

Abstract

The concept of bio-objectification describes how the ‘raw materials’ of living cells and tissues are subject to both technical manipulations and ontological transformations to produce novel ‘bio-objects’ such as cell lines and transgenic animals. Bio-objects are conceptually fluid, but also subject to literal circulation through biobanks and repositories. Making bio-objects mobile means producing them in such a way that they are capable of travelling across jurisdictions, institutional boundaries, and of moving between public and private sectors. This paper uses one particular bio-object –the human induced pluripotent stem cell (hiPSC), and a particular context, a European consortium dedicated to creating an open access repository of hiPSC- to explore what making mobilisable bio-objects entails. The bio-object not only has multiple strands of identity- legal, ethical, political, technical- but this identity is distributed across, and inscribed in, a variety of paper documents, digital records, as well as the biological material. Making bio-objects mobile means putting these heterogeneous components into circulation, which can entail travel through different infrastructures and at different speeds. Moreover, contemporary legal and ethical requirements for the use of human biomaterials require the formation of durable connections that tie bio-objects to places and persons of origin as a condition of mobility.

Keywords: bio-objects, mobility, regulation, stem cells

Introduction

This paper draws on the author's experiences of working in a large European consortium of universities and pharmaceutical companies, developing human stem cells as tools from drug discovery and toxicology testing. The Stem cells for Biological Assays of Novel drugs and predictive toxicology (StemBANCC) consortium. was a was funded to produce 1,500 human induced pluripotent stem cell lines (or 'hiPSC') from 500 unique human donors and to make these available, firstly to the 35 partner institutions in the consortium, and subsequently as an open access resource to the wider European research community (Author 2017a). My goal in this account is to report from 'behind the scenes' of the consortium, on the often hidden labour that goes into making and mobilising the materials and data. In particular, I am interested in how the requirement to be capable of circulation, affected the identity of the materials and data and the organisation of work around their production.

Making 'mobilisable' cell lines required making and sustaining connections between biological, digital and non-biological materials, and between people, places, and these 'objects-in the making', some of which can be more fragile and tenuous than might be expected. Moreover, enabling mobility required connections to stable entities that do not- or should not-move. All of this has consequences for understanding the longer-term consequences and viability of biobanks and other large-scale collections of biological material and data, which are currently being pursued by many governments and companies (Morrison 2017). Conceptually, I employ the STS literature on bio-objects as a way of framing and understating the hiPSC (Vermeulen, Tamminen and Webster 2012) and elements of the 'new mobilities' paradigm (Sheller and Urry 2006) to theorise the mechanisms of circulation of the materials and data that were produced.

The concept of ‘bio-objects’ (Vermeulen, Tamminen and Webster 2012) provides a theoretical framework to interrogate novel biological entities produced by the life sciences, such as the embryonic stem cell or the transgenic mouse. The term ‘bio-object’ reflects the idea that these are ‘living entities [...] made into objects [...] through scientific labor and its associated technologies’ (Holmberg, Schwennesen and Webster 2011: 740). Analytically, bio-object theory directs our attention to the processes and practices through which bio-objects are produced, described as ‘bio-objectification’ (Webster 2012). These processes commonly involve material transformations; the technical work that the scientific actors involved would recognize as the making of a cell line or a genetically-modified laboratory mouse. Bio-objectification also captures the parallel, overlapping processes through which the living entity is ontologically transformed in to a fungible object.

Bio-objects are inescapably hybrid, at once ‘life’ and ‘thing’. To assign bio-objects a definitive identity in one category or the other is to attempt an impossible act of modernist purification (Latour 2004). It is not that bio-objects never achieve closure; rather that stabilisation of their multiple, fluid meanings requires sustained work and tends to retain latent possibilities for future contestation and re-evaluation (Stephens and Dimond 2015). However, bio-objects do not only travel across contexts and categories of identity. They are often mobile in the more literal sense of the term, as they are enrolled in national and international flows of scientific material and data (Brown and Williams 2015).

The (dis)possession and circulation of biological materials has a long history, dating back at least to the colonial expeditions, botanic gardens and museums of the eighteenth and nineteenth centuries (Livingstone 2003). Circulation is rarely happenstance. More often, when individuals, specimens and information flow across geographical and administrative

boundaries they are propelled by political and economic imperatives. These same forces also support the assemblage of sociotechnical networks of people, institutions and material infrastructure through which such travel takes place (Sheller and Urry 2006).

Unlike seeds or ‘exotic’ animal specimens, bio-objects are not only collected, stored, exchanged and circulated; they require the above-mentioned technical manipulations to give them their form and value in contemporary global ‘tissue economies’ (Waldby and Mitchell 2006). Increasingly bio-objects such as JAX mice (Rader 2004), units of cord blood (Brown and Williams 2015) or human tissue samples curated by a biobank (Stephens and Dimond 2015) are explicitly intended for circulation and exchange. The sites of technical manipulation and processing where bio-objectification takes place thus became important nodes in the infrastructures through which these bio-objects are circulated. At these sites bio-objects are not only made for circulation, they are bio-objectified in particular ways to ensure they are *capable of being circulated*.

Thus, the mobility, and the mobilisation of bio-objects raises particular questions for our understanding of bio-objectification. How does a requirement for mobility affect the way entities are configured as bio-objects? Conversely, how do processes of bio-objectification affect the capacity of bio-objects to travel? What flows are enabled or restricted by particular configurations? These questions provide the starting point and theoretical ‘direction of travel’ for this paper.

The StemBANCC hiPSC consortium: Introducing the bio-object and its context

‘Induced pluripotency’ was first reported in 2006 by a team of researchers based in Japan. The term refers to a process whereby ‘ordinary’ cells of the body such as skin or hair cells are treated with a particular set of chemicals that transform, or induce, them to assume an embryo-like plasticity. This process, which has become known as cellular ‘reprogramming,’ illustrates how technical manipulations and bio-objectification are intertwined.

In reprogramming, induced pluripotent stem cells are literally *made* through a series of physical and chemical transformations that turn an excised piece of living human tissue into a self-replicating population of highly plastic cells existing outside the body in a vial or petri dish. As this vital matter is transformed, it is measured, tested and classified. These transformation events (c.f. Lezaun 2006), tests and resulting metrics are commonly recorded in laboratory information management systems (LIMS), batch manufacturing records, or lab books as part of the ‘evidence labour’ of scientific production (Meskus 2018). The creation and inscription of this technical, or scientific, identity is one dimension of bio-objectification.

As intimated above, bio-objectification occurs across multiple registers (Webster 2012). A bio-object may be rendered as a legal entity through enrolment in a particular regulatory classification (Metzler 2012) or scripted as a protected act of human invention through the claims made in a patent application (Biagioli and Buning 2019). Another aspect of identity may be configured through the bureaucratic register of institutionalized ethics. A bio-object in-the-making may require a consent form for donated tissue or a license to use embryos or laboratory animals from a national regulatory body. Many of these operations inscribe aspects of the bio-object within ‘standardised forms of bureaucratic accountability’ (Stephens and Dimond 2015:6) which render them knowable as legal, ethical, technical or economic entities.

For human-derived induced pluripotent stem cells (hiPSC), many of these parallel practices of bio-objectification also cluster around the reprogramming process, from obtaining consent for an initial biopsy, to recording the creation of a new stem cell line in an online registry to comply with funding requirements. In one sense, this is inevitable; the bio-object does not pre-exist these processes of bio-objectification; the transformation into a bio-object is effected through these practices. The plurality of registers in which these processes operate contributes to the ontological multiplicity of bio-objects (c.f. Mol 1999), while the temporality of their application gives episodes of bio-objectification a particular duration and diachronic unfolding. All of which makes the sites and practices of reprogramming a key site to study how hiPSC are bio-objectified and how their multifaceted identities are implicated in enabling (or constraining) their mobility as bio-objects.

Cellular ‘reprogramming’ technology is now widely available in kit form. As a result, hiPSC are made as a research tool in many laboratories across the globe. These may as often be intended for ‘local’ use in a relatively circumscribed location as for wider exchange and circulation (Meskus 2018). In order to investigate mobility, as both a factor shaping the production of bio-objects and a required characteristic of the bio-objects produced, this analysis focuses on a particular situation –the StemBANCC project - where large number of hiPSC were made explicitly for distribution rather than ‘local’ use.

The context of StemBANCC also helps to bring the hiPSC into focus as (bio) objects of political and economic attention. While they are not nearly as publicly and politically contentious as hESC, the social and political identity of iPSC is directly affected by the prior history of hESC. The fact that cellular reprogramming creates embryo-like stem cells while avoiding the use of human embryos or eggs, means hiPSC are often regarded as ‘ethical stem cells’ (Jha 2011). As a result, hiPSC rapidly came to be seen as an alternative to, or even a

replacement for, human embryonic stem cells and have taken on many of the translational aspirations associated with hESC (Hauskeller and Weber 2011). These include regenerative medicine, but also the ideas that human stem cells might be used to produce in vitro laboratory models of the diseases affecting the human body, and to test potential new drugs for adverse effects prior to actual human trials (Milne 2016; Author 2019).

The StemBANCC consortium was assembled to produce large numbers of hiPSC for use in developing these drug screening and disease modelling applications. These were explicitly ‘research grade’ lines, never intended to be implanted into any human being. The project was one of many consortia funded through the European Commission’s Innovative Medicines Initiative (IMI) funding scheme and, like all IMI projects was a partnership between public sector research organisations (mainly universities) and the pharmaceutical industry (Marelli and Testa 2017). The existence of the IMI reflects a longstanding political commitment on the part of the EU to promoting public sector research and development as a basis for future economic growth and development. The incorporation of pharmaceutical partners in IMI consortia is intended to ensure the research priorities of each IMI project are orientated to industry needs as a means to realise that anticipated economic growth (ibid). Through StemBANCC and similar hiPSC banking projects in other regions, hiPSC are enrolled in discourses of ‘accelerating’ research for ‘faster translation’ where translation, especially into a viable platform for screening small molecule drug candidates, is anticipated to reduce the cost of clinical trials and ultimately increase the financial sustainability of the European pharmaceutical industry (Author 2017a; 2019).

The IMI, with its emphasis on ‘acceleration’ and ‘translational’ research, provides a political-economic driver for mobilising hiPSC and a political and regulatory context in which their

identity was configured. The consortium's 22 universities and state-supported research institutions, 10 pharmaceutical firms and 2 small-to-medium sized biotechnology companies, spread across 10 countries defined the territorial, jurisdictional and institutional space over which mobility was required to operate for the duration of the project. A smaller number of partner institutions in the consortium acted as the physical and institutional sites of technical manipulation where the production of hiPSC, from initial recruitment of tissue donors, through reprogramming, to storage, quality control and shipping was situated. Ultimately, the StemBANCC consortium fulfilled its open access remit by transferring the cell lines and data produced during the five years of the project to another consortium, the European Bank for induced pluripotent Stem Cells (EBiSC), which was funded explicitly to create sustainable hiPSC banking infrastructure. The activities of EBiSC have been scrutinised elsewhere (Harmon 2018; Marelli 2016; Meskus 2018), so the remit of this study concentrates on StemBANCC, as both the site where bio-objectification occurred and the terrain over which mobility, at least initially, was defined and tested for the hiPSC.

Theoretical signposts

In order to study *how* bio-objectification and mobility intersect, it is useful to identify some points of conceptual overlap between the processes of bio-objectification and mobilisation (i.e. *where* they intersect). Here, three broad areas of correspondence are identified from previous theoretical and empirical work in each area. These three domains I term 'heterogeneous entanglements', 'tacit or hidden labour', and 'regulation'. This is not intended as an exhaustive list of possible congruities between bio-object and mobility literatures. Rather, expanding on these three areas of intersection is intended to provide useful conceptual 'signposts' for the analysis of StemBANCC hiPSC and is the focus of this section.

1) Heterogeneous entanglements

Mobility is not an inherent property of hiPSC or any other bio-objects. When bio-objects are successfully circulated, this movement is enabled through heterogeneous networks of facilities, containers, freezers, biobank staff, consent forms, courier services, regulations and legal agreements, existing transport infrastructure, transport logs, receipts, and registries. The biological materials and non-biological elements must be successfully co-ordinated and combined, or entangled, in order for movement to be achieved. The process of bio-objectification can also be viewed as a series of entanglements of the ‘bio’ (the biological material) with ‘non-bio’ elements as the identities of bio-objects are created through database entries, consent forms, journal articles, lab books, and other devices for recording and presenting information. The entanglements that enact bio-objectification and those that facilitate their mobility may even operate simultaneously. In their study of a biobank of excised cancerous tissue, Stephens and Dimond (2015) demonstrated how practices of documentation and accounting allowed previously ‘messy’ biological material to be identified and classified as a particular kind of bio-object, whilst also signalling its suitability for transfer (i.e. mobility) between compatible nodes in the network of tissue banks and research centres.

In this regard, digital records, databases and virtual infrastructure have a particular importance in the concurrent constitution and mobilisation of bio-objects. Brown and Williams (2015) note the important function of digital registries in producing ‘data doubles’ of cord blood units, without which their international circulation and exchange would be much slower and more difficult. Holmberg, Schwennsen and Webster (2011) describe this realm of digitised bio-objects as the ‘bio-virtual’:

a specific form of life, which exists as information, data and informational flows, that *mobilizes bio-objects* through data networks as a form of aggregative life (p742, emphasis added).

This serves as a reminder that mobility is not achieved through one basic network, but by ‘complex intersections of endless regimes of flow, which move at different speeds, scales and viscosities’ (Sheller and Urry 2006: 213). Digitised information has its own infrastructures, its own flows, and its own blockages, obstacles and constraints (Edwards et al 2011; Nadim 2016), that affect the movement of physical biospecimens by virtue of the inscribed connections between the material and the digital (c.f. Brown and Williams 2015).

These entanglements are one point of intersection of bio-objectification and mobility. As a theoretical signpost, they direct our attention to multiplicity and heterogeneity; entanglements with different infrastructure components can have different effects on both the identity of a bio-object and its mobility. This also reminds us to consider the multiple dimensions of mobility itself. In the context of bio-objects, circulation can certainly involve travel across physical space (for which freezing is often required), but often also travel between institutions, which may entail movement between the public and private sectors, and across regulatory regimes and national jurisdictions. Different entanglements, therefore may enable, constrain or direct mobility across different kinds of terrain.

2) *Tacit or hidden labour*

Having considered infrastructures of bio-objectification and mobilisation in terms of material (and virtual) components, it behoves us to also pay attention to infrastructure as *activity* (after Star and Ruhleder 1996):

A flow of material depends on much more than freezers. It takes groundwork to make people donate samples and to make researchers ship them to Copenhagen. We think of this work aimed at enacting sustainable relations as ethics work (Hoyer, Tupasela and Rasmussen 2017: 387-388).

Much of the mobilisation work described by Hoyer, Tupasela and Rasmussen (2017) is framed as being outside the formal job descriptions of the collaborating scientists and physicians they studied. It involved tacit judgements about what should or should not flow and labour that was often unacknowledged in formal descriptions of research collaborations. Similarly, much of the ‘data labours’ of scientists working for biomedical research infrastructures that allows digital flows is typically invisible, infrastructural work (Nadim 2016).

The emphasis in bio-object theory on practices and processes of bio-objectification also stresses the labour of making bio-objects. While the technical manipulations involved in producing a bio-object are more likely to fall within the bounds of formal scientific work, the ‘evidence labour’ (Meskus 2018) of logging the creation, identification and evaluation of bio-objects can easily slip into, or overlap with the logging and inscription work needed to make them mobilisable, as discussed above. In addition, the ‘ethics work’ of persuading people to donate samples and data described by Hoyer, Tupasela and Rasmussen (2017) is similarly necessary in obtaining the starting materials from which hiPSC are made. Moreover, the multiple registers in which bio-objectification occurs, highlights that relevant work may be carried out by actors ‘adjacent’ to the official scientific labour, such as patent attorneys, administrators or research nurses collecting informed consent.

Thus, labour, especially tacit or informal work, is the second point of intersection between mobility and bio-objectification. As a theoretical signpost, it reminds us to look not only at

infrastructuring labour, but also, following Nadim (2016) and Hoyer, Tupasela and Rasmussen (2017), at the relationships and interactions that make flows (and non-flows) of (linked) data and materials possible, and the work of sustaining these relations.

3) Regulation

. Regulations often form an important dimension or register of bio-objectification (Metzler 2012). For the purposes of this discussion, regulation incorporates both ‘top down’ formal laws as well as non-statutory codes of conduct, guidelines, policy directives, incentives, and institutional, professional and societal norms that can arise through more organic, ‘bottom up’ processes (Cambrioso et al 2017). This is most obvious with formal regulations as, for example, when instruments such as the European Directive on human tissues and cells¹ stipulates the range of legal categories of entity into which human-derived bio-objects must be placed.

Regulations are not simply mechanisms for directing conduct, they are themselves enacted (Cambrioso et al 2017). Even formal laws, instantiated in particular documents, must be interpreted through local practices. By way of an example, the aforementioned Directive requires that tissues and cells isolated from a human source must be traceable back to their point of origin. In StemBANCC this regulatory requirement was met by instigating a system of coding and labelling each specimen of human material collected (a process outlined in Author et al [2016] and which will be revisited in the Results section of this paper). In other

¹ Directive 2004/23/EC of the European Parliament and of the Council of 31 March 2004 on setting standards of quality and safety for the donation, procurement, testing, processing, preservation, storage and distribution of human tissues and cells.

words, the law required traceability, but what traceability came to mean was worked out in practical terms in the project.

Understanding regulation as practice provides an obvious connection with the other practices, those of bio-objectification and mobilisation, being studied here. Regulation can enable, constrain or direct the work underpinning mobilisation, affecting what kinds of circulation are permissible. Similarly, regulations inform the process of bio-objectification. We have already noted how formal laws can stipulate particular categories of entity that bio-objects may be placed into and that intellectual property claims can form one site where a particular version of a given bio-object is articulated., Enacting regulations may also involve particular tacit or ‘ethics’ work or may be realised through particular entanglements of bio and non-bio elements.

Methods

The research reported in this paper draws primarily on my own observations, experiences and work. I was employed on the StemBANCC consortium, through one of the partner universities, between November 2012 and January 2017. My responsibilities included; helping to prepare and submit a research ethics application for the project to a UK health sector Research Ethics Committee; helping to design and operate a system to ensure equitable access to the materials and data generated during the project; to be part of a team advising on ethics and data protection for the project; and helping to co-ordinate local institutional approval at the different clinical sites where patients were recruited. In my day-to-day experiences of work in the consortium, I had access to project-related websites such as the Stem Cell Database (www.stemDB.com), planning documents, Standard Operating Procedures (SOPs), emails, meetings and teleconferences, and benefited from ‘informal’ activities such as getting a tour of the biobank

where StemBANCC hiPSC were stored. In addition, organising institutional approval (sometimes known as ‘R&D approval’ for hospitals in the UK National Health Service) to recruit participants, advising on data protection, helping to devise a project biomaterials and data access plan, and contributing to the resulting StemBANCC Biorepository Materials and Data Access Committee (Author et al 2015) meant I was required to be familiar with the flows of people, documents, material and data involved in producing and mobilising the hiPSC. In some cases, I was directly responsible for carrying out some of the infrastructural labour this required.

I also had separate permission to carry out a social science study of StemBANCC. This was something I negotiated as part of my employment on the project. When I applied for the position, the consortium had already been funded, with a contract and project agreement in place. Most of the project work, broken down into the usual EU project tasks and deliverables, was already agreed. However, I was able to secure permission from the consortium management to carry out my own research on StemBANCC during my employment, provided StemBANCC work took priority. Initially I planned to research tissue donor’s perspectives on hiPSCs (e.g. how did they feel about commercial use, did they want, or worry about, feedback from genetic analysis of the material?). However, the imperative to get donor recruitment moving as fast as possible meant that additional social science research with donors was seen by the project managers as less desirable as it might slow down the recruitment process. Instead, and by this point employed on the project, I opted to focus on the working of the StemBANCC collaboration itself. A qualitative interview study on collaboration in consortia was approved, first by the project management, and subsequently through my local institutional research ethics committee, (REC) as a separate though parallel piece of research to

StemBANCC². I clearly disclosed my employment on StemBANCC to the university REC as part of the application. I did not explicitly discuss document collection with the REC or with project management for two reasons: firstly almost all of the documents and procedures I refer to in this paper were things I needed to be aware of for my official StemBANCC role, and secondly I was to an extent working out what I wanted to study and write about as I was actively working on StemBANCC tasks I was employed to complete. There was rarely a clear or conscious decision to collect something specifically so I could analyse it for this account, so it would have been very difficult to prepare a list of materials to get approval (or not) to have permission to use. I am personally satisfied that I was not conducting unduly covert research since I had explicit permission to treat the StemBANCC project as an object of social science research and at least some of my social science manuscripts on the topic (Author 2017a; 2017b) were reviewed by the consortium's publications committee prior to submission.

This paper is clearly my interpretation of the work of making StemBANCC hiPSC mobile. In some respects it can be read as an attempt at restitution or compensation for the fact that I was not able to make much impact *as an STS researcher* on the StemBANCC project itself, where my contribution was more in line with a standard 'ELSI' and administrative service provision role. However, it is not properly an auto-ethnography since my account depends on discussing actions and events I did not witness. Unlike my other papers from this study, I do not draw on my interview data here, as many of the people, besides myself, involved in mobilisation work were not available for interview. I emailed updated consent forms and other project documents to various sites but I never met the research nurses recruiting patients, not did I see fibroblast cultures being reprogrammed, and the account of mobilisation I want to tell requires these steps

² Research Ethics approval for this study was obtained from the Social Sciences and Humanities Inter-divisional Research Ethics Committee (IDREC) of the University of Oxford (Ref no SSD/CUREC1A/14-205).

to be described. This does mean some aspects of the process may appear smoother than they really were. Practical or procedural challenges that were ultimately resolved locally would probably never have been brought to my attention except by chance.

With that caveat in mind, the following analysis will recount the creation of the hiPSC from initial donation to storage in the central biobank, and the internal process of a partner institution making a request for a sample of a particular hiPSC line. Following the theoretical signposts described above, I will highlight the entanglements of bio and non-bio elements that contribute to both bio-objectification and mobilisation, draw attention to the hidden labour that underpins making and distributing hiPSC, and examine how the interpretation and enactment of regulations directs these activities. In doing so, I hope to show how the requirement for mobility impacts bio-objectification, what is required to make bio-objects travel, and with what implications for recent ‘big science’ investments in circulation of biomaterials.

Results

1) Making mobilisable bio-objects

StemBANCC was funded to create cell lines from patients in nine major disease areas: autism, Alzheimer’s disease, bipolar disorder, diabetes, migraine, neuropathy, Parkinson’s disease, schizophrenia, and patients with adverse responses to certain drugs, as well including a cohort of healthy volunteers. Individuals identified as belonging to these groups were recruited as study participants at eight clinical sites, located across three different European countries. Getting the first participant ‘in the door’ was already the result of considerable planning, negotiation over who to recruit and where the recruitment sites ought to be (see Author 2019)

and labour. Nonetheless, for the purposes of this analysis, the literal making of hiPSC and the concomitant processes of bio-objectification begins with the first clinical visit.

In addition to the clinical sites, four laboratories, based in three separate universities performed the work of reprogramming ting hiPSC from primary cell cultures. A biobank at a separate institution stored the finished cell lines and shipped them out to research teams based in the other consortium partner institutions. On arrival at the clinical site, each participant provided consent, by reading a participant information sheet and signing a consent form. The consent form gave permission for the reprogrammed material to be shared with academic and commercial entities and signalled participants' agreement to forfeit any further ownership or rights in the tissue (see Author 2019).³ They then provided biological material in the form of a skin biopsy and a blood sample (participants with autism for whom skin and blood sampling was considered potentially traumatic provided a less effective, but more ethically and clinically acceptable hair biopsy instead). Finally, each participant provided data about their family and medical history, current medications, and completed a number of validated paper-and-pen based screening tests for cognitive ability, depression, and Parkinson's-related hand tremors (e.g. hand drawing an Archimedes spiral).

The signed consent forms were stored at each clinical site. Each biopsy sample was recorded on a two-part proforma. On one sheet, the participant's name and address were recorded, along with the date, time, name of the person taking the biopsy, and the name of the clinical site. The second part contained the same data but without the participant's name and address. Both parts of the proforma, and the container holding the biopsy sample, were labelled with a freezer-

³ The associated information sheet also explained that the cells would not be transplanted into any person or used for reproductive purposes, although they could be used in animal experiments.

proof sticker containing a unique identifying number of the form ‘S-XXX’, where ‘S’ indicated the substance (a skin biopsy) and ‘XXX’ represented a number between 001 and 500.

The biopsy, along with the non-identifying section of the proforma was then sent to a local laboratory where it would be transformed into a fibroblast (skin cell) culture and separated into six aliquots. Each of these were labelled SF-XXX-0Y (SF for skin fibroblasts, and 0Y where ‘Y’ indicated aliquots 1 to 6). These samples, along with a further proforma recording the date, site and operator of the fibroblast culturing work, were then shipped to one of the four reprogramming laboratories where the long process of biochemically transforming cultured primary cells into a pluripotent state occurred.

Each successfully reprogrammed line was labelled SFC-XXX-0Y-0Z (again using a unique freezer proof label), where SFC indicates a reprogrammed (‘clonal’) cell line derived from fibroblasts and 0Z indicates one of up to four clones made from each sample. The identity (in the form of the code SFC-XXX-0Y-0Z) of each successfully reprogrammed cell line was recorded in the StemBD database by staff at the reprogramming site. Approximately 30 labelled vials of each iPSC line were shipped to the central biobank facility for storage and dissemination.

Each blood sample was labelled in a similar way, and sent for testing for the presence of the infectious agents Hepatitis B, Hepatitis c and HIV. Again, this data was uploaded to StemDB once the tests were completed. In all cases, the same three-digit number was used to identify samples belonging to that specific participant and only that participant (Author et al 2016). Each questionnaire sheet also had a space for the participant’s unique three-digit project identifier to be entered. The data from each questionnaire, minus the participants name and

address, was also entered into the StemDB website. The use of the same ‘XXX’ code enabled the details of the donor to be connected with details of the physical iPS line made from their tissue and the tests from that donor’s blood sample. For example, participant 123 gave blood sample 123 and biopsy S-123 which was transformed into fibroblast culture SF-123, some vials of which will have been reprogrammed to give hiPSC line SFC-123-01-01, all of which are also associated with dataset 123 on stemDB.

The making of a bio-object thus proceeded through a particular series of heterogeneous entanglements of bio (blood, skin biopsy, fibroblast cultures) non-bio (documents, labels, test tubes, vials), and digital (database entries) elements accompanying particular manipulations of the living bio-material (excising skin, turning it into a fibroblast culture, reprogramming this to a stem cell culture). Achieving these entanglements required considerable choreography of these heterogeneous elements. The outline of this process is represented in Figure 1 and described in more detail subsequently.

Figure 1: Flows and entanglements of biological, physical and digital entities in making a human induced pluripotent stem cell line.

This choreography was only possible because of prior flows of often mundane non-bio elements (labels, paper documents, test tubes), demonstrating that bio-objectification, like mobility, is dependent on a range of existing digital and physical infrastructures, many of the components of which are themselves, at least intermittently, mobile (Sheller and Urry 2006). At each of the eight recruitment sites, a standardised project consent form, participant questionnaire sheet and sample collection SOP and proforma were downloaded from a password-protected section of the project website and paper copies printed out locally. At non-UK sites information sheet and consent form had to be translated from the English originals to allow them to retain their function as they travelled. SOPs for fibroblast culture and reprogramming and proforma for recording each step were also downloaded by the staff at each laboratory charged with carrying out these tasks. The project website and its stored master document templates and SOPs do not represent Holmberg, Schwennsen and Webster's (2011) biovirtual; the documents are not 'data doubles' of bio-objects, but it illustrates that even everyday digital infrastructures and flows can have an important role in the preparatory work of bio-objectification.

Once downloaded, the sample collection SOP specified the designated equipment for taking the biopsy and blood samples, which could then be purchased from a supplier and shipped to each site. The freezer-proof labels containing the unique identifiers for each biopsy, blood sample, aliquot of fibroblast culture, and reprogrammed pluripotent cell line were all printed centrally using a special printer located at the main project biobanking facility. The right number of copies of each label then had to be shipped by conventional post to each clinical site and laboratory ready to be attached to the proforma and containers of biological material. Finally, data uploaded from the recruitment site (participant questionnaire responses) and reprogramming laboratory (cell line ID, quality control and biological characterisation data)

were integrated through the stemDB database to create the ‘data doubles’ of the finished bio-objects (Brown and Williams 2015).

As indicated in our ‘Theoretical signposts’, entanglements of bio and non-bio elements facilitated both mobilisation of the bio-object-in-the-making and the identify formation of the bio-object itself. Some were necessary for *immediate* mobility of the bio-object-in-the-making. Excised tissue and blood samples could not move from one physical site to the next (e.g. from clinic to laboratory) without being accompanied by the paper proforma documenting whichever transformation event- biopsy, fibroblast culture or reprogramming- had produced that material, and details of where, when and by whom the manipulation had been done. Other processes, such as the consent provisions or taking a blood sample and uploading pathogen-testing results, were necessary for the mobility of the hiPSC to the other partner institutions in the consortium and will be discussed later.

Several practices described above- collecting and storing a signed paper record of informed consent, the forms used to record each step from biopsy to reprogramming, and the quality control and cell characterisation data uploaded to stemDB - involved the kind of bureaucratic logging, recording and cataloguing of specimens described by Stephens and Dimond (2015). These loggings contribute to bio-objectification by contributing to the emerging identity of the bio-object. Brown and Williams noted that the use of digital cord blood registries created and made durable ‘*new patterns of correspondence* between data points and bodies’ (2015: 6 emphasis added). Both the digital and paper records employed in the making of hiPSC perform this role of creating new durable connections, or ‘patterns of correspondence’ in Brown and William’s terminology, between bodies, biological samples, data points and places. They make each sample not just ‘a’ skin biopsy or ‘a’ human cell culture but the product of a specific set

of actions performed at a specific site by a particular operator and originating from a particular donor-participant.

Several of these acts of recording are the result of enactment of existing regulations, especially the EU Tissues and Cells Directive. That Directive (2004/23/EC), and supplementary European legislation, mandates that adequate informed consent be given and recorded for any *de novo* collection of human blood and tissue. It also stipulates that such material be traceable from point of origin through all subsequent transformations and circulation (Author et al 2016). Here we see a regulatory foundation for the identity of biological material being conceived of in terms of its origin (in a person/place) and its subsequent movements across geographic and institutional space.

A similar notion can be found elsewhere in EU law, in the regulatory requirement for genetically modified organisms (GMOs) to be logged and tracked from the moment of modification (Lezaun 2006). This regulatory strategy is not confined to Europe. An informative example is provided by Hinterberger and Porter (2015) in their study of claims of national sovereignty over viruses and genomes. Concerned at the potential for biological data and material sourced within their jurisdictions to be appropriated by companies and researchers in other, wealthier nations, some states in the global south have claimed sovereignty over such materials through legal concepts such as ‘the Mexican genome’. Importantly, these claims to sovereignty do not render the samples and data to which they are applied immobile. Rather, ‘foreign’ researchers and companies can access and use materials and data from the global south, provided they continue to acknowledge the source nation and, commonly, agree to provide some sort of benefit sharing or equitable access to the future results of research or commercialisation.

Like the European GMO regulations, these provisions mandate that particular data and material be classified in terms of an origin point, whether as ‘Mexican’, ‘Indonesian’ etc. or arising from an act of genetic modification, and that this classification *travel with* the data and material. As Hinterberger and Porter describe it:

viral and genomic sovereignty create a tethering effect in distributed systems of biological research, one that roots specific virus strains and genomic variations to their supposed origin (Hinterberger and Porter 2015: 371)

Significantly for this analysis, the creation of a ‘tether’, an enduring legal and bureaucratic connection between biologically-derived material and data, and the idea of an ‘origin point’ - whether a hospital where a sample is derived, a laboratory where an organism is genetically modified, or a geopolitical entity like a state where material was sourced - comes to act *as a condition of their mobility*. Despite the apparent paradox, it appears that establishing and maintaining a link to a point fixed in time and space, actually enables bio-objects to become mobile.

This holds true for the StemBANCC hiPSC. Human tissue samples, and material derived from them cannot be used or distributed in Europe if evidence that they were collected with suitable informed consent and a recording of their origin point and donor are not demonstrable. The practices that create these records contribute to forming the identity of bio-objects, by making a durable connection between material and place or person, *and* act as a condition of their mobility across territories and institutions that operate within particular regimes of governance, in this case EU regulations. Perhaps unsurprisingly⁴, much of the tacit labour of making these

⁴ See e.g. Shapin 1989;

connections; manually transferring answers from written questionnaires to the online database, recording details of cell cultures, taking consent and so on, was undertaken by research nurses, technicians and postdoctoral researchers at the different hospital and laboratory sites in StemBANCC.

Given that ‘tethering’ (Hinterberger and Porter 2015) requires a connection to a fixed, non-mobile entity, it is also worth paying attention to what did not flow in making StemBANCC hiPSC. The personal and family medical history of an identifiable, living individual, as collected at each recruitment site, count as sensitive personal data under European data protection law. In order for this data to travel, in the sense of being made available to academic and commercial researchers in the StemBANCC consortium, it needed to be de-identified (Author et al 2016). The signed consent form and the biopsy proforma with the donor’s name and address thus cannot travel as they are inherently identifying. Instead, they remained at the clinical site. At the same time, the blood, tissue samples and data still needed to be both mobile and traceable to specific individual participants. The freezer-proof labels with unique identifying numbers (S-XXX, SF-XXX-0Y, SFC-XXX-0Y-0Z et cetera) act as a link between individual donor and the materials and data derived from them, as the same code links the sheet of the biopsy proforma bearing the donor’s identify and all the de-identified samples and data uploaded to stemDB. The simple freezer-proof labels are thus a material instantiation of the dual EU regulatory requirements for traceability of biological material and protection of personal data. Moreover, by connecting the non-mobile records of donor identity and consent and the circulated material and data, the combination of labels, proforma and database entries *perform the tethering* of mobile and fixed entities that allows the creation of mobilisable bio-objects.

2) *Making bio-objects mobile*

Having produced mobilisable bio-objects, this section recounts the subsequent steps as the StemBANCC materials and data were circulated to various distributed academic and industry groups in the consortium. As an IMI funded public-private partnership, StemBANCC had certain requirements for mobility built into the project agreement, signed by all these partner institutions. The StemBANCC cell lines and data were envisaged as an open resource, to be available to the ‘European research community’ broadly understood as including universities, large pharmaceutical companies, small-to-medium sized medical and biotechnology firms, and state or charity-funded research institutions. To facilitate this, the consent collected from StemBANCC participants was written to be broad, open-ended and uniform, ensuring the project’s stem cells could be made available for current and as-yet-unplanned ‘disease-related’ research regardless of the users status in terms of public or private sector (or indeed any hybrid forms) (Marelli 2016).

The European Commission also has a role as a ‘neutral broker’ in the IMI (Goldman 2014), providing a set of rules, embedded in each project agreement, on the conduct of both public and private sector institutions in each IMI funded project. These are intended to ensure ‘fair play’ by all parties and cover matters such when and how any intellectual property rights can be allocated. In StemBANCC, the grant agreement stated that all partner organisations in the consortium were entitled to access all the project stem cell lines and accompanying data on an equal basis, and that fair access would be overseen by an appropriate governance mechanism. Thus ultimately took the form of the StemBANCC Biorepository Materials and Data Access Committee (BMDAC) (Author et al 2015).

The data access remit of the project was largely limited to ensuring each partner institution had passwords for the protected areas of the project website and stemDB. The main work of the BMDAC was overseeing access to the cell lines. Despite their ‘data doubles’ being mobilised via stemDB, the irreducibly material nature of hiPSC meant they had to travel through separate infrastructure. A cell line order form was devised for internal project use, in the form of a downloadable document on the project website. This had to be printed-off, signed, scanned and submitted by email. This was later reconfigured as a digital order form built into the StemBANCC section of stemDB. In practice, both versions continued to be used throughout the project, as the paper order form was easier to use for requesting large numbers of cell lines at once and could be completed offline. Once submitted, all order forms went to a ‘BMDAC processor’ for review. This was one of my allocated tasks for a considerable part of the project.

An archive of emails from the processing of cell line requests submitted to the StemBANCC BMDAC contains some 2781 emails. This is not only testament to the volume of communication required to mobilise StemBANCC hiPSC, it also speaks to the variety of actions performed by those communications. The retained emails are only those that contain substantive exchanges and omits many further emails of ‘thank yous’, introductions, ‘out of office’ responses, general enquiries, and interactions that make up a lot of the work of sustaining cordial relations with consortium members in distant institutions, many of who we never met in person, or only saw perhaps once a year at meetings.

Figure 2 shows part of the order form, adapted from an original StemBANCC project document, that lists a series of checks to be performed by the BMDAC processor before a cell line can be shipped. These checks reflect the wider requirements for making hiPSC mobile

across the institutional and jurisdictional landscape of the consortium and are worth considering in more detail.

Figure 2: The BMDAC processor's checklist from the StemBANCC cell line order form

In the checklist shown in Figure 2, terms have the following meanings:

Term	Meaning
In scope / out of scope	Project partners could request cell lines for mandated StemBANCC research ('in scope' or 'level 1 requests') or for their own separate research uses ('out of scope' or 'level 2 requests').
External collaborators	People and institutions not part of the StemBANCC consortium, with whom consortium members wanted to share some materials and data for a specific piece of level 2 research work
Rare lines	hiPSC made from samples that were collected as part of a separate project using different terms of consent
QC testing	Quality control data- primarily reporting whether or not a cell line had been successfully reprogrammed and whether it had any chromosomal abnormalities
Pathogen testing	Results from testing participants' blood for presence of viral agents.
MTA	Material Transfer Agreement – a standard contractual agreement used for making project cell lines and data available to external collaborators

Table 1.0: Explanation of selected terms used in the BMDAC processor's checklist.

Several of these checks effectively served to enable or restrict mobility in a fairly binary way. Reprogramming is difficult, often relying on the tacit knowledge and craft skill of the operator (Meskus 2018), and far from infallible. Not all attempts at manufacturing a cell line were successful. A line that did not pass QC testing was not eligible for use and could not be shipped. Several countries require human biological material shipped across their borders to be certified as free of particular viruses (mainly HIV and hepatitis) as a biosecurity measure. StemBANCC pathogen testing used the participants' donated blood- collected as described in the previous section- as a proxy to test for the presence of infectious agents in the cell lines. Successfully passing pathogen testing was another condition of mobility for StemBANCC cell lines.

As discussed above, mobility of materials and data within the consortium was stipulated- in effect, propelled -by the project (grant) agreement, which took the form of a binding contract between the IMI and the partner institutions. Movement to third parties was outside the scope of this contract and thus required a separate agreement, in the form of a Material Transfer Agreement (MTA). A template StemBANCC MTA was drawn up for any project member wishing to share StemBANCC materials and data with non-consortium members. For 'out of scope' requests with a non-project partner, the presence of a signed MTA became another compulsory passage point to be reviewed by the BMDAC processor before mobility could be enabled.

The remaining check, for 'rare lines' requires some background. Not all StemBANCC hiPSC were produced from the *de novo* biopsies described in the previous section. Although the majority were produced this way, a small subset were reprogrammed from existing tissue

samples held by certain project partners. This occurred where previous research projects had obtained blood or tissue samples from patients with rare, usually monogenic, forms of the diseases being studied by StemBANCC. These monogenic cases of otherwise complex common diseases are considered especially scientifically and commercially valuable for studying the mechanisms of pathology (see also Author 2019), so it was eventually agreed these existing samples be reprogrammed as part of StemBANCC. Due to their origin in prior research projects, these ‘rare’ samples had separate, and different, terms of consent attached, which cell line requestors needed to be aware of.

The example of BMDAC processing illustrates the considerable amount of informal or tacit labour involved in making bio-objects mobile. The flows of information that attend and enable the mobility of biological materials are shown to be far from seamless (c.f. Edwards et al 2011; Vertesi 2014)) with considerable tacking back and forth between physical and digital systems. Making and sustaining these points of correspondence between bio and non-bio elements is labour, which sits, in my interpretation, somewhere between the ‘ethics work’ described by Hoyer, Tupasela and Rasmussen (2017) and Nadim’s (2016) data labours.

The influence of regulation is again significant. As in the previous section, formal statutory regulations continue to play a part, most notably in the form of national biosecurity laws that were enacted through knowing and communicating the pathogen testing status of the cell lines. Contract-based forms of regulation such as the IMI project agreement or the MTA, a standard tool for university technology transfer offices and life sciences companies alike, enabled institutional interests to gain purchase on and regulate the movement and use of bio-objects. Other examples were more ‘bottom-up’; the decision that cell lines not passing QC were not

suitable for use was the result of normative consensus among consortium members that such lines were not scientifically useful and not worth mobilising.

Many of these regulatory factors act as ‘gates’; directing and channelling the mobility of bio-objects, at times constraining movement- imposing conditions (e.g. of speed) or even mandating non-flows (Sheller and Urry 2006). At the same time they also, in many cases, contribute to bio-objectification. Having a cell line described as ‘pathogen negative’ or as having passed QC becomes part of its technical, scientific identity. When a set of cell lines and associated data are described in a Material Transfer Agreement, this constitutes an inscription of a particular ‘legal’ or contractual identity. Descriptions of ‘the material’ to be transferred are incorporated into the schedule of such contracts along with terms of use, including those mandated by the original consent forms, and matters of ownership, liability and capacity for further travel. Regulatory devices such as the MTA, or the terms of consent associated with original samples from which ‘rare’ lines were produced, encode certain flows or non-flows; what can move where and under which conditions, or via which gates. By contributing to the identity of the bio-objects which they regulate, such regulations travel *with* the bio-object, enabling them to act over space and time (as with, for example the original terms of consent persisting through the end of one project and into subsequent uses, even accompanying the transformation of the material into hiPSC). The mutual shaping of identity and capacity to travel that we saw in the making of the hiPSC as bio-objects, extends through the mobilising phase through further entanglements with regulatory devices such as MTAs, which modify, or add dimensions to, the identity of the bio-object. Thus, just as a requirement for mobility affects the making of bio-objects, so mobilisation also extends the duration or unfolding of the process of bio-objectification.

Discussion

In scientific texts and policy discussions about stem cell banking projects like StemBANCC and EBiSC, the focus is often explicitly on enabling access to the biological material (e.g. McKernan and Watt 2013). As we have seen, a vast array of heterogeneous elements- people, labels, money, equipment, ethics applications, documents, and more must be marshalled to even begin the process of making mobilisable cell lines. Adopting a bio-objects approach illustrates the value of moving beyond the idea that ‘what matters’ is circulating the cell lines ‘plus associated data’ while the various consent forms, MTAs, paper records, and labels are relegated to the background of necessary-but-tedious administrative work. In order for the biological material to travel, an array of non-biological elements- labels, pathogen testing certificates- and the ‘data doubles’ of the bio-virtual realm must also be mobilised. What looking at mobilisation makes clearer is that the bio-object *as an object of analysis* must be considered as made up of all these different components. Where ‘the cell line’ as conventionally understood might be a single entity with ‘associated’ data and records, from a bio-object perspective the diverse digital, biological and non-biological components each contribute to different registers of identity of the bio-object. These identities, or ontologies, following Mol (1999) are multiple; they refer neither to a single ‘real’ underlying (bio)object, nor to completely separate entities.

Mobilising a bio-object therefore means circulating a variety of heterogeneous components that contain and comprise different registers of its multiple ontologies. These different components- - may each travel via different infrastructures, from conventional postal services to websites, and at different speeds. If mobilisation *differs* across the heterogeneous components of the bio-object then what travels is literally not ‘the same’ bio-object. If any

given hiPSC line is shipped from a biobank *with* pathogen testing certificate, QC data, IP rights, donor medical records, record of consent, sample ID, etc. or *without* some or all of these elements, it is not the same entity despite (initially) being physically the same biological material.

Yet other components that make up the identity of the bio-object; consent forms, documents with participants names and addresses, signed MTAs, must not travel in order to facilitate, or permit mobility. Despite the apparent paradox, making bio-objects capable of being mobilised requires establishing durable links that tether each bio-object to fixed points, whether these might be institutions, a moment of transformation, or even a country. The very durability of these links between what does and what cannot travel, these tethers, becomes a condition of mobility, enabling circulation even as they place constraints or terms upon it. This is particularly apparent for cell lines as their identity is so bound up with their origin- in a donor, in a place and time of creation, and in records of those origin events. As living entities, cell lines change their properties in relation to their environment over time. These even applies to the genetic content of cell lines in culture (unless frozen and taken ‘out of time’). For such malleable, plastic forms, their status as objects (as things rather than life) depends on and requires the durable points of correspondence that are markers of the multiple legal, ethical, bureaucratic, technical, and social strands of their history and identity. Some of these, as noted move and others must stay fixed.

Bio-objects in circulation must therefore be considered distributed across physical, institutional and legal space, as well as across biological, non-biological and digital forms. This has implications for how we think about and value the different infrastructures through which

distributed bio-objects flow and the labour of enabling, co-ordinating and sustaining these flows.

Consider the final '*en masse*' transfer of cells, data and records from StemBANCC to EBiSC. The move enabled the StemBANCC consortium to fulfil its remit to provide an enduring open access resource of well-characterised cell lines for the European research community, by allowing another EU consortium, EBiSC to take responsibility for setting up a sustainable banking and dissemination infrastructure. As might be expected this additional round of mobilisation involved considerable further data labours. Consortia such as StemBANCC do not have legal personality to own materials, data, patents et cetera so at the end of the project (and the end of the project contract), ownership of the cell lines reverted to the institutions at which reprogramming took place while ownership of online or paper records reverted to the institutions holding the relevant website or archive. Multiple further MTAs were then required to transfer these distributed elements of the bio-objects to suitable institutions within the EBiSC consortium. Considerable work was also involved in trying to align formats and metadata requirements to allow data to flow from StemBANCC systems to the (separate) databases and registries used by EBiSC (c.f. Edwards et al 2011). Not everything was able to travel, and much was transformed in the process of travelling- for example, the EBiSC catalogue uses its own naming system for cell lines, which replaced the StemBANCC cell line IDs, although the latter are still listed in the information provided to users of the catalogue.

This process revealed the fragility of some of the tethers that tie bio-objects to fixed origin points. Demonstrating adequate consent for the 'rare' lines made from existing samples reprogrammed by StemBANCC had involved reviewing the original consent forms from the initial studies to see if they allowed for reprogramming to a pluripotent or immortalised cell

line. Where there was ambiguity or uncertainty about the terms of this original consent, a verdict on permissibility could be sought by contacting the research ethics committee or institutional review board responsible for overseeing the original study. If they sanctioned the reprogramming, then it could proceed. The ‘chain of consent’ can thus incorporate both the initial consent form, the assessment of compatibility with StemBANCC ethics, and the subsequent discussion with the REC. Much of the latter comes in the form of emails and ad-hoc internal MS Word documents. These are comparatively easy to share in the context of formal discussions between representatives of one consortium and another, but much harder to actually incorporate into the standard categories that make up the online catalogue of a stem cell biobank. Access to this knowledge is often held by individuals working in the various institutions implicated in the bio-objectification process. As such, it is subject to the vagaries of institutional memory. As people retire, move jobs and institutions (especially when many people working on consortia are on fixed term contracts that end when the funding ceases) the semi-tacit knowledge of what was done, and how that connects bio-objects to fixed points and events, risks being lost if detailed records, and instructions on how to find them and where they are stored, are not retained. Given that the identity of a bio-object and its capacity to travel are dependent on such tethers and that changing what can travel changes the bio-object, these neglected elements of mobility infrastructure have very real implications for the promise and sustainability of ‘big biobanking’ projects.

Conclusion

Making bio-objects capable of being mobilised requires a great deal of preparatory labour and organisation, not to mention the mobilisation and assemblage of many, heterogeneous elements. This is by no means smooth or simple. There are delays, disagreements over what to

do and when, and unanticipated challenges. For example, stem DB was not designed to collect the visual data (e.g. handwriting sample, family history trees) that participants were asked to complete, so forms had to be scanned and uploaded as images, but this raised the risk they would contain identifiable data (e.g. if people wrote their own name in the handwriting sample) and some records proved to be un-sharable due to confidentiality violations. A late move to collect additional blood samples as an alternative source of material to make hiPSC meant that Stem DB and much of the labelling and reporting system had to be adapted to include skin, hair or blood as an origin material etc.

Regulations, from formal EU and national laws on traceability and biosecurity, to contracts and MTAs, and terms of consent or a group of scientists' agreement on quality control provisions, each direct the conduct of actors doing the work of bio-objectification, but through doing so also contribute to the identity of the bio-objects being created and mobilised. One way in which they do this is by mandating the creation of durable connections between people, places, events and records, which tether the biological material to fixed, non-mobile entities. Such tethers (Hinterberger and Porter 2015) not only make particular records of origin and history part of the identity of the bio-object, they concurrently incorporate particular conditions of mobility into the legal strand of its identity. These conditions enable bio-objects to cross regulatory boundaries- whether national jurisdictions in the case of biosecurity laws or institutional boundaries in the case of MTAs and contracts. This mobility comes at a cost; flows are enabled but directed and circumscribed; not everything can flow everywhere or be used for any purpose and sometimes passage points, such as consulting the original terms of consent or a custodian or institution implicated in the official history of the bio-object for further permissions, are mandated.

The bio-object thus comprises biological, non-biological and digital components.. In StemBANCC the bio-object is not a vial of hiPSC; rather it is the vial of cells, their digital doubles on stemDB, the donor medical history and tests, their quality control and pathogen testing status, the terms of consent, their origin in a particular act of biopsy conducted at a specific location at a certain time, the contractual terms under which they are available (from StemBANCC, EBiSC or whoever) and the various records and documents that attest to these phenomena. If all the elements and tethers are not mobilised then what travels, and what is ‘reassembled’ by the recipient is not the same bio-object. Contemporary investments in ‘big biology’ infrastructure rarely recognise, or aim to support the maintenance of the durable connections that bio-objects require. Broken connection or partially mobilised bio-objects may experience their own limitations- for example if evidence of viral testing is lost they may not be able to travel, if details of consent are not attestable, journals may not accept publications based on those lines and companies will certainly be reluctant to work with them. It is likely that tethers can be reassembled and distributed bio-objects can be recovered or re-attached to their connections in at least some cases, but only at the cost of considerable, likely unacknowledged and potentially unrewarded, tacit labour as people are despatched to hunt through old records, emails and database entries.

Finally, as regulatory devices embed conditions of mobility into the identity of bio-objects themselves, the act of being mobilised actually changes this identity and adds another set of connections that must accompany the bio-object on its travels. In other words, the history- and thus identity- of bio-objects is not fixed, but is extended and added to as a direct effect of their mobilisation. This suggests that the work of sustaining bio-objects and their connections is ongoing and may even increase rather than decrease over time, which is rarely considered in the rhetoric of acceleration and translation that is so prevalent at the policy level. The long term

utility, or not, of these new large scale bio-resources will surely be a topic for future STS scholarship, although it could surely benefit from understanding the social lives of existing bio-objects from cell lines to modified mice, and how their identities unfold or are sustained over time.

Acknowledgements

The initial research leading to these results has received funding from the Innovative Medicines Initiative Joint Undertaking under Grant Agreement number 115439 (StemBANCC), resources of which are composed of financial contribution from the European Union's Seventh Framework Programme (FP7/2007-2013) and EFPIA companies in kind contribution. This publication reflects only the author's views and neither the IMI JU nor EFPIA nor the European Commission are liable for any use that may be made of the information contained therein.

Further work on this publication was carried out with the support of the Economic and Social Research council grant "Biomodifying technologies and experimental space: organisational and regulatory implications for the translation and valuation of health research (grant no ES/P002943/1).

I would like to thank Andrew Webster and Luca Marelli for helpful discussions on earlier drafts of this manuscript, and the four anonymous peer reviewers for their constructive input.

References

Biagioli, M and Buning, M. (2019) Technologies of the law / law as a technology. *History of Science* 57(1): 3-17.

Brown, N. and Williams, R. (2015) Cord blood banking – bio objects on the borderlands between community and immunity. *Life Sciences, Society and Policy*, 11(11), doi: 10.1186/s40504-015-0029-8

Cambriosio, A., Bourett, P, Keating, P. and Nelson, N. (2017) Opening the regulatory black box of clinical cancer research: transnational expertise networks and ‘disruptive’ technologies. *Minerva* 55:161-185

Edwards, P.N., Mayernik, M.S., Batcheller, A.L., Bowker, G.C. and Borgman, C.L. (2011) Science friction: data, metadata and collaboration. *Social Studies of Science*, 41(5): 667–690

Eriksson, L. and Webster, A. (2015) Standardising work as recursive process: shaping the embryonic stem cell field. *New Genetics and Society*, 34(1): 72-88

Goldman, M. (2013) New frontiers for collaborative research. *Sci. Transl. Med.* 5, 216ed22

Harmon, S.H.E. (2018) Responsible regulation in action? Responsible research and innovation and the European Bank for induced pluripotent stem cells. *Law, Innovation and Technology*, 10(1), 15-39,

Hauskeller, C. and Weber, S. (2011) Framing Pluripotency: iPS Cells and the Shaping of Stem Cell Science. *New Genetics and Society*, 30 (4), pp. 415-431.

Hinterberger A. and Porter N. (2015) Genomic and viral sovereignty: tethering the materials of global biomedicine. *Public Culture* 27(2): 361-386

Holmberg, T., Schwennesen, N and Webster, A. 2011. Bio-objects and the bio-objectification process. *Croatian Medical Journal* 52; 740-2

Hoeyer, K., Tupasela, A. and Rasmusen, M.B. (2017) Ethics policies and ethics work in cross national genetic research and data sharing: flows, non-flows, and overflows. *Science, Technology and Human Values* 42(3): 381-404

Jha, A. (2011) Look, no embryos! The future of ethical stem cells, *The Guardian* [online edition], 13th March 2011 Available at <https://www.theguardian.com/science/2011/mar/13/ips-reprogrammed-stem-cells> Accessed 08/04/2016.

Latour, B. (2004) *We have never been modern*. Cambridge, MA: Harvard University Press.

Lezaun, J. (2006) Creating a new object of government: Making Genetically Modified Organisms traceable. *Social Studies of Science* 36(4): 499-531

Livingstone, D.N. (2003) *Putting science in its place: Geographies of scientific knowledge*. Chicago: Chicago University Press

Marelli, L (2016) The co-production of scientific and Translational induced pluripotent stem Reprogramming platforms. Governance innovation in Cell research. Unpublished PhD Thesis; European School of Molecular Medicine (SEMM), Italy.

Marelli, L. and Testa, G. (2017) Having a structuring effect on Europe: The Innovative Medicines Initiative and the construction of the European health bioeconomy. In: V. Pavone, and J. Goven, (Eds) Bioeconomies: Life, technology and capital in the 21st century. Basingstoke: Palgrave Macmillan, pp73-10.

McKernan, R. and F. M. Watt. (2013).What is the Point of Large-Scale Collections of Human Induced Pluripotent Stem Cells? *Nature Biotechnology* 31 (10): 875–877

Meskus, M. (2018) Craft in Biomedical Research: The iPS Cell Technology and the Future of Stem Cell Science. Basingstoke: Palgrave Macmillan.

Metzler, I. 2012.On why states still matter: In vitro fertilization embryos between laboratories and state authorities in Italy. In: N.S. Vermeulen, S. Tamminen, and A. Webster (Eds) *Bio-Objects: Life in the 21st Century*. London: Ashgate, pp151-170.

Milne, R. (2016) In search of lost time: age and the promise of induced pluripotent stem cell models of the brain, *New Genetics and Society*, 35:4, 393-408

Mol, A. (1999) Ontological politics: a word and some questions. *The Sociological Review* 47(1, supplement): 74-89

- Morrison, M., Klein, C., Clemann, N., Collier, D.A., Hardy, J., Heißerer, B., Cader, M.Z., Graf, M and Kaye, J. (2015) StemBANCC: Governing research access to material and data in a large stem cell research consortium. *Stem Cell Reviews & Reports*, 11: 681-687
- Morrison, M., Moraia, L.B. and Steele, J.C. (2016) Traceability in stem cell research: from participant sample to induced pluripotent stem cell and back. *Regenerative Medicine*, 11(1): 73-79
- Morrison, M. (2017a) Infrastructural expectations: Exploring the promise of international large-scale pluripotent stem cell banks. *New Genetics and Society* 36 (1): 66-83
- Morrison, M. (2017b) “A good collaboration is based on unique contributions from each side”: Assessing the dynamics of collaboration in stem cell science. *Life Sciences, Society and Policy* 13:7 DOI: 0.1186/s40504-017-0053-y
- Morrison, M. (2019) Making cells worthwhile: Calculations of value in a European consortium for induced pluripotent stem cells banking. *Science as Culture* 28(1): 46-69.
- Nadim, T. (2016) Data labours: how the sequence databases GenBank and EMBL-Bank make data. *Science as Culture* 25(4): 496-519
- Rader, K. 2004. Making mice: Standardizing animals for American biomedical research, 1900–1955. Princeton, NJ: Princeton University Press.
- Shapin, S. (1989) The invisible technician. *American Scientist*, 77(6): 554-563.
- Sheller, M. and Urry, J. (2006) The new mobilities paradigm. *Environment and Planning A*, 38: 207-226

Star, S. L., and K. Ruhleder. 1996. Steps toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research* 7 (1): 111-34.

Stephens, N. and Dimond, R. (2015) Unexpected tissue and the biobank that closed: an exploration of value and the momentariness of bio-objectification processes. *Life Sciences, Society and Policy*, 11(14), doi.org/10.1186/s40504-015-0032-0

Vermeulen, S. Tamminen, and A. Webster (Eds) *Bio-Objects: Life in the 21st Century*. London: Ashgate.

Vertesi, J. (2014) Seamful spaces: Heterogeneous infrastructures in interaction. *Science, Technology, & Human Values*, 39(2): 264-284.

Waldby, C. and Mitchell, R. (2006) *Tissue economies: Blood, organs and cell lines in late capitalism*, Durham, NC, Duke University Press.

Webster, A. (2012) Introduction: bio-objects: exploring the boundaries of life. In N.S. Vermeulen, S. Tamminen, and A. Webster (Eds) *Bio-Objects: Life in the 21st Century*. London: Ashgate: pp 1-12.

Figure 1: Flows and entanglements of biological, physical and digital entities in making a human induced pluripotent stem cell line.

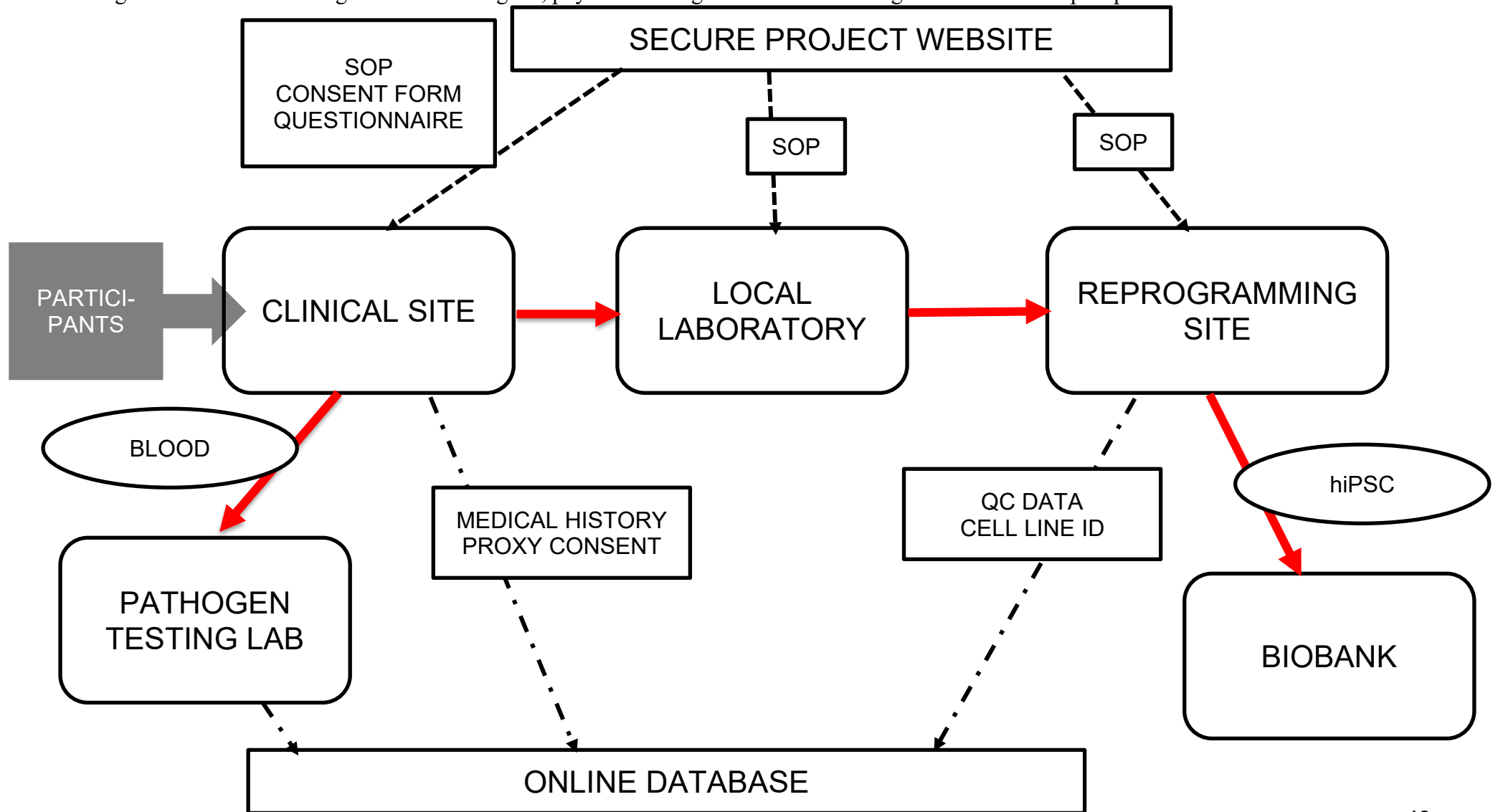


Figure 2: The BMDAC processor's checklist from the StemBANCC cell line order form



Part C: For Biorepository Materials and Data Access Committee use only

Date received:

- a) Is the request in scope? Yes ☐ proceed to d No ☐ proceed to b
- b) Does the request involve external (non-StemBANCC) collaborators?
Yes ☐ proceed to e. No ☐ proceed to c
- c) Are restricted-access lines involved? Yes ☐ proceed to f No ☐ proceed to d
- d) Is the line in stock? Yes ☐ No ☐
Has the line passed QC testing? Yes ☐ No ☐
Does the request require pathogen testing data? Yes ☐ No ☐
If Yes, is pathogen testing data available? Yes ☐ No ☐
If 'yes' to all, approve line and authorise shipping to sender.
If 'No' to any approve request but place line on reserve and do not ship until all required data is available and the line is in stock.

e) Have the following requirements for external collaborators been met?

	Yes	No
Copy of signed MTA received?		
Copy of signed side letter received?		
Receipt of original signed side letter confirmed by concentris?		

If 'yes' for all categories proceed to c

Otherwise return to Requestor for additional information or to explain what needs to change to make the request acceptable.

f) 'Restricted-access' lines

Date line provider informed of response:

Was an agreement reached? Yes ☐ No ☐

If Yes, briefly record the terms of agreement below and proceed to d

If No retain form for BMDAC records and reporting. Date:

StemBANCC BMDAC appraisal:

Request approved ☐ Date:

Request passed to HBRC ☐ Date:

Requestor notified of Appraisal ☐ Date:

