopoietic stem cells from blood, and to analyse how cells and cell lines are manipulated, cultured, and cell populations expanded. Beyond the laboratory, artistic

practices consider imaging techniques as another form of epistemic enquiry seeing, as artist Katy Connor writes, 'human bio-matter as an art medium [that] opens up an intriguing cultural space to critically reflect upon relationships between biology and technology, materiality and ethics, as well as the production of new cultural meanings through metaphor' (Fannin *et al*. 2020, 31).

This paper therefore presents a case study of 'critical making' and imag(in)ing which includes the first-person narratives of a scientist (Toye) and an artist (Connor) and a collectively authored discussion that also involves two social scientists (Kent & Fannin). The genetic manipulation and culturing of red blood cells is a new technology being studied by the Toye laboratory in Bristol. Within transfusion services, red blood cells are currently extracted from donated blood for treatment of patients, but techniques developed in the laboratory enable the cells, once obtained from donated blood, to be modified, cultured and expanded *in vitro*. Our collaborative work focused on this innovation. While the scientists in the Toye laboratory carried out their work to better understand and modify red blood cell production, the artist spent a short residency in the Toye lab, and the social scientists conducted research on patient and public perspectives on cultured red blood cells.

A short account of red blood cell technology within global blood economies

From the perspective of social scientists interested in health technologies, the ambition to culture red blood cells in sufficient numbers to transfuse sick patients raises compelling questions about the relationships between bodies, science and health care systems. Our work considers how the red blood cell culture technology might transform relations within blood economies and impact how we think about bodies and blood donation. Blood is ubiquitous insofar as it runs through the veins of all of us, everywhere. Haemolytic diseases of the blood system (e.g. anaemia due to sickle cell disease or thalassemia) are also widespread and

treatments with blood products are well established across the world. Yet, as already discussed elsewhere, the shape of global blood economies is complex and marked by social and health inequalities (Kent & Meacham 2019). There is an extensive literature on blood donation as a social practice, exploring how social bonds and concepts of citizenship have been linked to ideas of donation as a form of 'gift giving' (Titmuss 1970; Shaw 2008; Bennett 2015). But despite discourses of donation as universalising, concepts of risk have excluded some groups from donation and some bodies are constructed as more 'risky' than others (Kent & Farrell 2015; Kent et al. 2019). Gendered, racialised and sexualised bodies are positioned differently within global blood economies. The preferred donor is traditionally a white, male, heterosexual body. In most countries, blood supplies are protected by screening, a form of 'biosecuritisation' and blood economies are far more complex than commonly understood, entangling politics and biology (Kent & Meacham 2019). Some people are excluded from becoming donors while others do not have access to health treatments.

In this context the promise of stem cell-based therapies has been widely debated. Innovation in the field has accelerated in recent decades and scientific efforts are directed towards addressing the challenges of greater control over biological processes of cell differentiation, proliferation and transplantation. Such attempts have claimed success in some areas (e.g. cell culture of eye tissue, knee cartilage) while others have provoked controversy and concern. There are many sources of 'stem cells' and historically hematopoietic stem cells (HSCs) have been sourced from umbilical cord blood and bone marrow and successfully used in the treatment of leukaemia and other blood disorders (Martin et al. 2008). More recently there have been projects to modify and culture red blood cells using stem cells from other sources including donated adult blood, human embryonic stem cells, induced pluripotent stem cells or immortalised cell lines. The Bristol laboratory has, in collaboration with scientists from the UK National Health Service Blood & Transplant (NHSBT), successfully

cultured red blood cells from adult blood and cord blood and most recently created the research grade (not suitable for clinical use at present) BEL-A (Bristol Erythroid Line Adult) cell line (Trakarnsanga et al. 2017). Additionally, the laboratory is interested in the scope for using manipulated red blood cells for drug delivery in the body.

At the time of writing, preparations for a clinical trial to infuse healthy volunteers with cultured red blood cells derived from adult blood are underway, in order to measure cell survival rates in the body (RESTORE project)[1]. This will be the first-in-human transfusion of red blood cells grown under manufacturing conditions. Producing red blood cells *at scale* presents many technical challenges and NHSBT is providing the infrastructure and expertise to meet manufacturing standards and regulatory requirements. The manufacture of red blood cells on an industrial scale is often referred to by media reports as producing 'synthetic blood' (Connor 2015). Interestingly the scientific ambition to produce cultured red blood cells on a large enough scale for transfusion is often framed in terms of addressing 'unmet need,' citing global shortages in the blood supply, and of the value in producing *a 'universal blood product'*. The latter underplays the significance of variations in health care systems and blood supply chains that would shape how any such blood product would be distributed and accessed by those in need.

In Bristol, the focus of the trial is to produce enough blood cells for use in patients with haemoglobinopathies such as Thalassaemia and Sickle Cell Disease, diseases that are ethnicised and found in relatively small populations in the UK (Carter and Dyson, 2011). In the UK considerable effort is being made by NHSBT to recruit Black blood donors to address shortages in certain blood groups (NHSBT 2017). But as we found in our research, Black and Asian populations have complex relationships to national blood and health care services. The target populations for cultured red blood cells are the very groups for whom social

[1] See http://www.bristol.ac.uk/btru/work/trial/ (Accessed 8/08/19)

acceptability of the technology may be uncertain (Hale and Kent in preparation). What emerges from our study of patient and public attitudes towards cultured red blood cells is that for some people 'the "pristine brand-new cells" are thought of as safer, and cleaner than donor cells' (Hale and Kent in preparation). While often scientists and others sought to emphasise that cultured red blood cells were similar (in human character) or equivalent to donated cells and that this enhanced acceptability for some groups, others viewed these cells as different from donated blood and therefore safer and 'less human' (Hale and Kent in preparation). However, some key stakeholders were unconvinced by the claim that cultured red blood cells could meet unmet demand for some patients, such as those with very rare blood groups, believing that current treatments were comparatively effective and higher costs wouldn't be justified if these new therapies were more expensive. Crucially, in this study, trust in the services of the NHSBT was viewed as most likely to ensure the acceptability of the new cultured blood technology. At the same time, the strong message that blood donation is still vitally important to sustain life and deliver effective blood services ran counter to media coverage which propagated a vision of the future as dependent on a universal synthetic blood product.

Disentangling the politics of 'synthetic blood' and working together within this team we start to see the significance of 'scale' for understanding cultured red blood cell technologies - moving between the molecular level of genetic manipulation and the microscopic level of cellular activity to the global science of blood therapies, from the research laboratory to the manufacturing facility, from bodily interiors to healthcare systems. Our project sought to make sense of these multiple scales of blood *culture* in the dual sense of growing and cultivating and of generating meaning. We sought through our interdisciplinary work to explore and map the spaces between bodily boundaries, laboratories, and clinical transfusion services and between art, science and social science.

Art-science-social science collaboration

There undoubtedly exists a strong lineage of artists whose research engages with cell and tissue culture directly, often in hybrid art-laboratory settings, three notable examples being the *Tissue, Culture & Art Project* (Oron Catts and Ionat Zurr, est. 1996) and works by Paul Perry (*Good and Evil on the Long Voyage* 1997), and Art orienté objet (*May the Horse Live in Me* 2010).

Our focus in this research comes through our shared mutual interests and experiences in synthetic biology, and in this paper we draw on observations made by others involved in this area of interdisciplinary work. In synthetic biology collaborations between artists and scientists have become more common, motivated in part out of a desire by synthetic biologists to engage publics with their research (Reardon 2011; Damm et al. 2013; Johung 2016; Ginsberg et al. 2014). Public engagement and public involvement in research have also increasingly become a requirement of funders and our collaboration grew from relations established in this way.

Art-science collaboration in fields such as synthetic biology may also be the product of commonalities between artists' and scientists' views of their respective practices. The 'design' elements of synthetic biology have affinities with artistic practices that lend themselves to shared interest in process and openness to unanticipated outcomes. More fundamentally, artists and scientists may both be involved in the production of artefacts through processes of experimentation (Calvert and Schyfter 2017). Art-science collaborations can raise intriguing questions about the role of social scientific work and point towards new directions for social science research involving scientists. Reflecting on their participation in an art-science project entitled 'Synthetic Aesthetics,' Jane Calvert and Pablo Schyfter consider how their role as STS researchers raises important questions about the identity of

social science approaches to science while also demonstrating the potential for learning from how artists and designers engage with scientists. They suggest that the art-science collaborations they witnessed in the project provide models for renegotiating how social scientists engage with scientists, arguing for the development of what they call an 'emergent form of critique,' repositioning artists and designers not as producers of artefacts, but as 'epistemic partners' (Calvert and Schyfter 2017, 209-210).

Emergent critique, they suggest, is not aimed at unveiling a reality hidden by ideological presumptions in order to reveal the 'truth' of a phenomenon. Rather, an emergent form of critique, drawing on the work of Bruno Latour and others, would 'create spaces where mutually transformative discussions can happen between STS, art/design and science/engineering, as well as other groups' (Calvert and Schyfter 2017, 212). Emergent critique, in their view, involves being open to experimentation and risk, and to not necessarily knowing the outcomes of a collaboration in advance. They argue that this orientation enables social science to carry out work *with* science rather than *on* science. Drawing from this challenge to the practice of social scientists, we sought ways of building interdisciplinary collaboration centred around our shared interests in new blood technologies. Calvert and Schyfter also identify how observing the practices of artists and designers involved in the Synthetic Aesthetics project raised for them the 'uncomfortable' question of whether social scientists were as adept at collaborating with scientists as the artists were. Artists and scientists produce artefacts (but not only that); what do social scientists do?

From the outset, the role of social scientists in our collaboration turned on whether we were expected to deliver or facilitate 'public engagement' or to recruit publics to become involved in the research. One of the grant funding bodies' (NIHR) insistence on differentiating between *research* (the generation and analysis of data) and *public and patient involvement in research (PPI)* brought clarity to the role. As social scientists and artists we

initiated new questions about the culturing of red blood cells as a form of emergent critique that could assemble different perspectives, processes and actors and trace the complex relations between them. Our collaboration became an 'effective tool for creating understanding' (Koek 2017, 349) of the wider socio-economic implications of cultured red blood cells and their potential place within blood economies.

At the same time, we were keenly aware that despite the visibility of so many art-science collaborations, assessing the 'quality' or impact of a collaboration is difficult. As Siân Ede and Philip Ball (2017, 311) explain in their review of the increasingly complex and important art-science collaborations taking place over the last decade:

> while participating scientists often report positive personal experiences and value the opportunity to take a wider perspective on their research, very few would claim that projects actually advance scientific practice, let alone results.

Our work together involved many different practices: visiting the NHS Blood and Transplant facility and the Toye laboratory, collaborating on funding applications, presenting our work to each other in seminars, conferences and through informal discussions, and the artist's residency in the Toye lab. In preparing this paper, we took part in a writing workshop to develop a shared language to think about some of the artworks produced, as well as the materials and practices involved in the science, and we worked together to bring this shared language into the writing of this paper. At the same time, our experience collaborating suggests that reflecting on the artistic practices of (critical) making might require stepping back from the familiar frame of scientific (and social scientific) analysis in order to create space for more personal reflections. Measuring transformations of scientific practice that result from such collaborations could also involve the development of different modes of scientific reflection and new perspectives on the disciplinary practices of science. To illustrate this, we shift in the section that follows from our collectively produced language of

what ‘we’ did to include two first-person accounts from the scientist (Ash Toye) and the artist (Katy Connor) of the artist residency in the Toye laboratory. These reflections suggest that measuring the value of a collaboration can take many forms, and with unanticipated outcomes. The social science contributions help us situate how blood is used and explore social dimensions of red blood cell technologies not readily considered by the scientific community. We include these personal accounts from Katy and Ash of the residency experience they shared, to demonstrate how art-science collaborations can be mutually transformative, even of scientists’ own perspectives on their work. We follow this discussion with a detailed and collectively authored reflection on the practice of (critical) making of Katy’s artwork from her residency, *Synthetic Dwelling*.

A view from the lab (Ash Toye)

I am the Principal Investigator of a busy University lab that works on the production of blood cells from stem cells. At any one time, we have around ten researchers working independently and often collaboratively on projects that aim to eventually produce red blood cells for transfusion. My day-to-day job involves the management of scientific research, seeking funding and collaborations and teaching, but I am also fascinated with the idea of public engagement. I have a strong sense that I need to explain what my lab does to the public. This is because my research is publicly funded and I use material from blood donors in my research, so I think it’s important to communicate what we are doing with this gift and why.

I have always been interested in engaging with the public about science but for many years I have felt limited by the format; the focus usually is on the scientist speaking or telling people what they (the scientist) want the public to hear. To date, I have undertaken multiple public

engagement events e.g. Science Café formats or Pint of Science festival events, even a question panel-type event, but I feel the format of these events is constrained. Often, there is time for people to ask questions and this is by far the best part of public engagement for me, not knowing what the next question will be. From these questions you get to find out what people are fascinated by or are worried about and it's often the case that aspects of work that you thought may trouble the public are accepted. There is an incredible public trust in scientists' research and in what we do. I had been thinking for a while about using an alternative format, where someone else 'an independent advocate' talks about the scientist's research and then they feedback to the scientist what the public thinks about what you do. So, I was looking for something a bit different to do with public engagement, to push the boundaries of what can be done and get the science across in a new way.

When I was originally asked by Julie to meet with an artist who was interested in what we were doing, I actually jumped at the chance. However, although I am always interested in working with new people and collaborating, in the back of my mind I questioned whether interacting with an artist was a step too far? I didn't know what would happen or what would result from this interaction, but what I believed is that art could be a new way for a scientist to have a conversation with the public as an audience. After talking to Katy, I was convinced that an artist-in-residence could potentially become an advocate for my lab and the research that we do. The issue for me though, as a scientist, was reputation. You have a reputation as a lab and from the research and outputs that you produce. I had to ask myself, will people think: 'are you no longer a serious scientist?' So this also involves thinking of your own work, thinking about it in a different way and also trusting someone to take what you do and hopefully present it in a good light. We had no agenda to start, no experience with an artist-

in-residence. I just had to trust Katy and I offered her literally open access to the lab to see what it is that we do.

When I brought this idea to my team of scientists, there were the anticipated questions about 'why are we doing this?' but as I pointed out there was actually no pressure or requirement for them to do anything specific, other than to explain their work to the artist if she thought it was interesting. Everyone agreed it was an interesting thing to try out. There was no specific agenda for Katy, I gave her full access like a lab member, providing a swipe card, and no one from the lab prepared anything in advance; they just did what they normally did. What would come from this? Many of the people in the lab work in tissue culture and this is where Katy spent most of her time observing the scientists going about their work.

Numerous pieces of artwork have come out of the residency and have also been exhibited. My impression of the work that Katy produced, is that she (naturally) gravitated to the visual aspects of the project. Katy has always been interested in scale, so I think the natural thing was for her to explore what people were always looking at down the microscope or how people were using new materials to grow stem cells and blood cells.

Two pieces of work struck me for two reasons. The first was a microscope study of cultured blood cells. Katy spent hours and hours in our dark microscope room taking pictures of cells down the microscope. To be honest, the culture had not gone well and many of the cells were dead, but Katy liked the shapes and colours in the image. By using the black background and the natural microscope view this provided a really nice piece of art. The public would not know the cells were dying so I always smile to myself at that image. If the cells were all perfect then the image would probably not be the same or have the same visual impact. Katy

had found something beautiful from something that was a disappointment in the lab and also something everyone in the lab thought was mundane and took for granted. A view of cultured blood cells down a microscope!

The second piece was the exploration of the bone marrow mimicry project where we grow stem cells in an artificial polystyrene scaffold. This project is a bit like magic, you put a known number of cells in the scaffold and then over a month's time, cells keep coming out. The cells seem to like the inside of the scaffold and a proportion of the cells keep their stemness and can keep growing inside it as long as you provide fresh growth medium. To look at, the scaffold is a tiny piece of white polystyrene, just a tiny white cube that could easily be squashed. We had some electron microscope images already but Katy wanted to know what the environment surrounding the cells looks like in 3D. The concept of the scaffold art was born, but then the challenge began: how to see inside the scaffold in 3D and could we then blow this structure up to a larger scale? This work involved trying many different ways of imaging it. In the Vet School, they tried different scales of CT scan. The CT scanner had been used on a dog and a horse and then on our tiny scaffold. At first, the image that came out was just noise but then we saw the little pores inside and that it could be turned into a 3D image. The stroke of genius is that Katy used the scan to 3D print the scaffold, in different sizes. Being able to see it and touch it gave us a better way to illustrate it and to talk to a public audience about it, handing out mini 3D art pieces for the public to feel and touch – and we've used it as an aid to describe the scaffold project to other scientists. Although it's a tiny part of a large programme of work this image has generated the most interest. Nowadays if I am talking to people about this project, I always take a mini piece of Katy's art along to help explain what we do. We also handed out four replicas to the public in last year's Pint of Science festival in Bristol.

For me, science is often about results and finding something new, but this process and Katy's residency was about the journey. We had to trust someone to represent us and our work and we didn't really know what would happen. We got to see what we did from someone else's eyes and discover things that we did every day that we took for granted as fascinating in their own right. Now these pieces of art can be used to strike up a conversation with the public in a new way. I really appreciate the time Katy has spent with us and I hope this collaboration can continue!

The artist residency: critical making and reimag(in)ing in the lab (Katy Connor)

My residency began with a visit to the NHS Blood and Transplant (NHSBT) facility in Filton, Bristol. The NHSBT is one of the main arteries of UK blood distribution and the largest blood processing plant in Europe. It is one of five centres that together operate as the UK's national network: handling, testing and processing blood products donated through the NHS *Give Blood* scheme. Outside the shed-like architecture, it resembles many of the huge distribution warehouses nestled on the edge-lands of the city. Inside the facility, its vast processing operations are modelled on a specific, German car plant. Here donated corporeal substance becomes a biomedical product: scanned, tested, filtered, centrifuged and separated, many elements repurposed, others discarded as waste.

The Toye laboratory at Bristol University collaborates with NHSBT in order to 'scale up' the cell culturing process for use in the clinic.[2] The laboratory conducts research studies using red blood cells, while NHSBT collects, processes and distributes blood for transfusion. Here I was introduced to members of the Toye lab team, their facilities and the specific biological processes of *erythropoiesis*: the development and growth of red blood cells in the

[2] The Bristol Blood and Transplant Research Unit is a joint initiative funded by NIHR. See http://bristol.ac.uk/btru/. (Accessed 26/06/19)

body and by extension, in the laboratory. Unusual in this scientific context, the residency had no predetermined outputs. Rather I followed an experimental, open process, without a specific hypothesis or predetermined model. In order to understand the approaches taken by individual scientists, working with these red blood cells as highly controlled fluids in the micro-controlled environment of the wet-lab, I spent days *being in the lab*: sensorially responding to these bodily materials or 'bio-matter'. I discussed these cells with the scientists, watching their movements and documenting them onscreen, as lively materials. In addition to this, I attended and participated in academic conferences in synthetic biology, sociology, philosophy and art/science relations, as well as exhibitions and public events, and exhibited my work throughout.[3] After a full day spent in the laboratory, I'd disappear to the studio and reflect, considering, ways of working, making - and then bring work back to the lab to discuss.

In the laboratory I observed the scientists' oft-repeated, performative actions: pipetting, transferring, scanning, recording, identifying, analysing... a noiseless choreography of ritualised movements. Enrobed in their white lab coats, under the hood of the wet bench, in amongst shelves stacked high with plastic-wrapped dishes, trays, tightly packed pipettes, facing multiple monitors, optical microscopes and other, more ambiguous devices. In the workroom, peering into glass-fronted cabinets revealed stacks of jars, flasks and vessels, each containing brightly coloured liquids; iridescent pinks and scarlet hues, all incubated to body temperature. I became intrigued and asked many questions: what was it we were (actually) looking at? How did these materials come to be here? What was their lineage? I became excited by the bold opulence of the liquid medium in which billions of cells are grown, nourished and cultured. I was aware that as an outsider, my presence, whilst appreciated by some and politely tolerated by others, was highly unusual. At different moments I found myself looking into flasks, down microscopes, standing and being *present* within this environment. It soon became clear that what I was seeing

[3] See https://www.katyconnor.net/artworks for examples of practice.

in the flasks, watching in the microscopes and reflected in the monitors was very different to what the scientists were seeing, what *they* were looking at: what they were looking *for*. Imagination and sensation are central to the practice of the arts, and this period of standing, *being present* in the laboratory is key to the experiential aspect of art as epistemic enquiry, a process alluded to by Reilly (2002, 5): ‘take your body and its sensory receptors close to something, to maximise information gathered.’ Through using my body as sensorial apparatus, I could respond physically, viscerally to the spaces, the sights, the blood, the smells, the sounds. By contrast, what the scientists were looking for was objective knowledge.

I was politely informed, reminded that here in the lab, under scientific protocol, colour is instrumentalised; phenol red is used as a soluble signifier, referencing amounts of excess oxygen or CO_2 present. The colour of the medium changes from magenta to yellow, depending on the acidity of the liquids. At different points of study, looking at the bio-matter through another lens, phase contrast microscopes discard colour altogether: its shimmering presence seen as too distracting, too loud. Through these televisual media, the enlarged cells' movements are witnessed only in black and white. In early responses to visiting the lab, I collected some of the laboratory materials: glassware, spinner flasks and biochemistry textbooks, starting to consider them as sculptural objects. These cultural artefacts also have an embodiment: taking them out of the black-box context of the laboratory, into the public spaces of exhibition and juxtaposing them with other ‘synthetic’ materials, raises unanswered questions about the material cultures and constructed artefacts of scientific practice; metaphors for further exploration.

Whilst there were certain similarities between the laboratory and my studio as workspace - distinct areas for different material investigations, special technical equipment and shared space for seated, desk-based research - unlike the studio, dialogue and discussion here were viewed as distraction. Talking to the scientists about the specifics of their lab research

served to open out discussion into wider concerns, and contexts in relation to their lab research, but they were incidental: caught whilst doing routine tasks, imaging, or moving between spaces, and often difficult to capture. Side-notes, caught in secret, rarely shared. For my purposes, these personal insights were invaluable, and I held onto them like gold. Ultimately I was drawn towards this difference in approach, toward the alternate practices that frame these biomaterials, these 'technologies of living substance' (Landecker 2010) handled and experienced in the laboratory by the scientists (and by extension, the lab technicians and workers in the processing plant), and my immediate and preconceived response that I had towards an idea of growing 'synthetic blood' in the laboratory. Looking down a simple optical microscope I was astonished at these teeming, tiny red cells, highly visible in their viscous shiny iridescent liquid [Figure 1]. I was amazed by their lustre, their movements, their liveliness. Here in the void, the black surround of space, these cells appear planetary.

Synthetic Dwelling: Plans for posthuman survival. Part One: Replicating the bone marrow niche (2018)

Contemporary corporal representations produced in and through medical practices are highly mediated, algorithmic and abstract, revealing a virtual body realised in three dimensions through an array of digital imaging technologies[4]. The artwork produced from Connor's residency in the lab, *Synthetic Dwelling: Plans for posthuman survival. Part One: Replicating the bone marrow niche* (2018), reflects upon these themes through critical making, a practice that includes multiple methods of computed tomography (CT), digital fabrication and materials including industrial plastics. Plastics, or synthetic polymers are currently used both inside and in

[4] See the edited volume, *Becoming Image: Medicine and the Algorithmic Gaze*, Liz Orton (2018)

place of the body in broader instances of biomedical research, regenerative medicine and 3D bio-engineering.

Synthetic Dwelling originated from the residency, using the tools and image-making capabilities of high science and mediated imagery in its production. The work took as its starting point one of the small polyHIPE (**poly**mer **h**igh **i**nternal **p**hase **e**mulsion, a highly porous material) scaffolds observed in the Toye laboratory, used within the lab to culture stem cells derived from donated blood [Figure 2]. Measuring just 5mm the cubes are tiny support structures made from a synthetic polymer foam, designed and manufactured specifically to replicate the organic structure of bone marrow.[5] The artwork *Synthetic Dwelling* [Figure 3] reimagines one of these scaffolds: this tiny cluster of polyester bone marrow that mimics the mysterious spaces within the body where red blood cells originate. Within these synthetic spaces, millions of stem cells are cultured in the laboratory, immersed in the rich, iridescent growth media.

Fruitful discussions with laboratory scientists during the residency revealed an imaginative engagement with their cellular subjects, prompted by repeated practices of caring for the cell cultures. This often resulted in an anthropomorphism of the cells as living beings, practices first articulated by Dr Honor Fell (1936) from the Strangeways laboratories in Cambridge as the 'tissue culture point of view' (Squier, 2004) and alluded to by Catts and Zurr in their reflections on bioart (2008). Throughout the residency, scientists anecdotally remarked that the cells were 'happiest' living inside these replicant structures, where they could freely differentiate. The ways in which the laboratory scientists imagined the cells and recounted seemingly peripheral aspects of scientific methodology or discarded elements of encounter therefore became an integral aspect of the artwork, its conception and articulation. From the

[5] See Severn, C. E. *et al*. 2016. Polyurethane scaffolds seeded with $CD34^+$ cells maintain early stem cells whilst also facilitating prolonged egress of haematopoietic progenitors. *Scientific Reports* vol. 6 32149, doi:10.1038/srep32149

micro vantage-point of the cells living inside the scaffold, the spectre of the full-size human figure is enormous, almost architectural in scale. *Synthetic Dwelling* draws upon this to suggest a subtle empathy established with the cells and their micro-dwelling places, prompting multiple questions from the cellular point-of-view: how might it feel to be inside synthetic marrow? What might these interior spaces of habitation look like? What might *we* learn from the cells themselves?

In contrast to simple techniques of optical microscopy, making this work demanded imaging tools that could open and reveal nano-sized spaces such as Microscopic Computed Tomography (Micro-CT). Micro-CT scanning is a means of x-ray imaging in three dimensions, a similar device to that of the medical CT scanner used in hospitals and clinical practice but on a much smaller scale and with a much higher resolution. The task of scanning the scaffold involved numerous visits to machines and departments across the University faculties in multiple sites from clinical and veterinary practice to high-end nuclear physics research labs in order to scan the scaffold at the requisite scale. Taking upwards of 12-16 hours to scan a tiny speck of scaffold placed gently upon a pin, the Micro-CT machine imaged the complete internal structure of its object, generating a gigantic virtual matrix, a three-dimensional lattice of interlocking spaces and a maze-like warren of labyrinthine quarters, revealing manifold dwelling spaces wherein the blood stem cells burrow and grow.

Having created a vast virtual file on the computer, a tiny cuboid segment of the digital marrow niche was extracted, cleaned and rendered into a three-dimensional tangible object, using laser-sintered nylon as the method of fabrication. The resulting cube is a minute sample, a tiny fraction of its progenitor magnified from the nano-scale. As a tactile sculpture it is both biomedical scaffold and architectural model and a potent space for habitation. Placing a human figure inside at a scale of 1:50 the piece becomes a dwelling place. The sculpture reveals the intricate dwelling spaces inside, where the cells nestle. In shifting scales in this work the small

becomes large, enveloping the body and destabilising the human figure as a measure of scale. As a gallery installation *Synthetic Dwelling* presents the original 5mm polyHIPE scaffold alongside multiple mediated forms, conveying shifting perspectives onto the real, its enlarged architectural replica and an animated video of the scaffold's slices which produces a compelling loop of white noise. The marrow of synthetic bone reveals a potent space of electromagnetic static: is this noise at the heart of our corporeal technological medulla?

An important aspect of the project was not only making new imaginative artworks that explore metaphors of the impacts of synthetic futures, but also thinking about how an artist's presence in the laboratory could facilitate new engagements between scientists and their own practice. In this context the value of artistic research lies, as Borgdorff (2010, 50) states 'in its ability to offer the very reflection on who we are and where we stand that is obscured from sight by the discursive and conceptual procedures of scientific rationality.' Ash and his laboratory research staff were fascinated by the scale replica. Prior to this they had only seen the scaffolds as two dimensional slices made using an Electro-Scanning Microscope. As a three-dimensional model, the enlarged scaffold helps them visualise what is occurring inside the scaffolds and enables them to more easily engage others - including publics - in their research.

By disclosing both the corporeal and the synthetic in laboratory practices of bio-medicine, what *Synthetic Dwelling* as object, image and metaphor coming out of the residency reveal is a negotiated borderline between the experiential, biological, material and technological; a vital space, in which we negotiate our relation between the human and posthuman. In forging new collaborations with medical researchers, artistic research can 'open up' science by exploring some of the implicit assumptions of scientists' epistemic enquiries; interrogating dominant research agendas by putting them into conversation with other forms of knowledge.

Jumping Scales: Molecularisation of Health and Medicine

The distribution and unequal exchanges of blood across space suggest that although blood is universally shared, the context for the exchange of blood is marked by inequalities, unevenness, differences and hierarchies of all kinds. Blood types, we learned, exist in far more than multiples of A, B and O. Rather, blood types take on variation across and between bodies so that blood scientists identify 33 different blood groups (ABO being the most significant type for transfusion) with over 300 different antigens. However, the prevalence of certain blood types is also identified in many ways with specific populations. The leap from blood type to population identity is an attempt to 'map' onto human populations a geographical patterning of bodily typology. The geography of blood in this cartographic form is read as an alternative and more scientifically sound representation of human biological difference than that of other categorisations, such as race. The spatial distribution of blood types reflects what those in blood research argue is the legacy of planetary scale evolutionary processes and historical legacies of human migration flows over thousands of years.

Yet like organ matching, blood type difference gets 'racialised' in the blood economy (Kierans and Cooper 2012). The production of the 'ethnic donor' shapes the recruitment strategies of the national blood service as they attempt to attract donors whose blood can be used in the treatment of diseases such as sickle cell and thalassemia. Modifying and culturing red blood cells to use in the treatment of these conditions would potentially transform and circumvent the current ethnicization of donation strategies by producing a 'universal' manufactured blood product that could be more easily matched to the specific blood type of the recipient. The work we sought to engage in this project moved from this global scale understanding of blood type distribution to the scale of the body of the recipient or the donor, and the cellular level of the biological process of red blood cell generation and creation. Katy's work disrupts understandings of scale as a linear relationship between things, moving

from small to medium to large, from micro- to macro-. Her work enlarges and expands the cellular to make it visible to the naked (human) eye, much in the way that the laboratory tools of various scopes and scanners enable the visualisation and analysis of cellular processes of growth and development and of sub-cellular or molecular manipulation. Moving across scales to dramatically enlarge the very small or microscopic, her work makes these invisible processes newly visible, at times playfully so in the juxtaposition of the tiny human figure next to the radically enlarged model of the blood cell scaffold. We suggest that *Synthetic Dwelling* dramatises the increasing molecularisation of health, a term used to describe how medicine has increasingly turned to manipulating and transforming the body at the molecular level of the gene and gene sequence. But as Nikolas Rose (2001, 13) explains,

> This molecularization was not merely a matter of the framing of explanations at the molecular level. Nor was it simply a matter of the use of artefacts fabricated at the molecular level. It was a reorganization of the gaze of the life sciences, their institutions, procedures, instruments, spaces of operation and forms of capitalization.

The technology to manufacture modified and cultured red blood cells is situated precisely in this new space of the reorganised gaze of the life sciences. The laboratory-grown cells will eventually, researchers hope, be produced *at scale*, cultured in sufficient quantities to provide a viable replacement for some donor blood. Cultured red blood cell researchers cite how the increasing demand for blood simply cannot be met by the currently available donors, and efforts to increase donation among particularly desired populations has met with mixed success.[6] The interest in creating a manufactured product that can reduce the risk of transmission of blood-borne disease also drives the search for new ways to manufacture

[6] See https://www.nhsbt.nhs.uk/how-you-can-help/get-involved/key-messages-and-information/why-black-asian-and-minority-ethnic-donors-are-needed/ and NHSBT Annual Report 2018/19.

blood, especially in resource-poor contexts where infrastructure is not available to routinely screen donated blood (Lee et al. 2018).

The efforts to manufacture a cultured blood product in industrial quantities is, we suggest, concomitant with a reorganisation of the forms of capitalisation at work in the life sciences. Cultured red blood cell manufacture will likely be enabled by the involvement of a commercial enterprise although the views of prospective recipients of a cultured red blood cell product emphasise the importance of trust in the publicly funded health service to develop the technology over a for-profit enterprise. The industrialisation of red blood cell culture will make modified red blood a commodity that will undoubtedly circulate in new ways. The molecularisation of transfusion science is not just about the creation of new kinds of scientific artefacts – such as the cultured red cell or BEL-A cell line – but also about the changing institutional and operational dimensions of scientific practice.

Conclusion

Reflecting on our interdisciplinary collaboration we draw out several conclusions. First, there were distinct and different motivations for our investment in the collaboration. For the social scientists, it was an opportunity to expand understanding of how contemporary biotechnologies might challenge, undermine and rework notions of embodiment, and an opportunity to locate red blood cell manufacture within the broader economies of tissue and blood exchange. For the scientist, the motivation was to make science accessible and more open. This chimed with the requirement of funding bodies but ran deeper as an ethos and a value that shaped our shared conversations and that led to a willingness to open the laboratory doors to others. The request by the artist to spend time in the laboratory stemmed from her previous work on blood, a fascination with digital technologies, biomedical processes and problems of scale.

By opening the door on making red blood cells we also see the black box of science opened up in new ways. At the same, we suggest that in doing so, red blood cell research has escaped 'out the door'. While the laboratory works on understanding the biochemical and biological processes of red blood cell culture and modification, our collaboration developed different tools to manipulate and locate those processes. This manipulation and relocation play with scale by remaking the architecture of the bone marrow scaffold and thus bringing red blood cells into new contexts including the art exhibition and the science museum. At the same time, out in the world and beyond the lens of the laboratory microscopes, we see these 'bio-objects' (see Vermeulen et al. 2012) that are cultured red blood cells transformed into units of exchange – designed to circulate within health care systems and across national boundaries and to be transfused into diverse bodies. They are released from the institutions of science as sites of study, and new potentialities emerge in the molecularised era of the life sciences, subject to capture by commercial biotech interests or to promotion by state-funded agencies such as NHSBT.

Much has been written and said about relations between Science and Society and we have witnessed the ways in which these have been framed in policy terms. Others have explored in more detail elsewhere the shift from work on Ethical, Legal and Social Aspects (ELSA) of emerging life sciences to Responsible Research and Innovation (RRI) as a framework for science working *with* society (Owen et al 2012). Most recently the European 'Open Science' agenda has emerged to emphasise the use of digital technologies, networks and media for democratising and transforming science practice. The policy objectives of Open Science are to '[make] scientific processes more efficient, transparent and effective by offering new tools for scientific collaboration, experiments and analysis and by making scientific knowledge more easily accessible.'[7] We situate our collaboration within this

[7] https://ec.europa.eu/digital-single-market/en/open-science

shifting policy context and recognise the institutional barriers and opportunities that enabled us to work together. Our work illustrates the value of social scientists' and artists' critical engagement with scientific innovation. By challenging taken-for-granted assumptions about the scientific work of culturing and transforming red blood cells and bringing them out of the laboratory together we have engaged with wider audiences and publics. At the same time our collaborative practice has afforded new insights and different perspectives on the laboratory-based work of cell culture.

Using diverse 'epistemic practices' and working as 'epistemic partners' we have generated different types of knowledge that cut across our respective disciplinary locations. The scientist is focused on the microscopic, the processes and patterns visualised through complex technical means, and the cell in the flask. The artist re-imaged and re-imagined the cellular and scaffold structures and the spaces in between. The social scientists were immersed in thinking through the project's socio-technical relations, analysing the place of the laboratory within the biopolitics of blood exchange and the disassembly and reassembling of bodily materials (blood). Attempting to transcend disciplinary boundaries and hierarchies of knowledge, together we made efforts to open up the discussion of how manufacturing modified red blood cells provokes all of us to re-imagine cellular life.

Our work together underscores the importance of how health and medicine in the blood economy are molecularised, where the body is increasingly understood as being composed of genes, cells, and molecules that are open to manipulation and transformation. At the same time, our collaboration was made possible by a broader shift in the practices of knowledge production, that of 'opening up' science to non-scientists. Interdisciplinary collaboration in this sense is not simply about the bringing together of different perspectives but must also be understood in the context of efforts to challenge the role of experts in society. The devaluation of expertise in the field of climate change science has been the most

visible, and perhaps most negative, example of this shift. The increasing financialisation of scientific research also seeks to remove regulatory barriers and 'open up' the protected spaces of publicly funded science. More affirmatively, however, the Open Science agenda seeks to make science more adept at responding to social concerns, increasingly enrolling social scientists and artists as partners in pursuit of this aim.

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Figure 1: Synthetic Red Blood Cells

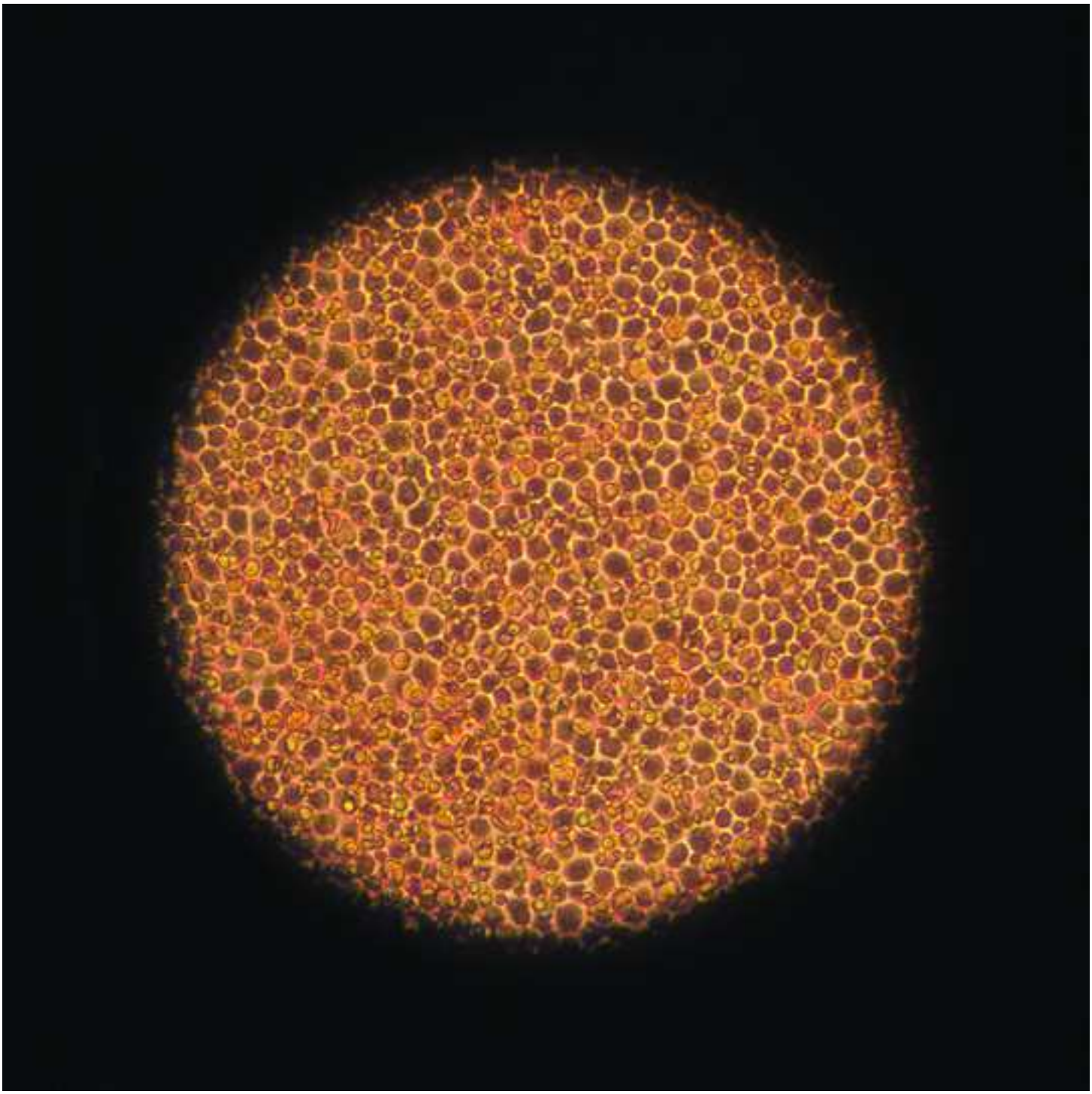
Photograph: Dr Katy Connor (2018)

Figure 2: Lab use of PolyHIPE scaffold, $5mm^3$

Photograph: Dr Ashley Toye (2018)

Figure 3: *Synthetic Dwelling.* Nylon sculpture $10cm^3$

Photograph: Dr Katy Connor (2018)



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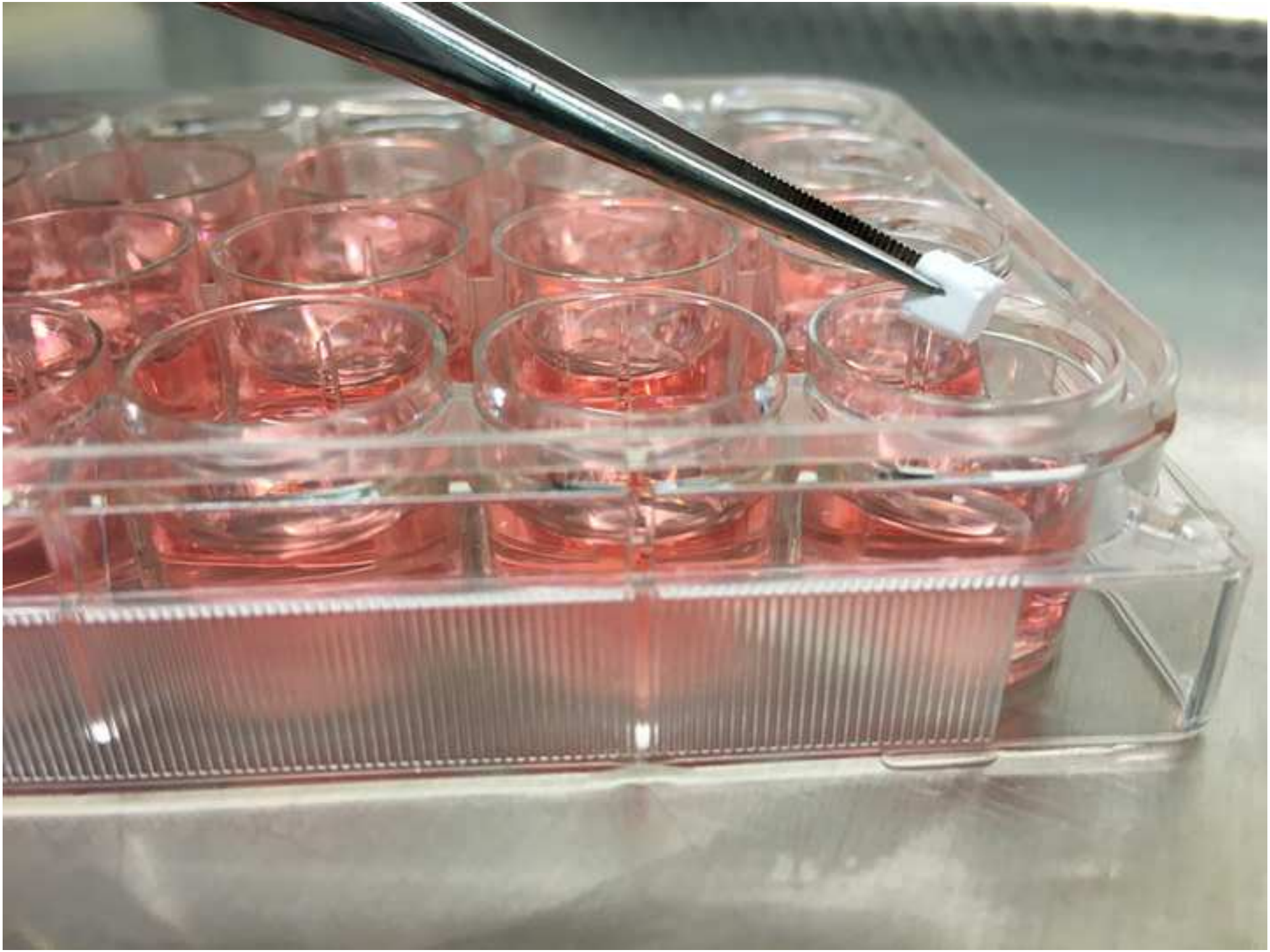

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