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“Placing the human in mammalian synthetic biology”

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For the original and inimitable Dr Stone,

I miss you so very, very much.

Abstract

Synthetic biology (SB) is the application of engineering approaches to construct novel biological entities and redesign existing ones. With aspirations to heal, heat and feed us, SB has captured the imaginations of scientists, social scientists, policy makers and industry alike. Mammalian synthetic biology (MSB) especially is framed as potentially transformative of human healthcare and medicine. Correspondingly, humans have become a key reference point for both technical and social enquiry. Recent decades have produced an abundance of social scientific research into SB. However, studies that focus on the human as a direct topic of investigation tend to focus on ethical enquiry 'downstream' of real-time research activities, or co-production of SB research with its wider social institutions (such as governance structures of human germline editing). Any research that focuses on the specific research activities themselves (such as experimental work or automation practices) only entangle the human indirectly. There exists no targeted empirical investigation into how, when or where the human appears in real-time SB research activities; the forms such appearances take; their patterns of presence and absence; or the work they perform. This thesis addresses this gap specifically in relation to MSB research.

I adopt an ethnographic approach to exploring four MSB projects 'in-the-making' that engage with biomedical topics and a range of human and non-human experimental systems. I follow these through a diverse set of research activities including laboratory work, organising project resources, reporting results, and engaging with different communities. I generate data using participant observation, documentary sources, and semi-structured interviews. I then deploy theory from Science and Technology Studies, Human Geography, and elements of Critical Discourse Analysis to interrogate how the human appears.

I demonstrate there are multiple ways the human can appear in real-time research practices. These range from biological materials being considered 'human', to imaginations of human health and future human consumers. However, I also argue that whether these human appearances *do* materialise is contingent on the other materialities with which they are entangled, the practices through which they are performed, and the function they can accomplish (such as negotiating value or accommodating non-specialist audiences). I also argue that human appearances are deeply rooted in notions of place. Where, when, and how they emerge is tightly coupled with notions of 'belonging' in some places and not others. This generates a set of associations between the human appearances, project materialities, and specific places of MSB research. Some places emerge as strongholds of human enactment (such as places of organisation), others emerge as strongholds of human estrangement (such as places of experimentation). Through demonstrating these contingencies and complexities, I disintegrate any notion of a stable, singular way the human appears as part of real-time MSB research activity. Finally, I conclude by advocating that the role of place be acknowledged and accommodated when engaging with human appearances in the context of MSB real-time research. Specifically, I suggest rethinking interaction in STS research to foster a more integrated and place-centric approach moving forward.

Lay summary

Synthetic biology (SB) is an emerging field of scientific research that aims to design and engineer new abilities into biological life. By configuring biology in novel ways, it hopes to solve many global challenges. One way it hopes to do this is by creating new medicines and therapies to improve human health. This ambition has resulted in much speculation about what this might mean for the future of medicine, and the human more broadly. Will we be able to modify ourselves in any way we want? What would that do to how we understand being human? These questions focus on how SB affects the human in the future; whilst they are exciting to consider, they risk overshadowing what is happening in the present. After all, much of SB's present-day research focuses on small, incremental changes to specific biological functions. This is especially the case for the research in mammalian synthetic biology (MSB). Instead of leap-frogging the present to focus on the future, this study shifts our attention to how MSB research activities relate to the human in present-day research. Currently, we know little about how ideas of the human permeate MSB researchers' everyday work. Does the human appear during the making - or making sense – of new biological systems, and if so in what way? Do ideas about human health or applications play a role at these early stages? Do researchers consider the human origins of the biological materials they use? These are all important questions to answer if we want to better understand - and ultimately have a say in - how SB develops in relation to human health initiatives.

To answer these questions, I explored a range of real-time MSB research activities. My findings show that the human does become part of the everyday work, but in varied and complex ways. Some of the common ways involve classifying biological materials as human, imagining projects' future health applications, and acknowledging researchers' own roles as curious and creative humans. However, these different understandings of the human only intermittently appear. They only emerge when they serve a useful purpose and are suited to the research activity. Even then, they only appear if they are seen as 'belonging' in the places where the research is being performed. There are specific times and places when it is appropriate to engage with the human in MSB research (such as negotiating with research councils to mobilise funds or talking to communities who know little about the research). Then there are specific times and places when it is not appropriate (such as conducting experiments). This thesis documents the distribution of human appearances and demonstrates how they are not only linked to specific research practices and utility, but also notions of belonging and place. I conclude by suggesting that if scientists and social scientists are to work together to ensure SB develops in a responsible and ethical way, the relationship between human appearances and notions of belonging and place must be accommodated in future social scientific research.

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Chapter 1: Introduction

1.1 Motivations

It was sometime in late 2014 when an article about synthetic biology (SB) on the World Economic Forum's (WEF) website caught my eye. Its title was provocative, and the article - though short - posited a handful of utopian and dystopian futures for consideration:

> **Will biology change what it means to be human?**
>
> The latest scientific advances will soon enable us to take charge of evolution itself. Synthetic biology is a new form of engineering that involves the creation of complex, new biological systems. It is the result of the confluence of knowledge in life sciences, engineering, and bio-informatics, and the most promising innovations in this new field – genetic design, protein manufacture and natural product synthesis – could have a revolutionary impact on our lives, particularly with regards to the production of energy and medicine. It brings with it gigantic opportunities and risks. Early innovations may include personalized, genome-specific medications for the treatment of cancer and degenerative diseases such as Parkinson's and Alzheimer's […] On the other hand, synthetic biology could also prove extremely hazardous […] Certain DNA products have huge capacity for virulence or pathogenicity. […] In addition to these security threats, the rise of synthetic biology poses a series of ethical considerations. […] Within a decade or so we will have the ability to enhance our mental dexterity, not only in terms of mental ability, but also our emotionality (or lack thereof) […] The very concept of biological and cognitive enhancements poses significant questions. […] The protective response required is not easy, but necessary. We must aim at creating oversight mechanisms that mitigate risks without stifling innovation."
>
> (Al-Rodhan - writing for the World Economic Forum, 2014)

I was intrigued; I had noticed that narratives of synthetic biology's 'gigantic opportunities and risks' were highly prevalent, and that they often entangled a variety of imaginations relating to the human. Such visions and imaginations appeared in discourse ranging from the UK government's policy documentation on synthetic biology right through to TEDx talks about sending humans to space. Yet as Marris and Rose (2012) explain, speculative utopian or dystopian futures such as those outlined above are exciting, but unhelpful. There are more pressing questions to be asked; for example, "[w]hat are synthetic biologists actually doing?" (Marris and Rose, 2012). After all, as Calvert and Frow (2013) note, "our understanding of the social dimensions of synthetic biology is very different when we move from

speculations to a closer investigation of what day-to-day scientific work actually involves" (2013:73).

Indeed, as time wore on, I became increasingly curious whether ideas relating to the human appeared as a reference point in the activities comprising the day-to-day SB work. I grew curious about the real-time work that went into making – and making sense of – the SB research. Did any human appearances emerge in the activities of making and making sense of research? If so, did they do so with the same prevalence as the wider narratives? What work did they perform in the present? If they did not appear, what else might appear instead? More to the point, what helpful things could we learn by knowing the answers to such questions?

1.2 Introducing 'real-time' SB research

Before proceeding further, it is worth elaborating what is meant by the term 'real-time SB research'. We can elaborate this by tackling its constituent parts: firstly, 'SB research'; and secondly, 'real-time'. In this way, we can build up a robust picture of what comes to count as the 'real-time SB research' in which this thesis is so interested.

We can understand the 'SB research' part of the term in relation to *what* activities and materialities are involved. 'SB research' is the set of ongoing processes, actions and material enactments that go into the making - and making sense of - new synthetic biology knowledge, materials, and tools. Under this formulation, a varied set of practices - and materialities enacted in practice - come to count as SB research. This includes experimental work such as the design and execution of experiments that give shape to synthetic biology research. It also includes iterative organisation and administration activities that structure and frame the work. Additionally, it also covers the assembly of articles, posters and presentations, and their subsequent enactment within wider communities through which research and outputs are ratified and given meaning. All these come together to comprise 'SB research' in what Pickering (1995) terms the 'mangle of practice' (1995).

We can understand the 'real-time' part of 'real-time SB research' in relation to *how* that research is experienced. 'Real-time' SB research - or as it is found in other parts of this thesis 'research in practice' or 'research in the making' - is an understanding of the research *as* it takes place in the immediacy of the 'here and now'. It focuses on the activities and materialities at the point in space and time that they are

practised into action (*in actu*). Myers and Dumit (2011) provide a useful articulation of 'real-time' when they describe it as being "at the pace of lived perception" (2011:255). It emphasises the immediate experience of the research activities and materialities enacted in practice as they unfold. For example, real-time research might include an experiment at the point it is run in the laboratory. It might also include the moment a presentation is delivered to an audience, or an article is written and the SB research it enacts performed anew and given meaning and legitimised through a community. Section 3.4.2 provides more examples, and we encounter many others throughout the empirical chapters.

This 'real-time', in the 'here and now' experience of research as it unfolds, contrasts with other ways that SB research can be experienced. For example, specific episodes of SB research can also be known or experienced retrospectively, or 'after the fact'. A researcher might experience and understand a particular experiment in a series of ongoing experiments after it has been completed. The difference here is that understanding the specific SB research episode once it is complete will be contextualised through what is subsequently known about its outcome that may not have been known during the time the action was actually performed (Myers, 1990; Rheinberger, 1999). A second contrasting example might be when researchers 'step back' from the immediacy of a research activity to reflect upon its progress. This often sees practitioners 'take stock' to formulate and understand their SB activities and materials through their role as part of wider social and political institutions (Michael et al, 2005)[1,2]. In contrast, 'real-time' keeps alive the immediate experience of the research as it unfolds, focusing on what is important to researchers at the point the activities are executed in the here and now.

As Calvert and Frow (2013) urge us to move closer to what SB research "actually involves" (2013:73), I soon realised it was the 'here and now' of that research - complete with its unknowns, uncertainties, and contingencies - that captivated me most. And thus, armed with an interest in how the human appears in real-time SB research and a better understanding of what that might involve, I set about exploring the existing literature.

[1] As we discuss in Section 3.4.2 these contrasting types of engagement still offer advantages to investigating what *is* real-time practice, but it is useful to be clear on the distinctions between them.
[2] As we shall see in Chapter 5 and 6, these *institutions* often form part of real-time research activities through their entanglements as contexts. However, what is different from this example is that there, those 'contexts' are made through the practice of research as it unfolds. *Not* through reflections from a distance as stipulated here.

1.3 Where are all the humans?

I began reviewing existing literature armed with a single question: where are all the humans in real-time SB research? This question initially led me to two separate sets of scholarship. It turned out that exploration into the human as a direct object of investigation in relation to SB was typically the purview of ethics (Grunwald, 2011). Meanwhile, exploration into real-time synthetic biology practices sat squarely in the wheelhouse of Science and Technology Studies (STS).

I first attended to the ethical literature. There emerged no shortage of enquiry into the relationship between the human and synthetic biology. However, there was minimal engagement with real-time SB research practices as a site of interest. Most ethical enquiry used speculative techniques focused on risks and issues of synthetic biology framed in terms of potential 'downstream' hopes, hazards, and futures (Priaulx, 2013)[3]. Such speculative investigation routinely focused on topics relating to how SB outputs might eventually change our relationship with being human. These included: whether SB medicine might result in different ways of viewing human bodies; the ethics of human enhancement; changing relationships between the natural and non-natural, and the human and non-human; considerations of human exceptionalism and emancipation from nature; 'playing god'; and other related topics (Chan, 2018; Bensaude-Vincent, 2013; Deplazes-Zemp, 2012; Evans, 2013; Douglas and Savulescu, 2010). Whilst there were many fascinating debates to be had, I was less interested in how synthetic biology might change future relationships with the human, and more interested in the practicalities of their entanglement in present day SB practice.

In this regard, the STS literature was more instructive. STS has an abundance of research into real-time SB research practices. Yet despite the range of available literature, there was - by contrast - minimal engagement with the human as a direct object of investigation[4]. There emerged some innovative STS and synthetic biology collaborations that implicated the human as a reference point in the exploration of novel entities and how they might trouble existing ways of thinking about (and categorising) biological materials. For example, Szymanski et al's (2020) art-led work on fusing human-derived mammalian cell lines with yeast cell lines provoked questions about categories, including how we might think about what it means to be

[3] Although Borry et al (2005) and Chan (2018) both advocate there is a will to move ethical enquiry 'upstream', this is limited material relating to this specific topic of enquiry.
[4] This reflects STS more broadly; the human as a direct subject of investigation is empirically underserved in STS in general (Jasanoff, 2015).

human (2020:715). Similarly, Agapakis and Tolaas (2014)'s attempt to defy existing boundaries by generating 'human cheese' brought together humans, bacteria, and fungi in a challenge to existing categories. However, in most cases, studies that focused on exploring *routine* SB practices rarely foregrounded entanglement with the human as part of their investigation. Many of them instead only implicated human appearances by merit of studying other, related objects of investigation.

Examples of such related objects of investigation include studies focused on the performances of SB practitioners where human appearances emerge by merit of the practitioners being human themselves[5]. For example, studies investigating practitioner intentions and expectations (such as studies by Hilgartner, 2012; Kastenhofer, 2013a; Frow, 2013; and Schyfter and Calvert, 2015); as well as practitioner physicality (such as framing the body as a hazard by Balmer et al, 2016; or interrogating automation practices by Mellingwood, 2018). Another related topic includes investigating metaphors or analogies where different conceptions of the human emerge through the rhetorical devices (such as studies by Hellsten and Nerlich, 2011; McLeod and Nerlich, 2017; and Kearnes et al, 2018). A third example includes investigation into policy performances such as those surrounding the human germline editing where the human emerges as a subject of governance structures (such as Martin and Turkmendag, 2021[6]). Whilst all these studies *implicate* human appearances in the context of SB research practice or technologies (whether through the practitioner body, their appearance in rhetorical devices, or as the subject of policy performance), their designation as a 'human appearance' (or not as the case may be) is *not* the focal topic of investigation.

Indeed, there exists no *direct*, empirically focused investigation into how the human appears across SB real-time research. Nor any interrogation into what work human appearances might perform, any consequences that might arise from the nature of the relationship in the present, or what we can learn from knowing the answers to these sorts of questions.

In setting out to respond to this lack of direct investigation, this thesis was born.

[5] Although, as we shall see in later Chapters, not all practitioner performances necessarily enact their specifically 'human' dimensions explicitly into presence. Section 2.3.1.3 provides further information on this distinction.

[6] It should be noted that this paper does not focus on synthetic biology specifically; it does, however, centre on the use of technology (CRISPR-Cas9) and genome editing (GE) practices that significantly overlap with synthetic biology's technology and goals making it significant to the SB context.

1.4 Research aims, questions, and clarifications

1.4.1 Research aims and questions

The overarching aim of this thesis is to understand the ways in which the human appears in the context of real-time synthetic biology research practices, specifically mammalian synthetic biology (MSB) research practices. Its primary goal is to generate a better understanding of what types of human appearances emerge in the context of MSB research; how, when, and where these appearances emerge; and what work they might do as part of the MSB research materialities.

As well as identifying a gap in direct, empirical investigation, my immersion in both scientific and social-scientific literature had shown me that the biomedically focused synthetic biology activities (ones that sought to gain insight into human health and diseases and yielded the majority of utopian and dystopian imaginations relating to the human) were increasingly focused on mammalian synthetic biology (MSB). MSB is the subset of SB that aims to engineer novel devices and functions into mammalian cells (or whole mammals) as opposed to bacteria or plants. Exploring synthetic biology to unpack how the human emerges in the context of real-time research is therefore well served by focusing in on the biomedically focused area of MSB research. There is a momentum to MSB research and, as we will see in Chapter 7, insights derived could potentially be helpful to STS's continued engagement with MSB as it continues to develop.

The overarching aim of this thesis also encompasses two specific objectives. Firstly, to contribute empirical evidence and socially robust knowledge generation to an area that is empirically underserved. Secondly, to generate helpful insight into the relationship between MSB research and the human that STS initiatives might be able to use to engage with MSB researchers more productively on human-related topics moving forward. In this way, my research intentions are part analytic and part normative.

To satisfy these objectives, I address one overarching research question (RQ), with four sub-research questions (S-RQs) to guide the investigation and add depth to the interrogation[7].

[7] Notwithstanding the hierarchy and dependence between the overarching and sub-research questions, these will on occasion be collectively referred to as 'research questions' as the thesis proceeds for ease of readability.

RQ: How does the human appear in the context of real-time mammalian synthetic biology (MSB) research practices?

S-RQ1: What types of human appearances are there (if any)?

S-RQ2: What are the circumstances of human appearances: how, when, and where do they emerge?

S-RQ3: What work do human appearances perform in practice?

S-RQ4: What can we learn from the answers we find?

1.4.2 Elaborating 'human appearances' as objects of investigation

To answer these questions this investigation takes as its research subject the ways in which the human appears in the context of real-time MSB research practices. To successfully investigate such a research subject, however, it is necessary to identify specific phenomena that can be observed and interrogated as 'objects of investigation'. In this thesis, these objects of investigation are any 'human appearances' that form part of the MSB research materialities and practices. At this juncture, it is useful to determine how best to understand the term 'human appearances'. This removes any ambiguity about what might qualify as an object of investigation and in doing so provides a robust understanding with which to navigate the rest of this thesis. The first step to doing this involves identifying what can be considered 'human'; the second, elaborating the term 'appearance'.

1.4.2.1 What can be considered human

There are two main ways to identify what might be considered 'human' during real-time MSB research, and thus what might be a candidate 'human appearance'. The first is to define up front what the 'human' is, then seek instances in the real-time research practices that satisfy that definition or criteria. For example, one approach might be to treat any physical object or being that contains human or human-derived biological material as 'human'. Under such an *a priori* articulation, any of the laboratory's human-derived cell lines or the human practitioners themselves (as well as any verbal and written references to those, real or imagined) could be considered 'human' components of the research. The second approach is to treat the term 'human' as a heuristic rather than a pre-defined entity. This allows anything that is actively given shape or understood as 'human' during the research itself to qualify. For example, any cells explicitly made sense of in the moment as 'human cells' or practitioners conducting themselves in a way they consider 'human' (as well as any

verbal and written references to those) could be considered human components. In effect, the *practice* of something as 'human' becomes its definition.

In this project, I take the latter approach for two reasons. Firstly, it pays close attention to what is meaningfully understood as 'human' in the specific context of the real-time research practices, rather than specifying *a priori* what is to be understood as human regardless of the context. In this way it remains both empirically- and participant-led, foregrounding the accounts of those directly involved as the research unfolds, rather than imposing definitions or categorisations onto the research. This is congruent with an approach that focuses on real-time research, creating another way to unpack what is important to the research in the here and now.

Secondly, it is permissive, leaving room to capture unanticipated ways the human might appear as well as a wide variety of potential forms. Based on what we already know about MSB in its wider social institutions (as well as other comparable biotechnological endeavours), the human could appear in a range of ways and through a variety of practices. We have already seen from the opening discussion that references to humans can be found across visions, promissory rhetoric, and risk discourse (entangled in notions of "personalized, genome-specific medications" or aspirations of "enhancing our mental dexterity" (Al-Rodhan, 2014)). Biological materials can also be designated as 'human' - a process that is inherently tangled up with governance structures and matters of regulation (Brown, 2003; Eriksson, 2012; Hinterberger, 2017; 2020). The human (as a generalised research subject) is also often used as reference point in the aims of biomedical research initiatives and projects (Hinterberger, 2020). Elsewhere references to patients and improving human health underpin the policy discourse that projects seek to deliver (see for example: SBLC, 2016). The term 'human' can even be used to characterise project aspirations or outputs such as a 'human goals' or 'human application'. Following the human as a 'heuristic' rather than pursuing an *a priori* definition allows us to remain alive to potentially unanticipated ways in which the 'human' (as permissively conceived of) may - or may not - come up in the context of MSB real-time research activity.

1.4.2.2 Understanding appearances

However, not all potential human components or elements that can be found entangled in the orbit of MSB research writ large end up actively manifested as part of the real-time research activities. The term 'human appearance' therefore denotes a potential human component (as understood above) that has gone on to become an

identifiable and apparent part of the real-time research materialities. In this way, the term ‘human appearance’ can best be understood as an outcome, an end result where certain components have been made or made sense of as ‘human’ and are now apparent or manifest as such in the research.

These human appearances do not ‘appear’ from nowhere though. As we will see in Section 1.5 below, it is a basic premise of this thesis that materials, meanings, apprehensions, and more - thus also human appearances - are ‘performed’ into being through practice. For example, ‘human cells’ are not *human* cells merely because they were designated as such in another context elsewhere, they are human cells because of how they are practised in the moment in question. The cells are ‘performed’ or ‘enacted’ into being as human. This applies equally whether the potential human component takes physical form (e.g. human cells, or human practitioners) or the form of an apprehension (e.g. visions of human health, or allusions to potential human applications). This is elaborated more concretely in Section 2.2; for now, it suffices to know there is a *process* to accomplish human appearances in real-time research.

Accompanying this notion of process is an inherent temporality. Human appearances are assembled into being through practice. How quickly that process occurs depends on the types of practices through which that happens, ranging from the quick to the protracted. For example, a verbal utterance from a practitioner designating a cell ‘human’ when giving a presentation is a quick enactment of a *potentially* human component (a hitherto unqualified cell) into presence as a human cell. Meanwhile, a debate between practitioners about whether a cell is - or is not - human often ends up being a longer enactment, the contested cell goes through a process of negotiation. The same temporal considerations also exist when potential human appearances are rendered absent. At the laboratory bench, a potentially human-related project goal such as a future human application may be rapidly rendered absent through repression (i.e. actively not thinking about it). Conversely, a practitioner wrestling with behaviour they consider ‘inappropriately human’ in the lab (such as overly empathising with their cells) may take longer to ‘eliminate’, resulting in a longer negotiation of the potential human component (practitioner feelings) into absence. As human appearances become enacted in practice.

Even after clarifying the term ‘human appearance’ as one that connotes the *outcome* of these processes rather than the processes itself, it can still generate ambiguity. The term ‘appearance’ has connotations of immediacy and apparition (as if from nowhere) that seemingly contradicts the notion that human appearances are

performed. This tension is most markedly noted when human appearances are discussed in relation to the processes of emerging, becoming, or being performed (for example, through phrases such as: 'human appearances emerge'). Given this tension, an argument can be made that the objects of investigation might better be conceived of through terms that simultaneously capture their process of becoming as well as the resultant material manifestation. If we were to take that position, the objects of investigation might be better articulated as 'human enactments' or 'human performances'[8].

In the face of this argument there are two reasons I continue to elucidate the objects of investigation as 'human appearances'. The first relates to the legibility of the work. Neither the readability of the thesis, nor the legibility of the key findings contained therein, should be underestimated. The common usage of the term 'appearance' makes the objects of investigation broadly legible to those less familiar with performative terminology such as enactment or performance (Pickering, 1995). Indeed, the term 'human appearance' initially came from remarks made by participating actors in this study. The concept is therefore generally more meaningful and accessible to a wider range of audiences (including the scientists within my study) than the concept of 'enactment' or even 'performance'.

The second reason is that the term 'human appearances' is more inclusive than 'enactment' or 'performance'. As we elaborate further in Section 2.2.5, what counts as present isn't always black and white. Some human components may be unambiguously present in real-time research and others unambiguously absent; but there is a third state where potential human components can ostensibly be absent from the research but remain entirely relevant to the research and apparent to the researchers involved *without* it being present. It is made 'manifest' in its absence through its significance (Law, 2004a:157). Terms such as 'human enactment' and 'human performance' are more concretely focused on the enactment of its presence[9]. Instead, the term 'human appearance' leaves room for manifestations that may technically be absent but are still apparent.

1.4.2.3 Terminology moving forward

[8] The terms enactment and performance are technically not synonymous; however, in line with Law (2004a), for all practical reasons in this thesis they can be used interchangeably.
[9] Enactment is also equally capable of negotiating something into absence. However, the enactments cannot be considered '*human* enactments' if the human is performed as absent, instead they would be enactments of something else.

With this elaboration in mind, all that is left is to clarify how these closely related terms will be used moving forward. Typically, the term 'human appearances' will appear in the context of *what* types of potential types of human appearances are apparent or manifest in real-time MSB research. Meanwhile, terms such as 'human enactment' (or performance, emergence, negotiation, and more) will more typically be found in discussion that relates to *how* human appearances become part of real-time research, or how they become elided from it. When these later terms are used, they capture more concretely the sense of process and temporality inherent in the process of making human appearances. That said, there is no hard and fast rule. Which term is used will also depend upon which might be more accessible or less confusing to the reader in the context of the story being told.

These advantages aside, being permissive about the objects of investigation - in both what can be considered human *and* what counts as an appearance - is not without its challenges. It leads to a proliferation of complexity and renders the object of investigation vague, and at times indefinite. I have attempted to elucidate some of that complexity in this section, but it is not possible to eliminate it. Here I turn to John Law (2004a) as he reminds us: "(Social) science should also be trying to make and know realities that are vague and indefinite *because much of the world is enacted in that way."* (2004a:14).

It is therefore the ambition of this thesis to make these vague and indefinite materialities a little more legible.

1.5 Brief synopsis of the argument

In this thesis, I outline an argument relating to human appearances in the context of real-time MSB research that centres on performances of materiality, practice, function, and above all else, place.

Specifically, I argue that how, when, and where human appearances emerge in the context of MSB is an act of performance. I demonstrate that there are multiple potential ways that human appearances can emerge in the context of MSB research practices. These range from physical experimental materials that can be considered 'human' (such as human-derived biological materials), to imaginations of human health-related outcomes and potential future human consumers. Yet I also argue that whether potential human appearances *do* emerge becomes a matter of performance and is therefore contingent on a variety of factors.

Firstly, human appearances (whatever form they might take) depend on the practices and other materialities through which they are performed. Not all practices or material configurations give rise to human enactment. Secondly, human appearances tend to emerge when they perform a useful function; they are also typically elided as 'insignificant' when they do not. Thirdly, human appearances are often inextricably connected with other human appearances. As such, one potential human appearance has the capacity to complement or complicate another's performance. For example, there are times when human appearances may provide a useful function but are still assembled into absence by merit of conflicting with other potential human appearances that are assembled there. Fourthly and finally, I argue that human performances are – above all else - deeply rooted in notions of place.

It is this last point that is most central to this work. Where, when, and how human appearances emerge is tightly coupled with notions of 'belonging' in some places and not others. Potential human appearances are spatially, temporally, and socially designated to specific places, and not to others. This generates a set of associations and attachments between the human appearances and specific places of MSB research. Some places emerge as strongholds of human enactment (such as places of organisation), whilst others emerge as strongholds of human estrangement (such as places of experimentation). Consequently, when it comes to human entanglements and enactments, there is no one stable way that they are performed or appear in the context of real-time MSB research. The multiple places of MSB real-time research all perform differently in relation to their human entanglements and enactment.

Throughout this central argument, I also demonstrate that that human appearances play a role in real-time MSB research practices, performing significant work in the present. As such real-time MSB entanglement and enactment of the human becomes a topic of interest to future STS research. Given the inextricability of human appearances from notions of place and belonging, I argue that any future STS research must recognise the role of place. Specifically, I recommend rethinking interaction in STS research in ways that re-enchants some older theorisations of place and encourages a more integrated and place-centric approach to pursuing social scientific enquiry on topics relating to human enactment in real-time MSB research. Specifically, I offer a discussion on using the concept of 'topical contextures' encountered in Chapter 2 as a potential method of intervention in STS-MSB interactions.

1.6. Outline of thesis

To generate the argument outlined above, this thesis is split into seven chapters.

Chapter 2 introduces us to the theoretical foundations of this project and contextualises the topic in relation to existing literature. With human appearances emerging in a wide range of MBS research activities, this chapter provides a detailed review of the social scientific literature through which to contextualise, analyse, and articulate the argument above. The review focuses in three core areas. Firstly, I review the social scientific literature relating to how MSB real-time research materialities can be productively theorised. MSB research entangles a wide range of concrete objects and abstract things (collectively termed materialities). To better understand how human appearances emerge as part of these materialities, I interrogate literature from the performative idiom of STS (Pickering, 1995) to theorise the way that materialities are enacted in practice and how best to theorise the presence, absence, and multiplicity of MSB research materialities that arise. Secondly, I review a selection of literature that contextualises the key practices through which the research materialities – and thus human appearances - are performed into being. I use this section of the chapter to evaluate Rheinberger's (1997) experimental systems; explore some of the literature on expectations, promises, and imagined futures through which to contextualise the promissory rhetoric around human health; and unpack theory on discourse practices to better contextualise the discursive performances of real-time MSB research. Thirdly and finally, I conclude with an in-depth investigation into theorisations of place. Throughout my empirical data, human appearances are frequently linked with ideas and expectations of place. I compile a comprehensive discussion of place using literature from STS and Human Geography, elaborating how place can be theorised; its relationship to underlying concepts of space, time, and complexity; and the role place plays in entrenching normative associations amongst enacted materialities.

Next, Chapter 3 elucidates the research design and methodological approach I have taken in this investigation to pursue the object of investigation. In this chapter, I elaborate on some of the core research design decisions I took in this study. I explain the decisions behind pursuing a multi-site ethnographic investigation, outline my approach to case studies, and document how I prepared for the field. As well as elaborating the methods I used to generate data, I also take the time to elaborate my data reduction practices, coding activities, and the use of Critical Discourse Analysis (CDA) to elucidate themes and findings in relation to the topic of investigation. I also use this chapter to pay close attention to considerations of ethics and reflexivity. Not

only do I provide a short discussion of ethical participant engagement, but I also reflect on the matter of both my presence and the nature of my research topic as a provocation to participants. I also conclude the chapter with important discussion on the ethical performance of writing and the steps I have taken that led me to present the complex set of materialities in the way that I have, and the ultimately political nature of methodological decisions.

Next, we turn to the empirically led part of the thesis: Chapters 4, 5, and 6 comprise the main empirical evidence of this study. I use each of these chapters to interrogate a different place of real-time MSB research practices for how they entangle and enact potential human appearances. With each empirical chapter, I first identify potential human appearances. Then I unpack how, when, and where they emerge, and the work they perform. Whilst doing this, I also analyse the data and generate the key themes and patterns to emerge in relation to human entanglements and enactments. In this way, each empirically led chapter stands in partial response to the overarching research question by generating the empirical data required for each of the sub-research questions. They comprise much of the evidence with which I make my central argument.

Specifically, I use Chapter 4 to interrogate the research materialities that gather in experimentally focused laboratories. Indeed, a significant proportion of real-time MSB research involves designing and performing experimental work. This is one of the key places of real-time MSB research to explore. In this chapter, I demonstrate that there are many potential human enactments entangled with MSB project materialities. However, most of them are actively negotiated into absence during experimental activities and identified as ‘belonging’ elsewhere. At every turn we encounter assertions that the human “doesn’t come up” or “is not relevant”. Human appearances are routinely ‘othered’ to alternative places of belonging such as ‘in nature’, or ‘in the future’. The few human enactments that do emerge are sorted and ordered in line with a “time and place” where it is appropriate for them to appear. My analysis culminates in an account of the experimental laboratory as a place that routinely eschews human enactment. This chapter therefore also provides valuable insight to the overarching argument about how absence and presence are negotiated in conjunction with each other.

Another way real-time MSB research is performed is through organisational work. I use Chapter 5 to introduce the ‘organising units’ (the Institute and the parent Laboratories) that negotiated and manage the projects. I demonstrate that organising units actively promote potential human-health related outcomes into presence in

ways that mobilise funding, generate interest, and provide direction to the individual projects. Any potential human appearances that might detract from this orientation' are elided from view. As such, organising units become places where human enactments of specifically 'biomedically relevant' human performances are prioritised and expected. Through their performance as future-orientated and enacting wider areas of opportunity, these human appearances bring not only a human presence, but a human *orientation* to the places of organisation. In providing this account, this chapter also provides an interesting point of contrast for how different strategies to manage tensions amongst human appearances and multiplicity of materialities contribute differently to not only the sociomaterial, but also the spatial and temporal ways that places are performed.

In Chapter 6, I tackle some of the more diverse practices of real-time MSB research. MSB research is not constrained to the laboratory or the laboratories and Institutes that organise it. In this way, this chapter contributes evidence for some of the real-time research practices that might otherwise get overlooked in a more traditional laboratory-based study. I use Chapter 6 to explore an array of real-time MSB research activities performed through the communities in which they belong (ranging from peer-reviewed publication to showcasing research). I demonstrate that in the context of specifically specialist communities, most potential human appearances are negotiated into absence, but retained as an implicit 'context', absent but still relevant to what is made present and thus still manifest. Where human appearances do emerge, they tend to be performed in the peripheral or ancillary parts of the research materialities such as metadata, or background information. Specialist communities therefore enact places of peripheral and manifestly absent human contexts. Meanwhile, I demonstrate the reverse is true with the human appearances in non-specialist community performances. During these performances of real-time MSB research, human appearances not only permeate - but also explicitly belong - in nearly every aspect of the MSB research enactments. With this integration, human appearances are part of the 'here and now' of project performances, and with that so too are the spatiotemporal dimensions they enact. Non-specialist community performances become integrated places of 'human inclusion'. In compiling this account, this chapter also plays close attention to the material arrangements and relations they enact. Specifically, it juxtaposes different community performances to demonstrate how the different material relations enact different types of complexity, and ultimately different types of places.

Finally, I use Chapter 7 to draw together the empirical evidence and analysis from across Chapters 4, 5, and 6 to address the two specific objectives outlined in Section

1.4.1. Firstly, I distil the existing observations and bring them together with theorisations from Chapter 2 to generate a comprehensive response to the over-arching question (and by extension its sub-research questions) outlined in Section 1.4. In doing so, I focus on not only the patterns and principles we can elicit about the nature of human appearances in the context of real-time MSB research, but also what we can learn more broadly. Throughout the discussion I elicit the key themes and assemble the argument outlined in Section 1.5. In this way, I use the chapter to satisfy the first objective to contribute empirical evidence and robust knowledge generation. Secondly, I turn our attention to satisfying the second objective: generating useful insights from the argument I have assembled. I use the final sections of Chapter 7 to outline my empirically led recommendations for rethinking interaction in STS research, specifically in relation to engaging MSB research with topics of human entanglement and enactment in a place-centric way. In doing so, I reframe the insights from my empirical work to offer a discussion on using the concept of 'topical contextures' (Lynch, 1991) encountered in Chapter 2 as a potential method of intervention in STS-MSB interactions.

With this outline in mind - and in an homage to my late father - I heed the call of my father's lesser known misquote of a better known misquote of Shakespeare:

> "Read on Macduff,
>
> And damn'd be him that first cries,
>
> 'Hold enough!'"

Chapter 2: Theoretical foundations

2.1 Introduction, aims, and overview

In the Introductory chapter, I identified a gap in direct empirical investigation and thus an opportunity to contribute to an underserved area in STS. Whilst opening exciting doors of opportunity, it also presents a theoretical dilemma. If investigation into the human as a direct object of investigation has historically been overlooked (Jasanoff, 2015), then to what literature and key concepts should we turn to better theorise human appearances when they do become a direct object of STS investigation? It is question that this chapter sets out to answer. In this chapter, I aim to present a set of theories and key concepts through which to contextualise, analyse, and articulate the empirical findings of this study. To do this, I draw on key scholarship from Science and Technology Studies (STS), Human Geography, and feminist material semiotic literature. Together this generates a theoretical foundation upon which to build the central arguments of this thesis.

I tackle this challenge by evaluating useful literature in relation to three core themes that underpin this thesis: materialities, practices, and place. Firstly, I introduce theorisations on how the materialities of scientific research can be understood. This provides the theoretical foundations to better understand the way in which human appearances become part of the realities of real-time scientific research. MSB research entangles a wide variety of both concrete 'objects' and abstract 'things' (collectively termed materialities). These include research goals and potential outcomes, expectations about future use of the products developed, an array of biological materials and apparatus, as well as the practitioners themselves. As part of these materialities, an array of possible human appearances can emerge. I unpack a range of literature to establish how these research 'objects' and 'things' can be theorised, how they are assembled, how they relate to each other, and in doing so illustrate how potential human appearances become part of them.

Secondly, I address some of the key MSB research practices encountered in the empirical work. If project materialities (including human appearances) are enacted in practice, it necessarily follows that we must pay attention to the practices through which they emerge to fully understand the circumstances of their appearance and the work they perform in the process. Real-time MSB research activities involve experimental research, organisational work, collaboration with both local and

distributed scientific communities, as well as periodic engagement with non-specialist audiences about research in the making. In this second section, I briefly introduce three complementary sets of theory through which some of the key MSB research practices that entangle the human as part of project materialities can be theorised. In the first instance, I introduce Hans-Jörg Rheinberger's work on 'experimental systems' to demonstrate how research objects are assembled into productive experimental formations, and the different roles that the materialities may take on. I then summarise some of the literature on expectations and promises. Synthetic biology is filled with promissory narratives (Frow, 2013) and many of these entangle human appearances in the form of imaginations of future human health-related outcomes of research. I outline some key theorisations from the 'sociology of expectations' literature to help understand how such human-related promises and expectations can become performative components of research materialities. I finish the section by detailing some core principles from discourse studies to indicate how MSB research can be theorised through its discourse as 'action' (Fairclough, 1992) and thus enactment. I point to some key literature that helps articulate the way MSB research is negotiated as it circulates through communities, and the accommodations (or new configurations) research performances entail. Together, these clusters of theory help situate human appearances in the context of the MSB real-time practices through which they emerge, and the work they perform.

Finally, the third substantive section reviews literature and theories that better explain how the situated materialities and practices of MSB research are also performed in conjunction with notions of 'place'. In the empirical data, many of the human appearances enact spatial, temporal, and social ordering practices. This results in certain places emerging as strongholds of human presence, and other places acting as strongholds of human absence. This section steps through how place is theorised in both STS and Human Geography to develop an understanding that helps theorise these patterns of human appearance. In this final section, I briefly summarise the engagement of STS with notions of place. I introduce three core features of place through which to theorise not only *where* materialities emerge, but also *how* materialities emerge. To ensure a robust grounding in place-related theory I introduce a range of the debates relating to place and tensions in the scholarship, before elucidating the underlying notions of space, time, and complexity that can help make sense of place. I then turn to literature from Human Geography to develop a detailed understanding of the 'sense of place', an important feature of my empirical data. I elaborate some key concepts of place in relation to sociomaterial associations and attachments they enact. Finally, I conclude by summarising some useful theoretical insights necessary to help make sense of the multi-faceted ways in which

potential human appearances emerge entangled with notions of place and outline the work that place can perform in real-time.

Across these three sections, I provide both the theoretical perspectives and the key concepts necessary to theorise: how MSB potential human appearances emerge as research materialities, how those materialities are enacted in practice, how those practices then enact places through their materialities, and how those places simultaneously sort and order the research materialities that constitute them. By combining these diverse – but complementary – social scientific theorisations, I produce a theoretical foundation with which to contextualise, analyse, and ultimately articulate the way that potential human appearances emerge in the context of MSB real-time research.

2.2. Materialities in practice, in principle

2.2.1 Introducing materialities in practice

One of the first arguments put forward in this thesis is that human performances are inextricable from the inter-related materialities and practices through which they emerge. As foreshadowed in the discussion in Section 1.3 to elucidate the concept of human appearances*, potential* human appearances may be entangled in multiple ways across the MSB research materialities, but it is only through the practices and performances of research that the potential human performances are concretely brought to presence or assembled into absence. Human appearances do not merely 'appear', they are performed into presence or absence. In this Section, I lay some theoretical foundations through which to better contextualise this argument and consolidate our understanding of 'human appearances'.

2.2.2 Aligning to the performative idiom

In his work describing 'the mangle of practice', Andrew Pickering (1995;1997) draws attention to two useful idioms through which to theorise science in the making. The first is an idiom of representation; the second an idiom of performativity. Pickering asserts that under the first – the idiom of representation - scientific practice is considered as producing a set of representations of nature. Any materialities of science are thus representations or constructions that correspond to 'nature' in some way. Any differences to emerge are due to differences in perspective or the contingencies of construction, the underlying material objects remain the same. The

second idiom – that of performativity – asserts that scientific practice does not produce a set of representations or constructions of nature, but a set of new materialities assembled through the practices in which they were situated. This interprets objects as being materialised into being – or *constituted* - by the practices through which they emerge; practices *make* 'nature', rather than merely representing it in some way (Law, 2004a; Law, 2019). In this way, any differences to emerge in the way the materialities are performed can be attributed to the emergence of differently materialised objects.

The research subject of this thesis (the way in which the human appears in the context of real-time MSB research practices) does not seek to construct a relationship between the materialities that emerge and what they represent. Instead, it seeks to understand their emergence and performance. In this way, the thesis is concerned with material performance over representation and fits best with the performative idiom. In doing so, it centres its focus on how the objects of investigation (in my case human appearances) are materialised into being through the practices in which they emerge.

In pursuing this approach, this thesis joins (and therefore benefits from) a wealth of other STS investigations also generating insights into material arrangements and their performance. Indeed, an interest in the material arrangements of scientific research from ethnographic studies focused on research practices. As STS studies started to unpack the material worlds that are performed into being through scientific practice, there emerged a lively interest in material objects and the things of research. This is something Pickering (2015) refers to as the 'ontological turn'. Indeed, Annemarie Mol's (2002) investigation into atherosclerosis at Hospital Z is an oft-cited example. In her investigation into the scientific performance of atherosclerosis, she drew attention to the emergence of multiple different material enactments of the disease (Mol, 2002). There were other STS studies focused on scientific activities 'in the making' that also pursued this route, unpacking research materialities in the making. This signalled an apparent 'turn' away from STS work that had hitherto been interested understanding the production of scientific knowledge (epistemology) towards an increased focus on the material objects (ontology).

2.2.3 Collapsing epistemology and ontology

In their work, Woolgar and Lezaun (2013) eschew the suggestion that this is a 'turn' to or from anything. They argue that STS has a long history in complicating the

separation between ontologies and epistemologies (2013:322). They argue that knowledge of objects and their performance have long been inextricably linked. They identify a long-standing interest in materialities that collapses the two, pointing to Haraway (1991) and Latour's portfolio of work, suggesting that epistemologies were hardly ever relegated to the 'cognitive'. Instead, they argue that the performative idiom flattens or collapses epistemology and ontology.

This flattening or collapse found resonance within the scholarship of the material-semiotic tradition. Material semiotics is a broad church of social analysis that emphasises attention to practices and explores the "practical anatomy of materially heterogeneous struggles and arrangements" (Law and Singleton, 2014:381). Material semiotic studies span actor-network theory (and its successors), an array of feminist approaches, studies in human geography, and more. They explore practices that are simultaneously semiotic (enacting relations and meanings) and material (enacting arrangements of things and objects) (Law, 2019). For scholars in this tradition, such as Annemarie Mol, John Law, Karen Barad, Donna Haraway, Bruno Latour, and more, the materialities of scientific research not only comprised physical objects (such as cells or apparatus), but also apprehensions, imaginations, and concepts (Law, 2004a; Latour, 2005; Woolgar and Lezaun, 2013). Indeed, as Gad et al (2015) assert:

> "We further indicate that an increasing interest in practice and materiality does not entail a diminished interest in the concepts and categories of informants. These categories are simply not seen as the only possible access points to the worlds of informants" (Gad et al, 2015:74)

According to Gad et al (2015), ontology is being 'epistemologized' and epistemology 'ontologized' (2015:75). This raises a question. How to think off abstract notions as part of the research materialities; how do they take on material form? How do human appearances that emerge in the form of imaginations and representations become materialised components of the project?

Amongst others, Law (2004a) and Woolgar and Lezaun (2013) argue that abstract notions become materialised through the material act of thinking (or imagining, knowing, comparing, discursive exchange, and more). It is the physical act of imagining a human health application (for example) that enacts them into being. Such abstract thoughts do not exist outside the material act, a priori. In this way, the materialisation of abstract concepts can be considered 'practical achievements' (Woolgar and Lezaun, 2013:236). They gain materiality through the act of thinking or imagining them. Therefore, just as physical objects such as human-derived cell lines

can be considered an accomplishment of a series of material acts, so too can materialising abstract concepts (such as an imagined human health application) through acts of practice. Treating abstract concepts and physical objects through this heuristic of 'practical achievement' affords an equivalence to the formerly ontological (physical), and formerly epistemological (abstract) research components during investigation. Under this theorisation of flattened ontology and epistemology, imaginations, expectations, and apprehensions are material and practical achievements just the same as physical research materialities (Gad and Jensen, 2014). This provides a useful way through which to symmetrically theorise both things (concepts) and objects (physical matter) that become entangled in MSB research materialities.

2.2.4 Introducing 'practical ontologies'

Given the collapsed distinctions between epistemology and ontology, Gad et al (2015) point to two alternative 'code words' through which to better make sense of these flattened research components and arrangements. They urge us instead to consider 'practice' and 'materiality' (2015:71). Specifically, Jensen (2010; 2014) argues that materialities (both physical and abstract) are "situated in practice" (Gad et al, 2015). This is something Jensen refers to as 'practical ontologies'. Jensen and Marita (2015) go on to elaborate:

> "The concept does not entail that such ontologies relate only to "practical issues." Instead, it means that they are about how worlds are concretely made, conjoined or transformed by the co-evolving relations of multiple agents; people, technologies, materials, spirits, ideas—or what have you" (Jensen and Marita, 2015:82)

In short: practical ontologies connect abstract ideas with physical objects and collapses them into a flat hierarchy of research materialities that are performed to being through practice. Human appearances are therefore materialised (ontology) through being made in practice (practical). It is this tenet of material enactment through practice that chimes with the data we encounter in the empirical chapters that I take forward to contextualise the way that potential human appearances are performed into being.

Proceeding with such a theoretical foundation, however, requires us to briefly attend to two additional considerations that become important as we engage with the empirical data. Firstly, practical ontologies must make room for the importance of 'absence' as well as 'presence'. If materialities are performed into being, then they are just as easily performed into absence. As we shall see in Chapter 4, human

appearances are routinely performed into absence during experimental laboratory performances. Secondly, practical ontologies are predicated on the notion that if materialities are performed into being through practices (Law and Lien, 2013) then it necessarily follows that multiple varying practices bring forth multiple varying ontological realities. This requires some elaboration and handling.

2.2.5 Paying attention to absence

Firstly, we turn to the importance of absence. Jensen and Marita (2015) draw on Pickering (1997) to suggest that practical ontologies entail a 'theory of the visible'. However, within the performative idiom what is made present also depends on what is made absent (Law, 2004a). For something to be made present, other performances must be rendered absent through the same process of enactment (Law, 2004a). Hetherington (1997; 2004) provides a helpful conception through which to understand this negotiation. He argues that 'multiple modes of ordering' are 'jostling' for what is performed into presence, and what is elided into absence. We see this in the empirical findings. Across the research materialities, different enactments of research materialities (such as project goals, biological materials, even practitioner performances) emerge differently in different places. When one version of a research materiality is performed to presence, this necessarily negotiates the rest of the alternative possible outcomes into absence.

To better understand the relationship between absence and presence, John Law (2004a) provides a useful set of terms with which to define presence and absence. He defines presence as an "enactment of relations that make some things (representations, objects, apprehensions) present 'in-here', whilst making others absent 'out-there'" (2004a:14). He also offers two separate ways to consider absence. The first form he terms 'manifest absence' (2004a:157). It relates to something that is absent from a performance but is - in some way – represented or manifest within it. This might be as a visible context "recognised as relevant to" but not part of the condensed 'in-here' of the performance. A way to think about this would be as context that is relevant to what is being performed, but not explicitly foregrounded. The second form of absence is something that Law terms simply 'absence', or Othering (Law, 2004a:157). This relates to something that is entirely disappeared from view and relevance, not required as context. Things that are negotiated into absence this way – or Othered - become "irrelevant to, impossible, or repressed" whether through insignificance, routine, or incompatibility (2004a:55,157). Across the empirical chapters, understanding the difference in these types of

absence is critical to understanding the nuance of how human appearances do and don't appear, and the work they can perform in both their present and absent forms.

2.2.6 Introducing multiplicity

Finally, we turn to the concept of multiple ontologies. Regardless of whether it can be considered a 'turn' or not, the interest in ontology and materiality has sparked debate in the STS community regarding the ontological implications of enacting materialities into being through practices (Balmer et al, 2016:28). If realities are enacted in practices (Law and Lien, 2013), then when there are multiple, messy performances and practices, the practical ontologies that are generated must also necessarily be messy and multiple. As Woolgar and Lezaun (2013) note, this idiom of practical ontologies and performative action can be a provocative approach. Not least that it gives rise to potentially multiple material enactments. A key question prevails, what to do about the multiplicity this engenders?

In her seminal work on atherosclerosis, Mol (2002) offers some suggestions for how difference and multiplicity is managed in practice. Some available strategies attempt to unify any multiplicity through explaining it away as perspective. Other strategies do not outright reject multiplicity but instead try to elide the complexity that comes from it, drawing it together in ways that acknowledges but simplifies complexity. In terms of the former – attempts to unify - some common 'perspectival' strategies Mol (2002) notes include 'layering', where there is one object, but different dimensions or aspects 'layer' on top of a singular underlying conception. Another perspectival strategy includes the notion of translation; one seemingly different material object 'translates' into another during different stages of its lifecycle. In this way, the 'same' object merely undergoes a linear translation. Closely related to this is the idea of 'submission', a hierarchical version of translation where different objects are sorted in line with local hierarchies, only the dominant remain visible. Another attempt to unify any notion of multiplicity include attempts to 'rationalise'. This involves asserting that one version of an object or performance emerges in one set of circumstances, whilst another is emphasised under a different set of circumstances. Meanwhile, in terms of the latter strategy that focuses less on unifying accounts and instead on eliding the complexity that follows, there emerge strategies to combine different performances into a composite object. For example, an object with multiple different parts to it – a practitioner performance comprised of many different facets for example. This attributes the multiplicity to the object, but in a way that can be reconciled into a coherent narrative.

Across the chapters that follow, we see a handful of these strategies in action as multiple contrasting performances of project materialities enact human appearances into being. However, one of the most pervasive strategies to emerge from the empirical work is an approach from the latter cluster of strategies (eliding complexity not multiplicity). This separates multiple enactments by distributing different objects into different places. It is to the separation by place that we pay keen attention as the empirical chapters unfold. Foreshadowing many of my findings, Mol notes “work may go on so long as the different parties do not seek to occupy the same spot” (2002:115). Indeed, as Cresswell (1996) notes, place is one of the easiest ways of either including or excluding particular positions and performances.

2.3 Unpacking key practices

"Realities are enacted in practices" (Law and Lien, 2013:363)

2.3.1 Assembling materialities through experimental work

Jensen (2010) and Gad et al (2015) demonstrate that research materialities are situated in practice. Across the wide variety of MSB research practices, there are three key sets of practices that enact much of the MSB research encountered in this fieldwork. To better contextualise how the potential human appearances form part of the research materialities is to also understand the practices that bring them into being. The first of the key practices through which MSB research is performed in real time is laboratory-based experimental practice.

2.3.1.1 Introducing experimental systems

In a hugely comprehensive investigation into the diverse and varied material arrangements of scientific research, Rheinberger (1997) provides an account of the materialities, meanings and practices through which laboratories are organised and the experimental research is performed. Rheinberger refers to these materialities as ‘experimental systems’, comprising of things, objects, concepts, spaces, and places associated with the research. He unpacks how these ‘experimental systems’ are configured through research practice and performed in relation to each other as the “elementary, functional units of empirical research” (Rheinberger, 2011:311). Rheinberger (2011) captured the utility of his theory best when he outlined the following:

> The advantage of the concept of experimental system lies in its faculty to think and to bind together essential, but nevertheless very different and heterogeneous aspects of the scientific research process - such as instruments and measurement apparatus, preparation arrangements of different kinds, the necessary skills to use them in meaningful ways, the research objects, and not least the spaces in which these moments are brought to interact with each other in productive and creative arrangements. The notion is thus not one to describe science as a system of theoretical concepts. Rather, the category describes the process of research as a materially mediated process of the generation and the proliferation of knowledge, or to speak with the French anthropologist of science Bruno Latour, of "science in action" (Latour (1987)). (Rheinberger, 2011:310-311)

Rheinberger (2006) argues in the performative idiom (Pickering, 2015) that experimental systems do not simply represent a 'reality' of any kind, but instead unfold and are "brought to articulation". Rheinberger suggests this process is a kind of 'practical realisation' (Rheinberger, 2006:96), or – to use the terminology of Woolgar and Lezaun (2013) – a 'practical achievement'.

In its original formulation, Rheinberger's (1997) theorisation states that the "experimental systems" (1997:1) undergoing materialisation can be understood as "the basic unit of experimental activity" that ultimately also materialises the questions posed by the scientific community (1997:28). Put simply, experimental systems are the arrangements that constitute the immediate experimental 'set-up' required to explore a particular scientific question at hand. The experimental systems comprise two inextricably linked elements. Firstly, what he terms the "epistemic things" (1997:30), those things which are the unknown or loosely unknown object of investigation and in the process of being defined. They can include physical structures, biochemical reactions, biological functions, pathways, and more. Secondly, the "technical objects" (1997:30), that which are the better known, characterised, and predictable experimental conditions, the accessible and (temporarily) stabilised elements configured to provide epistemic access to the unknown objects of investigation (epistemic things). These include instruments, theorems, protocols, even practitioners as instruments of enquiry themselves, and more. Indeed, if one understands research as being materialities situated in practice (as Jensen (2010) and others assert we must), then experimental systems also necessarily entangle a wide range of components associated with the wider laboratory - and indeed, even beyond as we shall hear from Michael et al (2005) in Section 2.3.

Rheinberger (2011) would later summarise the differences between epistemic things and technical objects succinctly as follows:

> "Epistemic things are therefore notoriously underdetermined; they are, so to speak, undefined *per definition.* In contrast, the technical objects - at least temporarily - are defined in a characteristic manner. They consist of instruments, apparatus and devices that at the same time made possible and constrain the grip on epistemic objects." (Rheinberger, 2011:312).

Specifically, Rheinberger (1997) uses the term epistemic "things" rather than 'objects' on account of their "irreducible vagueness" (1997:28) and their status as currently unknown and thus absent from the very experiments designed to give them form (1997:28). 'Things' are undefined, vague, and underdetermined. Correspondingly, 'objects' are more concretely defined - albeit temporarily so - and predictable in their functionality. Knorr-Cetina (2001) meanwhile prefers to characterise these as 'partial objects' (2001), suggesting it better captures the dynamic nature of them being an object in the making. Regardless of nomenclature, both scholars agree on the preliminary state and indefiniteness of the objects of experimental investigation.

What is perhaps more crucial in Rheinberger's work is that the terms 'technical object' or 'epistemic thing' are functional designations; these labels are roles that are performed rather than designations of 'inherent' structural identity. This sees these terms operate in line with practical ontologies. As Rheinberger (1997) argues early on, "[w]hether an object functions as an epistemic or a technical entity depends on the place 'or '"node" it occupies in the experimental context" (1997:30). At any given time, an 'epistemic thing' may be elaborated sufficiently to itself become a 'technical object'. Alternatively, a 'technical object' may lose its temporary stability and become an 'epistemic thing' in its own right. As well as arguing these as 'roles' rather than structural identities, Rheinberger (1997) also observes that they are roles at the two "extremes" of a scale (1997:30), this leaves room for what he terms "halfway hybrids" - for example the results of an experiment that is somewhere between a technical object and an epistemic thing.

2.3.1.2 Adapting the heuristic for synthetic biology

To be able to use Rheinberger's (1997) experimental systems in a project about synthetic biology, it is necessary to evaluate its 'goodness of fit'.

In the decades since Rheinberger's (1997) work was produced it has withstood challenges (such as those from Bloor (2005) who critiqued Rheinberger over his use of 'epistemic' for material objects). It has also seen complementary clarifications (such as Knorr-Cetina's suggestion that the epistemic things should be considered 'partial objects', 2001:190). However, when it comes to its use in MSB, it does

require some adaptation to be considered fit for purpose. Specifically, the roles must be adapted to accommodate the nature of synthetic biology as a 'technoscience'.

Rheinberger's (1997) original enquiry investigated a traditionally 'analytic' form of biological enquiry where the goal is to better understand biological structure and function. However, many scholars draw attention to the differences between so-called 'traditional science' and 'technoscience' asserting that synthetic biology operates more as a technoscience than a traditional science discipline (Bensaude-Vincent, 2013; Kastenhofer, 2013b; Nordmann, 2015; Gelfert, 2013). One difference that is routinely identified relates to how the objects of inquiry can be theorised. Nordmann (2015) argues that its objects of inquiry cannot be held as representations of nature as they are inseparable from the means of inquiry. Consequently, he argues that Rheinberger's (1997) 'epistemic things' should not be considered purely epistemic, they must also account for the role of construction.

This argument links into a plethora of debates about the relationship between making and knowing (for example, see Leonelli, 2009; or Keller, 2009). None of these specific debates trouble Rheinberger's analytic in a way that requires accommodation in this thesis. Adopting a performative stance, Rheinberger (1997) stipulated at the time of writing that "one certainly misses the specific nature of the procedure if one considers it simply as the 'theoretical' representation of a 'reality' of any kind." Rheinberger (1997) instead asserts that what *practically* occurs is 'reality's' emergence *through* the experimental technical objects. In this way, Rheinberger presents an epistemic object of *praxis*, necessarily dependent upon - and indivisible from - its technical objects. To Rheinberger, separating the epistemic from their construction is not ever possible, thus any challenges along these lines become a moot point.

If the charges of insufficiency were levied only in relation to the debate of what counts as 'epistemic', the technoscientific nature of SB would not be worth mentioning here. However, being a technoscience also brings another consideration to mind; how research goals are understood. Indeed, synthetic biology tends to enact a 'two-fold orientation' towards *goals* of comprehension - as characterised by Rheinberger's (1997) original work - and *goals* of construction, *not* characterised by the original theorisation. As Kastenhofer (2013b) observes:

> "It is not unusual in technoscience to set one goal (e.g. executing precision engineering in the context of biology, building a comprehensive model of a cell) with the hope of accomplishing side goals in the process (e.g. enhanced understanding, new instruments and techniques and, hence, new technological capabilities)"

Kastenhoffer (2013b) argues that understanding-for-construction and construction-for-understanding play a central role that is emblematic of synthetic biology practices. Given the prevalence of human appearances entangled in relation to potential research outcomes and goals, it becomes important to recognise 'two-fold' orientation of research goals. As we shall encounter in the empirical chapters, some project goals emphasise the unknowns of human biology as a project goal; whilst others emphasise the construction of potential tools for human-health. These necessarily enact different human appearances as part of the research materialities. To account for this nuance, it is necessary to pursue a heuristic that accounts for the dual nature of the research goals.

One way to do this is to theorise the outputs of experimentation as both technical objects of construction and epistemic targets themselves. I draw on Kohl and Falk (2020) who suggest that the objects of investigation in SB (formerly 'epistemic things') can simultaneously be performed as 'technical objects' - part of the temporarily stabilised known entities of experimental systems through which knowledge is gained - and the 'epistemic things' they seek to understand through making them. In this way, they can be considered 'techno-epistemic objects'. Moving forward, the outputs of the experimental systems can henceforth be understood as 'techno-epistemic objects' to account for their role as both objects of comprehension and objects of construction during SB experimental materialities.

2.3.1.3 Practitioners as part of an 'ensemble of changing interactions'

A question remains about how to think of practitioners in relation to the materialities of experimental systems.

As touched upon in Chapter 1, there exist plenty of studies into the practitioner performance. Across the STS literature there have been studies into tacit knowledge of practitioners, interrogation of affective behaviours, theorisations on subjectivities, and much more. It is not the remit of this chapter to dwell on the array of theorisations of practitioners any more than it is to dwell on theorisations of other potential materialities that entangle the human (such as the multiple ways biological materials can be theorised). However, as we step through the empirical findings, there are two aspects of practitioner performances that emerge as significant to the central thesis I present. The first aspect relates to how practitioner performances become entangled as an inextricable part of the research materialities; including how they therefore interact with other human appearances within the experimental systems. The second aspect relates to how practitioner performances can

themselves enact a ‘human appearance’, performing as ‘uniquely’ human (Knorr-Cetina (1999).

In terms of how practitioners form part of the experimental systems of project work, Rheinberger (1997) does not explicate practitioner performances in much detail. Yet he does make his position clear in the epilogue to his 1997 work as follows:

> “The scientist, as an authoritative speaker, is not the ultimate master of the game. But as a humble subject, he or she finds him- or herself captured in an inextricable relation of internal exclusion with his or her objects. He or she makes them, but only insofar as they make him or her. This movement is continually deferred and subverted by its own products […] Experimental systems are comparable to ecological niches. A niche is neither defined by its inhabitants nor by the physical parameters of the habitat. It is an ensemble of changing interactions”.” (Rheinberger, 1997:226-227)

In sum, practitioners can be understood as being in an ‘inextricable relation of internal exclusion’ with the research materialities, and part of the experimental systems performing as an ‘ensemble of changing interactions’. Later, Rheinberger (2011) would add more detail to this inextricability. He positions the research itself as ‘delegating’ to the technical objects to identify and record the traces the experimental interactions with epistemic things leave behind, with researchers attending to those traces. In conjunction with these traces, practitioners either constrain attention to one possible event or account, thus eliding other possibilities; or they enact a liminal attention that leaves room for a field of possible events. In this way, the interaction between the experimental traces and the practitioner performance actively co-constitutes or ‘materialises’ experimental realities into being.

Rheinberger (1997, 2006, 2011) provides useful clarification for how practitioner performances inter-relate with other components within the experimental systems. However, he offers little in the way of unpacking the ways in which experimental systems might ‘make him or her’ as part of that ‘internal or external conclusion’. Here, Knorr-Cetina (1995) adds complementary depth to Rheinberger’s (1997) analysis by elaborating the ways in which experimental work might ‘make’ or ‘affect’ the practitioners:

> “[I]n the laboratory, scientists are, on the one hand ‘methods’ of going about inquiry; they are part of a field’s research strategy and a technical device in the production of knowledge. But they are also, on the other hand, human materials *structured into* ongoing activities in conjunction with other materials with which they form new kind of entities and agents” (Knorr-Cetina, 1995:5).

She goes on to explain that as part of the 'social order' of experimental systems, such 'human materials' are reconfigured through practice and are "malleable with respect to a spectrum of behavioural possibilities" (Knorr-Cetina, 1995:19)[10]. These reconfigurations can foreground (or correspondingly elide) specific ways of being amongst the practitioners. Practitioners are therefore also performed as 'practical achievements' and enact practical ontologies (Woolgar and Lezaun, 2013; Jensen, 2010).

Knorr-Cetina (1999) illustrates this idea through an example of a surgeon performing as an instrument in the operating theatre. She identifies how such a surgeon is unable to perform basic 'everyday' scenarios (such as answering the phone) during theatre; their 'everyday' capabilities are performed into absence. She argues that the surgeon is "no longer adapted to him/herself - as an everyday person" (1999:94). I apply this notion of being 'adapted to' or performed 'in relation to' something to human appearances. Practitioner performances can emerge in ways that see the practitioner 'adapted to' themselves as 'particularly human', such as foregrounding performances of curiosity, generating 'human error', or using their own body as illustrations of human biology). Alternatively, practitioner performances can emerge in ways that do not emphasise these 'human' behaviours. For example, practitioner performances as part of a protocol, or an instrument, consequently eliding any orientation to themselves as 'human'. Human practitioner enactments are performed into presence or absence through the materialities and practices of experimental systems in just the same way that other project materialities are.

2.3.2 Promises, expectations, and performativity

In Rheinberger's work, he asserts that experimental systems are always locally situated and embedded in social and institutional aspects (Rheinberger, 2011). There is an array of 'non-experimental' practices and institutional contexts in which experimental practices are 'embedded'. However, Rheinberger does not elaborate on the nature of that 'embedding'. Consequently, neither does his theorisation of experimental systems. To better understand the wider, non-experimental 'embeddings' or practices – and thus how human appearances emerge through these - we must turn to alternative literature. One body of work that is particularly useful in making sense of the distribution of potential human appearances as part of

[10] Arguably, it is possible to suggest that humans themselves emerge as their own 'techno-epistemic objects' in the experimental systems. On one hand, stable methods of enquiry, on the other hand vague and still in process, being known by the same processes through which they emerge.

the wider social, political, and institutional contexts of experimental work is the scholarship on the promises, imaginations of the potential outcomes and outputs. Specifically, the performativity of expectations relating to the future.

2.3.2.1 Promises, expectations, and types of new arrangements

Synthetic biology (and by extension MSB) is a field that is future-orientated and rich with promises attending to market goals and societal needs (Frow, 2013). Synthetic biologists and policy makers position the field as a novel and revolutionary endeavour, and the promises that scientists make to policy makers about the capabilities of what they can deliver help gain scientific, social, and political commitment (Schyfter and Calvert, 2015:360). SB is so filled with promissory rhetoric that Bensaude-Vincent (2013) describes as an "integral part of the technoepistemic culture of synthetic biology" (2013:23). In the opening statements of Chapter 1, I have already drawn attention to some of the imaginations of human health prospects to emerge from the World Economic Forum. As we step through the empirical chapters, we continue to find expectations and promises of human health prospects, although performed through real-time practices they emerge as more modest in nature. So, how can we productively think about and situate these future-orientated potential human outcomes as part of real-time MSB research practices?

STS has a rich body of investigation into expectations and promissory rhetoric[11]. Underpinning much of the research is the premise that expectations, promises, and visions of the future perform very real, very material work in the present. Promises and expectations are not the preserve of an unrealised or abstract epistemology but are 'ontologised' through material action in the present (Gad et al, 2015). For example, in some of the early literature from the field, Harro Van Lente (1993) asserts that expectations "do something: advising, showing direction, creating obligations" (1993:191) in the present, they are not mere 'representations'. This performativity of expectations in the present is echoed through the myriad studies that followed Van Lente's early work. However, whilst there is resounding agreement of such performativity, there is less agreement on specifically how this performativity is accomplished.

Tutton (2017) provides a good summary for the various stances different scholars take. On one hand, Van Lente (1993) adopted a social constructivist view. His work

[11] For more information see: Van Lente and Rip (1998), Brown et al (2000), Hedgecoe and Martin (2003), Adam (2004), Borup et al (2006), Eames et al (2006), Adams and Groves (2007).

stands representative of the semiotic strand of this body of theory where matter followed from meaning: material arrangements emerge in response to the imaginations and expectations. Meanwhile, at the other end of the spectrum Adam and Groves (2007) champion an entirely materialist account. They argue that matter extends through time and futures, and - as we will hear in Section 2.4.5 - the future is always in process (Adam, 1990). With matter being constantly in motion, they argue that meaning follows from matter. Meanwhile, most other scholars fall somewhere between these poles, including this study. In line with the principles laid out in Section 2.2, I adhere to the material semiotic interpretation of expectations where both meanings and the matter are mutually brought to presence through practice. For example, in Section 2.2.2 we saw how imaginations such as human health outcomes can come to be materialised through the material acts of thinking, imagining, comparing, discursive exchange, and more. This renders abstract imaginations and visions 'concrete' in real-time research as practical achievements. The circumstances through which these practical achievements arise, however, require a little further elaboration.

Fujimura (1987) argues that for research to be 'doable', the scientific priorities and practices of the experiment, the laboratory, and wider social worlds need to be brought into 'alignment'. Clarke (1998) elaborates upon this doability to argue that research problems rely on researchers aligning their research problems across not only the experimental capacity, laboratory level of organisation and direction setting, and demonstrating significance for wider social worlds such as scientific and extra-scientific communities, but - critically - it also includes fiscal support. She argues for an inclusion of 'profitability' as well as significance into the definition of doability (1998:85-89). Expectations, promises, and visions play an important role in securing such alignment and profitable doability. They form a significant part of the negotiations that occur during between scientists, policy makers, and funding bodies (Frow, 2013; Schyfter and Calvert, 2015).

Indeed, Schyfter and Calvert (2015) go on to provide a specific example of the 'making and moulding' (2015:361) that expectations do in conjunction with intentions, and institutional arrangements. They explain that promises (from the scientists) and expectations (from the funders and policy makers) are collectively formulated and established through a recursive set of negotiations between synthetic biologists, funders, and policy makers. They also demonstrate that promises, expectations, and institutions shape each other. For example, synthetic biologists' promises shape expectations from policy makers and funders, which manifest specific institutional arrangements, which in turn shape the promises that synthetic biologists make. In

their investigation the authors use this simultaneous performativity to account for how synthetic biology emerges into being as engineering discipline (Schyfter and Calvert, 2015).

Meanwhile, Eames et al (2006), generate a useful conceptual framework through which to consider the work that these promises, expectations, and imaginations do more broadly. They argue that promissory rhetoric and future-orientated imaginations can be considered 'guiding visions'. These are visions or imaginations of potential futures (such as human-health related outcomes) that connect the priorities of the 'social worlds' with those of the project 'experimental worlds'. Through the authors' work on the hydrogen economy, they put some shape around the different types of 'practical achievements[12]' or material arrangements that emerge through the performance of expectations and promises as 'guiding visions'. Firstly, the authors suggest that guiding visions negotiate alignment around common goals, aligning and uniting interested parties in a common purpose. Secondly, guiding visions mobilise resources and support necessary to proceed. Both actions generate new material arrangements of research activity and resources. To accomplish consensus and agreement, visions are left purposely open and 'vague' to afford 'interpretive flexibility' and make it easier for different groups to find resonance with the ideas (Eames et al, 2006). Thirdly, they generate meaning and direction for the day-to-day research and help to define research priorities. In doing so, they generate a direction for the experimentation to pursue. Fourthly, expectations generate a sense of 'momentum' through the proliferation of projects also being materially configured through their practice (Eames et al, 1006:362). This reduces the risk of pursuing the agenda, making more institutions more likely to pursue the same agendas, thus configuring the arrangements of entire fields of work. As Schyfter and Calvert (2015) have already identified, the material configurations to emerge from guiding visions in turn feed back into the promises and expectations that create them in the first place.

2.3.2.2 Materialising different temporality and spatiality through experimental systems

As outlined above, guiding visions generate direction for the experimentation to pursue. As they perform this work, the visions become inextricable from the experimental systems through which they are to be delivered. Specifically, the techno-epistemic objects (objects of investigation) enact the imaginations, expectations, and promises into being as the 'purpose' or 'aims' of the experimental

[12] It should be noted this is not the terminology Eames et al (2006) use themselves. I take this term from Woolgar and Lezaun (2013) to interpret Eames et al's (2006) types of material arrangements.

research. Indeed, as Frow (2013) reminds us, synthetic biologists are heavily focused on designing and creating new entities for useful purposes. Delgado (2016) unpacks some of this future orientation in her work tracking SB design practices and demonstrating the different ways that they move action from referential anchoring from 'back' in reality to 'ahead' in the future. Through SB real-time research practices, notions of future temporality are foregrounded in the present.

Perhaps surprisingly given experimental systems are machineries for "making the future" (Rheinberger, 1997:33), the original experimental system theorisations did not speak much to how these longer-term temporalities are enacted into presence through experimental systems and practice. Instead, a 2005 study by Mike Michael and colleagues investigating the effects of expectations on stem cell research (a similar future-orientated technoscience) provides us a useful way to conceptualise the integration of future temporalities into Rheinberger's (1997) account of experimental systems. Michael et al (2005) observe:

> "Flowing through the complex practices of the stem cell scientists are also longer-term temporalities: expectations about the viability of the program per se, about the ethical arguments and regulatory practices that affect human embryonic stem cell research, about the prospects of cross-disciplinary collaboration and the impetus toward "translational research" promoted by research funders and policymakers alike" (Michael et al, 2005:376)

Through embodying the hopes and visions of imagined futures and these 'longer-term temporalities', research objects can be understood in more ways that merely operating as the original 'technical objects', or 'epistemic things' (or techno-epistemic objects in the case of MSB). Enacting longer-term materialities into presence as part of the research materialities generates a range of additional roles and performances of research objects.

Indeed, continuing to draw on Rheinberger's (1997) distinction of the concrete (objects) and the vague (things), Michael et al (2005) argue that entanglement with expectations around future use, governance structures, regulatory frameworks, and moral imperatives, sees research objects performed to presence as 'regulatory objects' (when well characterised and understood), or 'ethical things' when not. Meanwhile, when experimental research objects become entangled with imaginations of future trajectories such as potential human health-applications, research objects are performed as 'translational objects' (when well characterised and understood), or 'collaborational things' (when not). In performing such roles, research objects no longer orientate towards their experimental roles. Instead, they

act as ‘tokens’ of the futures, priorities, and ideals they entangle (Schyfter, 2011). They materialise societal priorities into being in the present through their own performance.

Yet, expectations, imaginations, and promises do not just entangle longer-term temporalities, they also entangle additional spatialities. They encompass and enact wider places in space than just laboratory-based experimental work, just as they encompass and enact wider points in time. There are two ways this can manifest. Delgado (2016) draws attention to the first time in her work exploring the future orientation of synthetic biology. She argues that as well as shifting SB action ‘ahead’ towards the future, SB practices can also shift action to alternative ‘geographical’ points “where members of the SB community collaborate to make it happen” (2016:928). As expectations become entrenched within institutional arrangements, SB materialities can not only be shifted to locate “action at a distant time”, but also “action at a distance” (Delgado, 2016:928). In doing so, the spatial and temporal ‘footprint’ that experimental systems enact in their practice is greatly increased.

The second way expectations can practically accomplish wider spatialities for research materialities is through broadening what the research objects ‘represent’ or act as a proxy for. Research objects (both technical objects and techno-epistemic objects) can be considered both in terms of what they enact in the specific experimental system, but also what wider biology they stand in for. Ankeny and Leonelli (2011) provide a useful set of terms to understand how specific components of experimental systems can represent not only themselves but also a wider group of organisms. The specific phenomena or set of biological behaviours under investigation about which experimental claims are *directly* being made are known as the “representational target” of the experimental systems (2011:8). This might be a specific cellular pathway of interest in a specific cell line, for example the ‘Wnt pathways’ in ‘canine derived kidney cells’. However, biological materials can also stand in as tokens or ‘models’[13] for other organisms or parts of organisms that can be considered sufficiently similar, such as *human* kidney cells or endogenous human biology. This is termed the object’s “representational scope” and describes the “extent to which researchers see their findings as applicable *across* organisms” (Ankeny and Leonelli, 2011:8). As both canine and human cells are mammalian, they share many similar features. There is a high probability the findings from one are applicable to the other. In this way, through imaginations, expectations, and promises

[13] This is not to be confused with acting as a model organism. An experimental model stands in for a particular biological pathways or function; model organisms stand in for whole organism systems of interest to scientists (Ankeny and Leonelli, 2015).

about the applicability of results, experimental systems enact a second set of elongated spatialities beyond those restricted to the experimental systems in the laboratory.

In sum, experimental systems are constantly 'in process'. They embody different priorities, roles, and even different spatial and temporal dimensions as they become entangled with different sets of practices and 'embeddings'. What remains consistent, however, is their enactment of these additional dimensions in the *present*, through their real-time MSB performance.

2.3.3 Discourse practices

2.3.3.1 Discourse as practice

MSB research materialities have much of their day-to-day physical performance configured in laboratory-based research work, but not exclusively so. They are also performed to presence through a range of other practices such as organisational work, or presentations and articles performed for wider communities. In Chapters 5 and 6, we follow some of these practices to places of performance beyond the experimentally focused laboratory. To help us contextualise how human appearances emerge through these distributed real-time research practices, it helps to consider the organisational and communication practices as 'discourse'[14].

Foucault (1970) defines 'discourse practices' as the social practices and operations of making knowledge, including any processes that go into mobilising the abstract concepts (such as the production, distribution, and consumption of discourse). Across much social theory, the term 'discourse practices' can be found interpreted as linguistic practices. Notable examples include texts in discourse scholarship including those by Potter and Wetherall (1987) and Fairclough (1992; 1995). However, Bacchi and Bonham (2014) argue that Foucault's concept of 'discursive practices' has been much misunderstood. They vent their frustrations at the uniquity of the term as a synonym for *linguistic* practices. Instead, they assert that discursive practices - as developed by Foucault - "refers to the practices (or operations) of discourses, meaning knowledge formations" *not* limited to linguistic practices (2014:173). In this way, discourses are sets of practices in the broader sense. They combine materiality and language together to produce accounts of enacted realities

[14] As already outlined, discourse theory is a vast area of research. This section seeks not to cover its theories in any exhaustive way, but instead provide sufficient information to establish a broad heuristic for the discursive enactments we encounter in this study.

(Bacchi and Bonham, 2014:176-177). Bacchi and Bonham are not alone in re-enchanting the inextricable materialities of discourse practices. Hook (2001) includes instantiations of the body, spaces writ large and physical objects into discursive practices. In addition, in a body of work on 'mess' in the social sciences, Law (2004a) describes discourse in its materialist, Foucauldian version as: "a set of relations of heterogeneous materiality, that recursively produces objects, subjects, knowledges, powers, distributions of power" (2004a:159). It is this material and semiotic understanding of discourse with which this thesis proceeds.

It is also important to note that everything we have so far encountered in terms of enacting materialities in practice can therefore be considered discourse. From the practical ontologies and practical achievements in Section 2.2 to the performance of experimental systems and performativity of imaginations and expectations in the preceding parts of Section 2.3), they are all discursive sets of practices of making and mobilising knowledge. When considering performances of MSB research from the laboratory performances to those of wider community engagement, MSB research is habitually performed through tables of data, imagery, written protocols (Latour and Woolgar, 1986); practitioners own bodily performances (Myers and Dumit, 2011); as well as packaged into presentations, articles, talks, posters, demonstrations, and more.

Treating such MSB real-time research performances as 'discourse' furnishes us with two key foundations that help us make better sense of the empirical findings in relation to these knowledge-making and community practices. Firstly, in line with the performative idiom, discourse (such as a protocol, report, or presentation) does not merely represent a reality that exists somehow behind the discursive performance - it is not a 'depiction' of a reality 'elsewhere' - it is the reality itself (Fairclough, 1992). Discursive performances of MSB research do not simply package up research and mobilise a representation of it for other audiences and communities, it is a performance of MSB research. For example, whilst experimentally focused laboratories enact MSB research through physical experimentation, other places such as the Institute enacts MSB research through discursive summaries and physical institutional arrangements. Elsewhere, as research is 'mobilised' amongst a range of communities, it is also performed anew through presentations, demonstrations, talks, articles, and more. All these different discursive enactments come to count as real-time MSB research in practice. In this way, any human appearances to emerge as part of these performances of the MSB research are not representations or depictions of versions generated elsewhere but are instead a new performance. This provides a more mutable conception of scientific practice, where

multiple enactments and ontological performances of research materialities (including human appearances) co-exist (Graham and Herndl, 2013:113).

Secondly, there are three inter-linked ways in which discourse generates its realities, and thus three inter-linked performances through which human appearances can emerge as in the process. Discourse is comprised of more than just content (whether material or linguistic), it also performs as a discursive practice, and an enactment of sociomaterial practices (Fairclough, 1992; Szymanski, 2016). All three are inter-linked and inextricable from each other. In practice, this means that any example of discourse – whether experiment, publication, presentation, demonstration, or more - becomes an object of investigation on three counts: what it conveys through its content (and what is correspondingly negotiated into context); the ways in which it conveys its content; and as an enactment of the sociomaterial relations through which it has arisen and performed. For example, a conference poster about MSB research does not just generate meaning through the content it makes present (and what it makes absent); it also generates meaning in the way it is discursively structured and performed (through rhetorical metaphor and more); it also arises through the sociomaterial performances that led to the actor being at the conference to present the poster in the first place, the aims the participant has in attending the conference, what they want the poster to accomplish, who they want to be targeting, and much more. As Knorr-Cetina (1983) asserts, there is no way to infer the nature of participant's actions from text alone (1983:178), there are other considerations of discourse beyond the text.

2.3.3.2 Negotiating content and context

Given the prevalence of themes of human absence as well as potential human presence in the empirical findings, it is worth briefly elaborating on how the scholarship on discourse manages themes of presence and absence across these three inter-linked performances. This helps us better understand the distribution of potential human appearances in the empirical discourse, the practices through which they are negotiated into those patterns, and the work that can be accomplished through their configurations.

The negotiation of what is made present or absent in the eventual content is managed through the concept of 'context'. In his investigation into absence (already introduced in Section 2.2), John Law provides us a useful working definition of context as what is not made present, but nevertheless remains relevant to what is made present (Law, 2004a). Additionally, as Flowerdew (2017) also reminds us,

context is not ‘given’, it is made. Indeed, Woolgar and Lezaun (2013) observe that adopting the performative idiom and its principles of enactment eschews the notion of ‘context’ as a priori explanatory action, context is as much of a practical achievement as presence (Woolgar and Lezaun, 2013). Asdal (2012) describes this well when noting that contexts are not “lying out there, in the external surroundings so to speak, but rather something which is integral to the very action” (2012:388).

Context and text are woven together as realities are made in practice; what becomes ‘text’ (present) and what becomes ‘context’ (absent from the text) in any given situation are made simultaneously through the same sorting and ordering processes (Hetherington, 1997). In this way, discourse becomes subject to much of the same considerations of negotiating presence and absence we identified in Section 2.3.1. Understanding this helps us better contextualise the findings we encounter later in the thesis, especially in Chapter 6 and its interrogation of community performances. Potential human appearances are negotiated into presence (content), manifest absence (context), or entirely excluded through the same sets of processes. Correspondingly, what is made absent is just as much an integral part to what is made present (Law, 2004a; Asdal, 2012). It is in understanding this relationship between content and context that we can better understand how potential human appearances negotiated into context continue to perform work despite being absent from the content of real-time MSB practices.

2.3.3.3 Unpacking rhetorical performances

There is a vast array of literature that elaborates the performative approach to enactments and inter-related practices that have been sketched out in the two preceding sections. Szymanski (2016) characterises some of the differences in how different fields handle the different inter-linked dimensions of discourse practices. In her exploration of (specifically) written texts, she observed that traditional STS scholarship often emphasises the sociomaterial production of texts with little interest in their content (Latour’s work on inscription devices provides a good example of this). They are often treated and analysed as sociomaterial performances; the content and discursive elements of their performance remaining less well served. Conversely, however, Szymanski (2016) demonstrates that the field of science communication focuses too much on the content and too little on the sociomaterial performances through which that content is generated. Occupying the middle ground, however, are some of the studies associated with the rhetoric of science. This can offer a ‘more than content’ approach to discourse practices (Szymanski, 2016). Whilst there is too much to dwell upon in detail, I wish to briefly introduce a

couple of studies that elaborate some of the rhetorical mechanisms through which scientific practice is performed. As we shall see in the empirical chapters, rhetorical performances are one of the key mechanisms through which potential human appearances are negotiated into specific places of presence (and by extension absence). Elaborating their key features, provides us useful insight to more specifically characterise the potential human entanglements that emerge through their performance.

In 1986, Jeanne Fahnestock published a paper titled ‘Accommodating Science’. Reflecting on this work 12 years later, Fahnestock observed that when she first wrote the essay, it built on a small but substantial body of scholarship in the rhetoric of science. In the decade since writing the original paper, she had observed the field grow exponentially. Indeed, in the 1980s and 1990s in STS alone, there had emerged a ‘rhetorical turn’, yielding a large body of work on the techniques of scientific discourse. These include Gilbert and Mulkay (1984), Latour (1989), and Bazerman (2000), amongst others.

Fahnestock’s (1986) article itself took ideas from classical rhetoric alongside techniques from discourse analysis and elucidated some of the key rhetorical differences between writing for a scientific audience and writing for a non-specialist audience. It is these rhetorical differences that generate different performances of potential human appearances. The basic premise of Fahnestock’s (1986) theorisations is that when scientific research is performed for a non-scientific audience, there are a series of changes it undergoes to ‘accommodate’ audiences who lack familiarity - and specialist knowledge - about the field. In doing so, she elucidates the rhetorical practices through which accommodations – and thus different discursive enactments - are generated.

Fahnestock (1986) makes three inextricable points about these ‘accommodations’. Firstly, the ‘genre’ of discourse shifts when changing from communicating with specialist audiences to communicating with non-specialist audiences. Fahnestock (1986) argues there are three types of genres: forensic (technical) discourse where participants evaluate matters of ‘fact’ that have already been performed; deliberative (debating and arguing) discourse where participants debate the merits of particular facts and claims; epideictic (celebratory or lamenting) discourse where participants celebrate (or blame) the facts or claims (1986:277-278). Fahnestock (1986) observes that scientific papers designed for a scientific audience are primarily forensic, though they “cannot ignore creating a reason for their reporting” (thus enacting deliberative elements within them) (1986:278).

Secondly, and relatedly, this shift also brings with it some changes to the information performed to presence in these epideictic enactments. For example, Fahnestock (1986) observes that amongst communities who lack pre-existing knowledge on particular topics, research is often packaged up for audiences in relation to potential applications (such as potential human health applications) or in relation to the wonder of the findings (such as the novelty of new medicine). As we progress through the chapters, we will see how potential human appearances often emerge entangled with appeals to 'application' or 'wonder'. Another related 'accommodation' sees a great emphasis on results or potential outcomes in epideictic performances. Fahnestock (1986) argues that rather than favouring detailed accounts of the technical aspects of experimentation, much of the data or 'signs' are elided in favour of the effects they produce. She terms this a 'leap to results' (1986:284). This 'leap to results' is also accompanied by an increase in the certainty with which claims are made. For example, there is a noticeable reduction in 'hedges' – rhetorical devices designed to introduce a modality into, or qualify claims being made (Lakoff, 1973) - introduced to invoke qualifications, uncertainties to the claims.

Finally, this shift in the certainty, also correlates to the types of claims that are made through real-time MSB research accounts. Fahnestock (1986) asserts that engagement with non-scientific and non-specialist communities changes the types of statements that are made about scientific research. Technical or scientific accounts are interested in arguing in the 'first stasis'; whether something exists and can be proven example. Meanwhile, epideictic accounts debate the value of what science might be able to prove, rather than arguing for its proof in the first place. All these accommodations generate differences in the way that different communities perform their research. In identifying divergent performances dependent upon the research materialities clustered into different communities, potential human appearances can be entangled differently dependent upon the situated materialities of their performances, and the accommodations that are performed as a result.

Not long after Fahnestock's (1986) publication, Greg Myers (1990) produced another significant piece of work in the rhetoric of science. In his comprehensive work on 'Writing Biology', Myers (1990) interrogated different enactments of real-time biological research activities and provided an account of the rhetorical performances he encountered. In one particularly pertinent chapter, he investigated scientific articles published in Science and Evolution as well as non-specialist articles by the same authors in the popular journals Scientific American and the New Scientist (1990:214). In doing so, Myers (1990) provides us a way to group differences

between specialist and non-specialist audiences into two separate ‘narratives’ (or broad discursive enactments). He argues that professional journals generate a “narrative of science” (1990:142) that are mainly focused on mechanisms and processes of experimental systems, the processes of technoscientific manipulation, and the nature of targeted experimental claims to generate a “narrative of science” (1990:141-192). Meanwhile, non-specialist journals generate a “narrative of nature” (1990:142). These include focusing not on the mechanisms and processes of experimental systems, nor the processes of manipulation, but instead on the natural effects and phenotypic outcomes or results being investigated. As part of the ‘narrative of nature’, he echoes many of Fahnestock’s (1986) observations. For example, Myers (1990) concludes that non-specialist performances “get[s] to the point quickly” (Myers, 1990:171). He also observes the skipping of signs and traces in favour of focusing on the effects, including potential human applications of research. In doing so, he also observes the shift in certainty of claims, the language through which that happens, and how a leap to results can often change the entire structure of the argument.

Finally, emerging from some of the related scholarship from the Science Communication community, Davies et al (2019) offer us one additional conception to add to Myer’s (1990) characterisation of the narrative of science and the narrative of nature. They argue that there are also narratives or stories about science, or ‘narratives about science’ (Davies et al, 2019). In their analysis, Davies et al (2019) assert that when science being performed as part of culture, there emerge stories about science that shift from accounts focused on presenting ‘facts’ to accounts that present scientific activities through a combination of experience, identity work, fiction, and emotion. There emerges a shift away from accounts of explanation to accounts of expression. Across the discourse literature, these types of anecdotal or story-based narratives find resonance in multiple guises as fables, folk tales, and more (Padian, 2018). Dahlstrom (2014) goes on to argue that when engaging non-specialist audiences with scientific research, these types of narratives are easier to comprehend (and indeed are found to be more engaging) when they involve stories and anecdotes in relation to the research. The traditional ‘logical-scientific communication’ – those underpinning Myer’s (1990) narrative of *science* - do not enjoy the same success.

The three narratives provide a shorthand to consider the different roles, structures, and purposes of many of the discursive enactments. They also provide additional contextualisation and insights to the practices through which we will encounter a range of human enactments. However, it is also prudent to strike a note of caution

here in terms of the extent to which these theorisations can help guide contextualisation of the empirical results. Firstly, both Fahnestock and Myers' accounts are written from the perspective of social construction (rather than the material semiotic stance of this investigation). This elides any significant focus on sociomaterial practices through which the texts were analysed. Secondly, Fahnestock (1986) also focused on 'popularisation' of scientific accounts to the exclusion of all other potential circumstances of accommodation. These studies must be considered in terms of their theoretical sensibilities to understand where they yield applicable insights and where they do not.

Specifically, this discourse scholarship can help provide a way to think about the research performances and how they differ in rhetorical performance across a range of communities and audiences. In this way, they give shape to the wider social and institutional 'embeddings' (Rheinberger, 2011) of the real-time research in wider sociomaterial and discursive practices. Each of the three 'narratives' offers a short-hand, or characterisation through which to contextualise the rhetorical performances we encounter in the empirical chapters. They offer a way of understanding the types of discursive performances through which projects are performed and potential human appearances are entangled. Some types of communities emphasise one set of rhetorical and discursive project enactments, others generate another. As we shall see in the pursuant chapters, different 'narrative' types enact the potential human appearances very differently. It is through identifying these three broadly characterised 'narratives' (complete with their specific rhetorical characterisations and performances), that we are better equipped to situate potential human appearances in broader practices and consider a 'more than content' approach (Szymanski, 2016).

2.4 Performing place

2.4.1 Introducing place

Finally, we turn our attention to place. One of the core arguments put forward in this thesis is that the way the human is performed in the context of MSB research practices is deeply rooted in notions of place. Specifically, human appearances are constitutive of - and constituted by – not only the practices through which they are performed, but also the places they enact as part of that process.

In the first two sections of this chapter, we have paid close attention to materialities being situated in the practices through which they emerge. Materialities are enacted in practice (Law and Lien, 2013) and can thus be considered practical ontologies (Jensen, 2010) and practical accomplishments (Woolgar and Lezaun, 2013). Focusing on the practices through which materialities emerge (in this case experimental systems, promissory narratives, and discursive practices) is a prevalent approach in STS to situating materialities. Analytically, however, there are other ways to theorise the concept of situatedness.

Throughout the empirical work, explicit notions of place emerge as an actor category[15] in the empirical data and are heavily implicated in how human appearances are navigated, performed, and experienced by participants during MSB real-time research practices.

In this section I introduce a third key body of literature – social scientific work on theorising 'place' - to help make sense of these empirical observations. The significance of using place as an analytic lies in its ability to account for not only spatial and temporal performances of human appearances enacted in practice, but also the meanings, associations, and attachments that are generated through their 'practical achievement' – not only with other materialities but also the niche or 'locale' to which they contribute. Notions of 'place' extend beyond the ordering of enacted materialities in space and time to also account for their simultaneous social (or in the material semiotic tradition of this thesis, sociomaterial) ordering. Establishing a nuanced understanding of place therefore enables us to unpack not only where and when potential human appearances emerge, but also how they become situated there and with what effect.

2.4.2 A brief clarification of place and space

Before proceeding further, it benefits this argument to be clear on the relationship between space and place on which this thesis rests. Space has a long-standing and complicated history with place (Agnew, 2011). However, in contemporary scholarship on the relationship, there emerge two main strands of thought. One is deeply rooted in Michel de Certeau's theorisations of space and place, the other in Henri

[15] Here it is important to remember that 'actor' is used in its material sense (Marcus, 1995). It is not synonymous with human 'participant'. Instead, an actor can be an idea, object, thing, concept, and more. As already outlined, these are materialised into projects through *action*. Under this conception, an 'actor category' points to a repeated empirical enactment as opposed to an analytic category that I have engaged as the researcher.

Lefebvre's. In the first conception, De Certeau (1984) asserts that space is 'practiced place'. Drawing on metaphors of language, he argues that place can be considered a grammar or the letters of the alphabet – a stable set of a priori components - whilst space can be considered the words, sentences, or scripts to emerge from such underlying components. In his theorisation, place operates as the concrete and space reconfigures it into new forms.

By contrast, however, Lefebvre's ideas are the exact reverse. He asserts that place (what he sometimes terms 'concrete space') can be considered a specific and situated version of a more generalised or abstract notion of space (Agnew, 2011). From Lefebvre's (1991) more materialist position, he draws on imaginations of relations and fluidity. In doing so, he likens space to the abstract, citing fluidity and a context of flows and ever-changing material relations. He suggests that place (or 'concrete space') is a concrete manifestation of specific situated moments, through which practices, actions, experiences are materialised. In Lefebvre's conception, it is place not space that is the articulated moments. It is place where we interact with and potentially intervene, making concrete the more abstract space. In this way, place can be considered 'practised space' (Elden, 2004).

It is this latter conception of place that much of the feminist, sociomaterial STS, and human geography literature takes forward. It is also this latter conception of Lefebvre's that underpins the rest of this thesis. With that in mind, I turn to the engagement of STS with this notion of place.

2.4.3 The waxing and waning of place in STS research

Decades of STS research have demonstrated that spatial and temporal considerations are integral to the practices of making - and making sense of - science and technology (Hess, 2001; Gieryn, 2002, 2006; Law, 2019). In some theorisations, geographical (or regional) dimensions of 'where' science gets made are emphasised, in other theorisations the relational and spatiotemporal dimensions between objects, things, ideas, and the broader emergent materialities are emphasised (Law and Mol, 2001). In this thesis, place becomes important in three ways. Firstly, to 'locate' potential appearances of the human within broader real-time research materialities. Secondly, to articulate the relationships and hierarchies between competing practical ontologies and how the different spatial and temporal dimensions enacted by human appearances generate a spatiotemporal niche or 'locale' or gathering of MSB real-time research. However, it is the third way that place becomes important that is most useful. Thirdly, place helps us understand how

potential human appearances are experienced and socially ordered (the ‘sense’ of place) by participants through their ‘practical achievement’ both in relation to the materialities and practices with which they are gathered or co-located, and the broadly locatable places to which these enacted materialities give rise.

To build a productive place analytic, it is useful to understand some of the different theorisations that have been developed in the social scientific literature. I start by charting the engagement of early STS ethnographic work in ‘placing’ or situating science. This brief review also helps situate this study within a broader social scientific interest in notions of place, a matter we return to for discussion in Chapter 7.

Hess (2001) splits STS ethnographies into two generations. The earliest, first-generation STS ethnographies emerged at a time when much of the focus of science studies work was spent refuting the logical positivist concept of ‘placeless science’. These early ethnographies tended to focus on better understanding how scientific knowledge was made, unpacking the credibility of knowledge claims, and elaborating the social and technical considerations that went into making such knowledge. Many of these early investigations were undertaken in scientific laboratories, earning the moniker of ‘Laboratory studies’. As Knorr-Cetina writes in 1992:

> “Scientific laboratories have become a popular subject in social studies of contemporary science. From a status of nearly complete neglect only one decade ago they have risen to the center of analysts' attention and have given their name to a whole approach in the new sociology of science. (Knorr-Cetina, 1992:113)

As part of this work, these ‘laboratory studies’ helped established the situatedness of research in the making, and the situationally contingent and localised decision-making processes that go into scientific practice (Hess, 2001). Indeed, Knorr-Cetina (1992) attributes much of the laboratories’ significance to their performance as specific places where the natural and social order are iteratively configured and reconfigured through practice (a theme of Knorr-Cetina’s work over the pursuant decades).

There are multiple laboratory studies that contributed to this situationally contingent and ‘placed’ notion of scientific practice. Knorr-Cetina (1992) points to Michael Lynch as one of the earliest practitioners of laboratory studies. From the mid 1970s, Latour and Knorr-Cetina also emerged as leaders in the field, followed by Traweek in the late 1970s. As momentum grew into the 1980s, other scholars including Steve Woolgar, Ronald Giere, Andrew Pickering, Trevor Pinch, amongst others contributed

more laboratory studies to the scholarship, consolidating the 'placed-ness' (as opposed to placeless-ness) of scientific practice in specific laboratories and their practices[16]. At the same time, Actor Network Theory (ANT) studies began to emerge, as exemplified by the work from Latour and Woolgar (1979), Callon (1986) Latour (1999/1987). Moving away from the sociology of scientific knowledge (SSK), ANT scholars increased their focus on technology (Latour, 1987; Callon, 1986) and actively emphasised the co-constitution of technological and social considerations as part of scientific practice. In their conception of scientific practice, ANT studies encompassed a wide range of activities spanning both inside and outside the traditionally conceived of laboratory. This included bench-based experimental activities, as well as the inscription ('textual') activities of science, and the 'translation' of knowledge outputs as they 'mobilised' in settings beyond the laboratory (Latour, 1987/1999). Indeed, it wasn't long before a variety of other first-generation ethnographies also began to move beyond what was classically conceived of as 'the laboratory' to encompass a range of other scientific 'field sites' in their endeavour (Hess, 2001).

In the 1980s, these STS ethnographies continued to thrive. At the same time there also burgeoned an interest in the reciprocal relationship between policy, politics, and the making of science (Hess, 2001). In line with this expanded focus on wider social dimensions of scientific practice, a 'second generation' of STS ethnographies emerged to pursue this focus. As the understanding of what came to count as scientific practice grew, so did wider disciplinary engagement from fields such as anthropology and feminist studies. Indeed, these ethnographies also enjoyed wider attention throughout Western Cultures – especially the United States – expanding what was traditionally a Europe-centric locus of investigation (Hess, 2001). As interest in topics of co-production between social and technical dimensions of scientific activity grew so too did the range of places of investigation and social institutions explored. Ethnographies more routinely followed 'actors' to multiple sites, social institutions, and groups of participants (Marcus, 1995). With these, the places associated with scientific activity broadened. Many of these investigations focused on exploring how scientific activity and knowledge making practices mobilised and gained traction in wider social institutions such as governance structures,

[16] Knorr-Cetina (1995) is clear to demarcate *laboratory* studies and targeted investigation into *experimental procedures.* For example, Shapin's (1988) investigation into places of experiment share many of the same sensitivities and interests in understanding social and technical dimensions; however, he restricts his focus to the *experiment* itself. Knorr-Cetina (1995) meanwhile argues that laboratory studies incorporate not only the experimentation practices but also the cultural aspects of scientific practice beyond experimentation and its procedures (1992; 1995).

constitutional or regulatory frameworks, and ‘society’ more broadly. These expanded the repertoire of places where science ‘was done’.

Alongside this expansion - and in the wake of the success of the early STS ethnographies in eschewing the logical positivist notions of ‘placeless science’ (Hess, 2001) - the early emphasis on ‘placing’ scientific activity waned (Agnew, 2011). Many of the second-generation ethnographies instead prioritised elaboration of the social structures, relations, and co-production of scientific practice with wider social institutions rather than elucidating places of scientific research. Some scholarship retained an interest in theorising these sites as places where science was made. For example, Gieryn (2002, 2006) was a staunch advocate for the continued investigation into place and its continued role in helping to explain the legitimacy of knowledge claims, or scientific “truth spots” (2002:6). However, in most investigations the emphasis of situating scientific activity in specific ‘places’ gave way to a new focus.

Indeed, a new generation of STS studies had started to emerge focusing primarily on the practices and materialities of research. Pickering (2015) suggests that as we entered the 21st century, ethnographies in STS scholarship (as well as anthropology more broadly) had taken what Woolgar and Lezaun (2013) described as an ‘ontological turn’. The focus of STS ethnographies proliferated to include an array of investigations into all manner of materialities, objects, and practices. Many of these contemporary STS studies tended to instead instrumentalise place as a site or locale in their own studies, a well theorised and understood way in which to bound and situate research practices. For example, even Annemarie Mol (whose work with John Law we shall turn to shortly contributes to theorisations of concepts of space, time, materiality, and place) treats places within her own ethnographic research on atherosclerosis as ‘sites’ of practice – or an uncomplicated ‘where’ – of practice, rather than drawing on a richer conception of place that entangles its performance as a site, locale, and set of associations and meanings (Graham and Herndl, 2013:114).

In recent years, there has been some exception to this treatment of place as an uncomplicated ‘where’ of practice. STS research has seen a renewed interest from some scholarship in the field to critically engage with and reflect on place in an analytic capacity. In particular, several of these studies have used spatial and temporal dimensions of place as an explicit lens through which to analyse the formation and shaping of fields, disciplines, research areas, and even large-scale collaborations.

One particularly relevant example for SB is Meyer and Molyneux-Hodgson's (2016) investigation into SB as an 'emerging' field. This study traces SB and its development in the UK and France to analyse the effort and labour that goes into building a "'place for' synbio" (2016:62). The authors interrogate local configurations of SB research initiatives and tie them into non-local arrangements and contexts to build a picture of the epistemic spot it occupies in the disciplinary landscape, and the mechanisms through which such 'placing' takes place. Using the lens of spatial and temporal dimensions, place provides a tool that offers "insight into the interplay of scales, materials, policies, and practices" configuring the emerging science (2016:76). A second example can be found in Vermeulen's (2018) exploration into another research field 'under development', that of systems biology. Here Vermeulen (2018) argues that systems biology is choreographed through different three key movements in space (aggregation, circulation, and oscillation), demonstrating a topological view of discipline building activities, and the institutionalisation – or subsequent disintegration – of a scientific field.

Yet despite this recent demonstration of the analytic power of spatial and temporal dimensions of scientific research, place is still typically underserved in contemporary STS enquiry. There is limited engagement in exploring place in empirical detail or elucidating theorisations of place; plus, there is a more markedly noticeable underserving in relation to some aspects of place than others. To better elucidate this gap in scholarship, however, it is first necessary to step through how place is theorised in existing STS ethnographic research. We will then return to this discussion in Section 2.4.7 and 2.4.8.

2.4.4 Theorisations of place through STS ethnographic research

There are three key features of place with which early STS ethnographies engaged. Firstly, there is its location, or its "site in space" where something can be situated (Agnew, 2011:326). This is the 'where' of any given place. Secondly, there is its locale, its operational performance as a setting where practices, materialities, and everyday life happens. This can be considered as the "material form" of place (Gieryn, 2000:466). Thirdly, there is the "sense of place"; the gathering of norms, moral orders, associations and meaning (Agnew, 2011:324-325). This can be considered the 'meaningfulness' and experience of place. However, whilst there emerged consensus that under this conception, 'place matters', there was – and continues to be - much discord in how each of these features of 'place' can be theorised.

STS scholarship has typically engaged in debates that entangle the first two features: place as a 'site in space' (location) and as a 'setting' (locale) of materiality and action.

One of the main debates amongst the early STS ethnographies focused on the extent to which these sites and locales of scientific practice are physically and geographically 'fixed'. Understanding this debate helps us contextualise the different ways it is possible to locate places, and thus the ways that project participants perform the places of their MSB research. The sociologist Thomas Gieryn represents one side of the debate. Gieryn (2000; 2006) is a vocal advocate for interpretations of place fixed in geography. These can best be considered as a conception of place as specific 'regions'. In his work on place, Gieryn (2000) frames place as geographically locatable and positions its material concreteness as key to understanding its role scientific activity (though he concedes that the boundaries around such sites are 'elastic')[17]. In a similar commitment to the concrete, Shapin (1995; 1998) argues that physical sites are defined by: locales, barriers, ports of entry and lines of sight that necessarily bound it and separate it from other environments (Shapin, 1998)[18].

Meanwhile, representing the other end of the spectrum are the sociologists Bruno Latour and Steve Woolgar. Latour and Woolgar (1979) take a different stance, theorising place in ways that eschew geographical fixedness and emphasise networks and connections rather than specifically *geographical* referents of locatability (Henke and Gieryn, 2008). In their conception of scientific practice – echoed in many of the subsequent ANT studies such as Latour (1983), Woolgar (1990), Latour and Callon (1987), amongst others – Latour and Woolgar (1979) theorised the situatedness and 'locatability' of scientific practice through the relations between their materialities and the arrangements that condensed, rather than geographically bounded and fixed sites. Places of science could be theorised as specific configurations of 'networks' of components, differently configured at different moments of scientific practice. In doing so they urged a rethink of what could be considered inside and outside of place of science – such as the laboratory – in the first place, emphasising a relational view of space and place[19]. In doing so, Latour and Woolgar (1979) actively diminished the importance of the geographical and

[17] For Gieryn, virtual 'places' are not places in the same way that physical places are.
[18] Although it should be noted his studies focused on the situatedness of *experiments* in particular places, not scientific practice writ large.
[19] This happened simultaneously to Callon and Latour (1992) challenging social construction as insufficiently accommodating the materialities upon which the theories relied (Jensen et al, 2017). Arguably, it is at this juncture that the focus on materialities and 'ontology' (ways of being) entered mainstream discussion within STS (Jensen et al, 2017).

physical aspects of ‘place’, instead theorising ‘open spaces’ that are materialised into concrete, locatable sites through specific *configuration* of networks of components that operate through them (Latour and Callon, 1987).

Indeed, in his text ‘Give me a laboratory and I will raise the world’, Latour (1983) reflects on the laboratory as a site of knowledge production and elucidates this dissolution of the rigidity of inside / outside boundaries quite eloquently[20]. In it, he provides an account of Louis Pasteur’s famed work in anthrax vaccinations, demonstrating that Pasteur’s success was in no small part due to the way he configured *what* he performed as his laboratory. Pasteur found a compromise between executing a sufficient “displacement” of his research from the laboratory to include the farm site to extract what he required to progress his vaccinations; but without displacing too far into the un-clinical environment jeopardising the success of the vaccine, nor displacing too little and farmers losing interest (1983:151). As Latour (1983) then writes:

> “In this succession of displacements, no one can say *where the laboratory is* and *where society is*. Indeed the question ‘where?’ is an irrelevant one when you deal with displacements from a lab in Paris to some farms then back to Paris, drawing along with it the microbes and the farmers’ interests; then to Pouilly le Fort where an extended repetition is staged, then to the whole agricultural system through statistics and bureaucracy. (Latour, 1983:154).

In this account, Latour (1983) suggests we think of the laboratory as a site of scientific activity that is in constant negotiation, comprised of arrangements of relations and materials, “just a moment in a series of displacements that makes a complete shambles out of the inside/outside and the macro/micro dichotomies” (1983:168). Under this conception of locating and identifying 'sites’ of research, the rigidity of specifically geographical fixedness holds no sway.

In between these two opposing stances, we find the work of other scholars. One proponent who adopts a more centrist relational approach is Karin Knorr-Cetina. She argues that places are indeed ‘relational’, open to constant renegotiation, and more about process rather that physical sites. However, she stops short of collapsing these into a network conception. Instead, through her work with laboratories, she argues that the site emerges through the processes that are gathered, they are a “relational unit” (1999:44). Places are relational units enacted in practice. This is a

[20] Latour (1983) does so as part of ‘three threads’ of an argument articulating how laboratories gain traction in knowledge production. These include “the dissolution of the inside/outside boundary; the inversion of scales and levels; and finally, the process of inscription” (1983:163).

fundamental point for this thesis moving forward: practices make places. Specifically, places are constantly negotiated through the practices and materialities that give rise to them (Knorr-Cetina, 1999; Law, 2004a). Thus, places are constantly being made and remade, enacted in the practices that gather there. As Hetherington (1997) argues places are "generated by the placing, arranging and naming the spatial[21] ordering of materials and the system of difference that they perform" (1997:184). They are "the effects of arrangements of spaces, times, things, people and events in materialities" (Hetherington, 1997:197).

In addition, Knorr-Cetina (1999) argues that places may also be broadly 'locatable', but *only* through locating the practices and enacted materialities that comprise them at any given moment in time, places themselves are not fixed, nor can they be reified. Instead, they change shape, expand, contract and are remade through practice and the materialities that they gather and perform. In short, a place's work as a 'locale', constantly changes the 'site'. The two are inextricable from each other and combine to generate place as a 'practical achievement'. It is this notion of place as a 'relational unit' enacted in practice that best fits with the approach to materialities outlined in Section 2.2 as well as the empirical findings we will encounter moving forward.

Under this conception of places as practical achievements or enacted in practice, it stands to reason that places are also porous. Being constantly negotiated through their materialities and practices, things 'escape' and 'gather' (Cresswell, 2014). For example, practitioners themselves move across the different places as they participate in different MSB research activities. There are 'routes' in and out of the places that emerge, established by practices of gathering and dispersing.

2.4.5 Underlying notions of space and time

To contextualise the complexities of the relationship between materialities, practices, and the places to emerge – and thus better contextualise the patterns of human appearances and their entanglement with notions of place - it is necessary to briefly pause this elaboration of 'place' to consider some related notions. Underpinning the theorisations of place are two other related concepts: that of space and time. As we shall encounter in the empirical chapters, MSB human entanglements and enactments are heavily entrenched in spatiotemporal discourse. There emerges a

[21] Hetherington (1997) also argues that "places move in time as well as in space" (2007:193), as well as the social ordering that generates 'sense' of place. His use of the term spatial here is not taken to exclude temporal dimensions.

“time and place” for the human to appear, often that is “far in the future”, or “back in the past”, “out there” “in nature”. As project participants ‘place’ the human appearances, they do so by locating them in both space and time, bringing to presence particular understandings of both. Yet there exist different configurations of space and time. To theorise the empirical findings through notions of place is necessarily to recognise the spatial and temporal dimensions they enact, and the different ways that materialities are distributed across them.

First, we turn our attention to the concept of ‘space’. As already introduced in Section 2.4.1, ‘place’ can be considered a specific and situated version of a more generalised or abstract notion of space (Agnew, 2011), or as Lefebvre refers to it, ‘concrete space’. Place and space are thus inextricable; place emerges from, or through, space, and through these emergent performances of place, space is configured. Yet, there is no ‘one’ theorisation of space, and thus no one simple place-space relationship into which potential human appearances are entangled and help to configure. It is to the work of Law and Mol (2001) I now turn to help unpick the array of potential spatial aspects of place[22] that can be encountered in empirical investigation.

The most familiar and ubiquitous notion of space corresponds to the idea of plotting geometrical space in three dimensions. Law and Mol (2001) describe this ideation of space in terms of Euclidean geometry, where space correlates with the ideas of designated regions in three dimensions, and space measures the distance ‘between’ things in those three dimensions (Hetherington, 1997). This notion of place thus appears under a variety of monikers including ‘Euclidean space’, ‘regional space’, ‘geographical space’ and more (Law and Mol, 2001:612). Gieryn (2000; 2006) and other proponents of a fixed, geographically locatable notion of ‘place’ draw on notions of regional space. Perhaps one of the most durable examples in sociological work is Goffman’s (1959) use of dramaturgical metaphors to designate places of social activity into backstage and front-stage regions. In Goffman’s work (1959), he looks at the subjectivities and identities that arise from such regional performances (including the notions of public and private spaces) (Shortt, 2015:636). This is arguably the most common and thus conceptually straightforward theorisation of place we encounter in daily life. Indeed, throughout the empirical chapters that

[22] This thesis takes much inspiration from the sociomaterial scholarship of Law and Mol (amongst others). In keeping with the STS tradition in which this thesis is written, I have drawn on Law and Mol’s (2001) characterisation of space. For a compatible account of the similar theorisations of place – but provided through the vocabulary, scholarship, and concepts of human geography, see Agnew (2011).

follow, we encounter many regionally performed notions of place in relation to the enactment of human appearances. These also include dramaturgical inspired references such as human entanglement in scientific activity belonging “behind the scenes”.

Law and Mol (2001) then contrast this type of space with ‘network space’. This is the underlying conception of space articulated by Bruno Latour and other proponents during many of the early ANT studies. Here, network space does not correspond to regions or coordinates. Instead, Law and Mol (2001) point us to notions of topology rather than geometry (2001:612). Serres and Latour (1995:60) articulate network space best when they talk through an example of two points on a flat surface (like a handkerchief). They illustrate that when the surface is flat, the two dots are separated. This represents Euclidean or regional space. However, when the surface of the handkerchief is crumpled: “two distant points suddenly are close, even superimposed […]” (1995:60). Rather than drawing on a three-dimensional, Euclidean geometry, Serres and Latour (1995) argue for the rifts of ‘nearness’ and ‘farness’ of topology. In line with other sociomaterial scholarship, Hetherington (1997) argues this topological approach lets the objects “speak of place” (1997:184). In a Leibnizian view of relational space, he argues that centring the materialities that gather in the ‘locales’ as core to configuring space into places: material performances create topology.

Indeed, theorising place through studying the performance of objects and materialities gives us two additional ways to consider the underlying space made concrete through place. The first of these other concepts is ‘fluid’ space. Law and Mol (2001) liken this to the space that is adjacent to, or ‘Other’ to the network. What is made present in any given space exists in relation to what is not made present. Specifically, Law and Mol (2001) draw on de Laet and Mol’s (2000) work on the Zimbabwe bush pump to illustrate this point. Under this theorisation, objects neither move from regional space to regional space, nor do they network from one place to another, but instead, they move at the margins, bits being changed, adapted, made present then absent, belonging to other networks, comprised by multiple regions and multiple networks. Over time as an object ebbs and flows it gathers different regions and places into its performances, its character changes, the places and spaces it occupies change, but it retains resemblance as an object (Law and Mol, 2001).

The last type of ‘space’ is that of ‘fire’ space. Like ‘fluid space’, the core conception here is also that what is rendered present within a region, or within a network also exists in relation to what is not rendered present (Law and Mol, 2001). However,

unlike the ‘fluid’ conceptualisations of space where objects gradually morph in relation to what isn’t rendered present, with fire space Law and Mol (2001) liken the relationship to that of the flickering of fire (2001:616). At any given time, an object can be negotiated into presence in one form (such as biological materials enactments as specifically “human cell lines”) and just as easily rapidly rendered absence in favour of an alternative performance the next (such as enactments of biological materials not as specifically human cell lines, but as lineage-agnostic “expression hosts”). It is this notion of ‘fire space’ that Law (2004a) draws on in his work to demonstrate that what is made present is simultaneously contingent upon - and inextricable from - what is made absent that we encounter in Section 2.3. This is a particularly helpful conception when considering the ways that human appearances are present in some project performances, and not in others. The concept of ‘flickering’ of presence and absence helps us understand the ‘multiple modes of ordering, jostling in negotiation of presence and absence (Hetherington, 1997).

It is important to recognise that in theorising places as relational units enacted in practice, the relationship between place and space can be configured differently through different performances. Both Hetherington (1997) and Law (2004a) conclude that ‘space’ is perhaps best understood as a complex interrelation of multiple modes of ordering, rather than as persistent and singular in its identity. Space is filled with competing materialities (and entanglement with counterpart alterities) jostling in a negotiation of presence and absence to comprise the eventual ‘practical ontologies’. Throughout the performance of materiality into being through practice, places are also constantly assembled and disassembled (Cresswell, 2014) and as such, they also demonstrate continually changing relationships with the underpinning notions of space. As Law (2004a) reminds us: “Space is not, as it were, the same everywhere, essentially neutral. It is […] being built differently” (2004a:135). Indeed, Star (1991), Serres and Latour (1995) and Law and Hetherington (2000) all remind us of the same: multiple spatialities emerge and coexist during the performance of scientific practice.

The second important underpinning concept of place is that of time, or notions of temporality. In Section 2.3, we have already seen the importance of experimental systems (including human-derived biological materials) as vehicles for ‘making the future’ (Rheinberger, 1997). We have also seen the importance of imagined futures and expectations (such as imaginations of future health applications) in making the present (Eames et al, 2006; Tutton, 2017). Through both these clusters of practices,

research materialities emerge as deeply temporal enactments. Afterall, as Cresswell (2014:21) attests, places enact temporal dimensions:

> "The components of place - materialities, meanings and practices - all contribute temporal dimensions to place as they are lived, felt and recalled."

Understanding how time is conceptualised helps us elucidate the place-related circumstances of how potential human entanglements and enactments emerge.

Barbara Adam (1990) provides two theorisations of time that prove useful to analyse and characterise the temporal dimensions of human entanglements and enactments. Firstly, she introduces us to what she terms 'clock time'. This is a spatialised, abstracted notion of time that results in a linear view of the future being situated further along a temporal 'line' than the present (Adam, 1990). This is arguably the most common notion of time we encounter in performance of day-to-day modern society. Secondly, there is instead a performative notion of time, where the past and the future are "constantly created and recreated in a present" (1990:39). Under this conception, pasts and futures only ever exist in the present, and the present is always 'in process' (Adam, 1990).

In her work with Chris Groves, Adam further elaborates what these ideas mean for understanding futures, a key component of the promissory rhetoric and performances of SB and MSB research (Frow, 2013). Adam and Groves (2007) elaborate that when theorising time as linear, 'clock time', futures can be understood as "present *futures*". This is where futures are imagined whilst in the present but imagined as being distinct from the present, projected along the linear temporal 'line' to an 'out there' separate from the 'now' (2007:28). Meanwhile, Adam and Groves (2007) explain that in line with performative notions of time, the future can instead be understood as "future *presents*". In this conception, the future can best be described as attempting to bring ideas about the future into the present and making materialising those futures into being through unfolding a series of presents until such ideas are brought to life (2007:28)[23].

Once again, as materialities are enacted in practice, materialised imaginations of futures, representations of pasts, and enactments of the present that gather as part of the 'locales' negotiate different versions of temporality into being at different times. As Matthews and Livingstone (2017) advocate, time is experienced differently in

[23] Indeed, Adam (1990) unreservedly urges us to eschew the spatialised, abstracted, and linear notion of 'clock time' in favour of temporalities that are "constantly created and recreated in a present" (1990:39).

different contexts. These different negotiations lead to different configurations of places, each entrenching its own version of temporality into its ongoing performance (Cresswell, 2014). Just as multiple spatialities emerge and co-exist during the performance of scientific practices, so too can different performances of temporality.

2.4.6 Packaging material arrangements in space and time as 'complexity'

Both the materialities that gather in 'locales' of scientific research, and the notions of space and time underpinning 'sites' of scientific research, can be held together and theorised through the concept of complexity. Different materialities - and the configurations of space and time they enact – generate different performances of complexity. Packaging materialities in space and time into a characterisation of complexity provides a short-hand through which to group how places are performed in relation to materialities, space, and time. It helps combine complicated notions of space, time, and the relationships between different materialities into a digestible characterisation.

John Law (2004b) introduces us to research by Chunglin Kwa (2002) characterising two opposing notions of complexity: the 'romantic' and the 'baroque'. Law (2004b) (see also Kwa, 2002) argues that romantic approaches to complexity operate by looking 'upwards and outwards' to make sense of the relations between materialities, space, and time. Different space, times and materialities are construed as stretching into a global 'reality' comprised of multitudes of interconnecting components (Law, 2004b:14), each occupying a discrete segment of space and time. In this way, space is typically performed as regional, and time is performed as linear, stretching out backwards into pasts and forward into futures. As such, 'everything has its place', each component is designated to a point in space and time, and the complexity of romantic systems arises from detailing exactly how everything (in its place) links to everything else.

Meanwhile, the contrasting 'baroque' approach to complexity operates through different performances of materiality, space, and time. Instead, it works on the premise that "everything is already present if we just look hard enough" (Law, 2004b:22). Baroque notions look 'downwards and inwards' to understand the relations between materialities, space, and time. The things and objects that comprise materiality in effect become an enactment of everything that goes into making them (Law, 2004b). They 'encompass' - and thus bring into the present – the pasts, futures, and differently spatially-situated presents all at once (Agnew and Livingstone, 2011). In this way, space typically encompasses fire space in relation to

its materialities, with multiple materialities jostling for foregrounding; and time is typically performed as a process of series of 'presents'. The complexity of baroque systems therefore arises from detailing how everything is entangled into a series of potential relations, pending enactment into a presence or absence in a series of 'nows' (Law and Mol, 2001; Adam, 1990).

2.4.7 Introducing a 'sense of place'

In 2011 the human geographer John Agnew observed that in general, the world seemed to be becoming increasingly 'placeless', a shift he elaborated to suggest: "space-spanning connections and flows of information, things and people undermine the rootedness of a wide range of processes anywhere in particular" (2011:319). He drew on Friedman (2005) amongst other scholarship to demonstrate that in broader Western thought, space seems to be 'conquering' place. He proceeded to argue that what lies behind the 'intellectual diminution' of place (Agnew, 2011:319) is an imagination of an isolated and passive 'place'. Agnew (2011) goes on to argue that theorisations of place have much to offer beyond this narrow conception of place as a spatiotemporal referent. Specifically, he draws attention to the third feature of place introduced earlier in this discussion: the 'sense of place'.

In its most basic form, a 'sense of place' refers to the attachments, expectations, and associations that emerge through the performance of a place that subsequently afford it a specific and distinctive 'quality' (Cresswell, 1996; Gieryn, 2000; Agnew, 2011). Cresswell (1996:3) brings the concept to life most succinctly when he elaborates a 'sense' of place as incorporating 'social space[24]' as follows:

> "[…] the word place turns up in common phrases such as 'a place for everything and everything in its place' or 'know your place' or 'she was put in her place.' In these expressions the word *place* clearly refers to something more than a spatial referent. Implied in these terms is a sense of the proper. Something or someone *belongs* in one place and not in another. What one's place is, is clearly related to one's relation to others. […] they are *expectations* about behavior that relate a position in a social structure to actions in space. In this sense 'place' combines the spatial with the social — it is 'social space'. Insofar as these expectations serve the interests of those at the top of social hierarchies, they can be described as ideological."

[24] Cresswell (2014) terms this 'social space', hence my use of this terminology. In keeping with the material semiotic approach in this thesis, this could arguably be better described as 'sociomaterial space'. For the purposes of this discussion, however, and given its use to demonstrate an inclusion of social dimensions into an already material discussion, I have opted to retain Cresswell's original terminology.

In sum, these ‘situated’ expectations and social hierarchies enacted in the associations between research objects and ‘sites’ (thus generating ‘locales’ of practices and materialities) also give places their ‘meaning’.

As we shall see, these associations, expectations, and hierarchies are routinely encountered across the empirical chapters of this thesis. As well as potential human appearances being enacted through spatiotemporal discourse that ‘locates’ them into sites and locales, they are also routinely entangled with associations of belonging to specific places of performance and subject to social ordering through their association with them. For example, Livingstone (2007) observes that in when it comes to ‘locution’ – speeches, debates, lectures – there are certain protocols that are taboo in certain places, but not others (something we will also see in Chapter 6). As both Agnew (2011) and Cresswell (2014) assert, place is not just a matter of ‘where’ materialities assemble, but also a matter of ‘how’ materialities assemble, including normative judgements of what ‘should’ and ‘should not’ be present.

Traditionally, when it comes to elaborating this third feature of place, the late twentieth century STS ethnographies busying themselves with notions of place rarely foregrounded discussion of it. Instead, it has fallen on other disciplines (such as sociology, anthropology, and geography) to explore the ‘sense of place’ in empirical detail and elucidate the notion.

There are of course exceptions within STS literature. A few STS studies do generate some empirical discussion of the ‘sense’ of the places they are studying, though often not using that term. For example, Knorr-Cetina’s ethnographic investigations refer to the ‘culturally imbued’ nature of situated practices and materialities (Knorr-Cetina, 1988). She draws on Merleau-Ponty’s work to explain how engaging with and experiencing the world is neither subjective, nor objective, but instead is a performance “a world-experienced-by” or a “world-related-to” (Knorr-Cetina, 1995:143) that gives rise to meanings and associations of specific practices and materialities as part of the performance of places as ‘relational units’. Elsewhere, Henke (2000) highlights the emergence of a sense of place by drawing attention to the ‘experiential’ nature of the relations with materialities. Meanwhile, scholarship from Latour (1999) and Law (2004a) provide conceptual explanations for the way in which relations between participants, materialities, and the conventions of the places themselves occur and fit into their overarching theorisations of place, space, and time. These studies all encompass some discussion of the norms, experiences, and meaning that places enact, corresponding to what Agnew (2011) considers the ‘sense’ of a place. However, this type of discussion is infrequent and often does not

dwell on affective attachments and associative dimensions for their explicitly normative effects. Even contemporary STS studies that have re-engaged theories of place in the last ten years tend to discuss this third aspect only in the context of more dominant discussion of the spatial and temporal dimensions of sites or locales which better serve their research goals[25]. In sum, STS continues to omit any targeted empirical and conceptual elucidation of the 'sense' of place, and rarely discusses normative notions of what belongs or what is 'proper' (Cresswell, 2014).

There is perhaps one notable STS exception that pays attention to the social ordering of a place (its 'sense') as much as its spatiotemporal dimensions. This is Lynch's (1991) work on 'topical contextures'. In this work, Lynch (1991) gives the 'siting' of knowledge production a slightly different treatment than his peers. He argues that notwithstanding the importance of the site and locale of the laboratory bench, there is more to the 'place' of scientific work. He puts forward a revised understanding of what place encompasses, emphasising what he considers less obvious aspects of space, technique, and language. Lynch (1991) conceptualises places of scientific work (in his case, laboratories) as locally organised 'topical contextures'. In its most basic form, a topical contexture is a combination of equipment, devices, and action (the 'technological complexes'), and the corresponding ways of experiencing and ordering the physical and perceptual space they enact (their 'spatial grammars'). He ties these topical contextures to episodes of practice (as opposed to physical structures) that typically disappear when certain activities end. In this way, places of scientific practice can be understood as being made up of multiple, transient technological complexes, each associated with specific spatial grammars or ways of experiencing and ordering them.

Lynch's 1991 treatise is dense, and while the technological complexes (and the physical space they occupy) are relatively straightforward to grasp, the inclusion of perceptual space requires a little unpacking; for it is in this that he encompasses what Agnew (2011) would consider the sense of place. According to Lynch (1991), 'perceptual space' is how any given place is experienced, seen, and understood in any given moment. There are different ways to experience the perceptual space of places of scientific practice. For example, it can be visually experienced where objects are *seen* and cast into relation with each other that way; it can also be

[25] For example, Meyer and Molyneux-Hodgson (2016) provide an interesting discussion of laboratories that belong to idealised networks based on anticipated 'good-will' strategies of sharing, fragmenting into their own in-groups and conventions of practice (2016:73). This highlights the role of such norms / expectation, but is quickly subsumed back into reflection on the spatial and temporal dimensions of sites and locales that better serves the paper's core argument.

phenomenologically experienced, where a place is organised in relation to the embodied practitioner and how they physically navigate the space (Lynch, 1991)[26]. These are just two of a variety of ways that a space can be affectively experienced, navigated, and understood. What they both share though, Lynch argues, is an organisation through referential spatial predicates[27] such as 'above/below', 'inside/outside', 'before/behind' and similar notions (1991:53). It is through these spatial predicates that the normative associations and expectations of places of scientific practice are made material. For example, what is considered 'inside' or 'outside' a space is subject to symbolic meaning and expectation around what should or should not be experienced there. Indeed, throughout the empirical chapters that follow, we will repeatedly encounter examples of places being ordered through spatial predicates in ways that enact a sense of what is 'proper'. Through such spatial predicates, Lynch (1991) provides a mechanism to accommodate the role of ordering and conventions (or 'social space', Cresswell (2014)) in shaping the topical contextures that comprise places of scientific practice.

In this way, Lynch's (1991) elucidation of topical contextures provides a symmetrical STS approach that ties together the 'site' (a locatable setting), the locale (what is gathered there), and the 'sense' of the place (how the objects that dwell there relate to each other, including what *belongs* where and how). Yet the concept has not been taken up more broadly by the STS field. Very few scholars draw on topical contextures as a conceptual tool with which to examine places of scientific practice, and there is negligible attempt to develop its ideas further. Yet the associations and attachments that generate this 'sense' of place and its normative power can be an important analytic lens (Cresswell, 1996; Law, 2004a; Agnew, 2011). As the empirical findings of this study will attest, they become particularly pertinent in this investigation. Entanglement and enactment of human appearances are deeply associated with normative assumptions and expectations of where such appearances do and do not belong. Understanding the normative associations and attachments that are associated with any given place (and how that generates a 'sense' of what is proper) is crucial to understanding the complexities of how the human appears in the context of MSB research.

[26] As such, perceptual space should be understood permissively in this thesis, and should – like all apprehensions and similar – be considered as materialised though practical achievement (Law, 2004a).
[27] Although termed 'spatial' predicates, they are also inextricable from considerations of time; for example, for one practice to occur *before* another entangles an inherently temporal dimension.

We return to Lynch's (1991) ideas of topical contextures again in Chapter 7, but for now, to develop a more in-depth understanding of the third aspect of place, it is the literature from other disciplines, especially Human Geography, that proves more useful.

2.4.8 Elucidating a 'sense of place'

Human geography scholarship not only gives us the useful characterisations of the sense of place at the start of this section (courtesy of Cresswell, 2014), it also offers a well-developed body of literature to elucidate how a sense of place can best be understood, and the mechanisms of how they are enacted in practice.

There are two main ways that a sense of place is generated. Firstly, through human actors' associations with a particular material (or social) feature of a place, perhaps one that improves their ability to navigate their relationship with a place. An example of these features might include a memory enrolled in recalling the place, an object associated with it, or a function that the place might perform. Secondly, through entanglements of meaning and qualities with the material elements assembled in a particular place. These meanings could include familiarity with a particular aspect, value judgements around relative safety or desirability, or imaginaries of people or objects within it. Cresswell (1996) expands upon this last point. He suggests that there is an implicit set of sociocultural expectations established and enacted during place-making activities that are constantly made and remade as the 'sense' of place emerges. Cultural associations and material attachments that are performed into being are therefore often 'normative'.

The mechanisms typically work in conjunction with each other. The 'sense' of a place adds to the way that places operate as processes of reconfiguration (Knorr-Cetina, 1999; Massey, 1999). The constitutions of places are repeatedly made and remade through expectations, value judgements, and associations. Some material elements are negotiated into presence, actively associated as 'taking place' in these specific places; others are assembled into absence by merit of not 'belonging' there. Indeed, Cresswell (2014) concludes that it not only a place's site (location) or locale (material form) that contributes to its sense of 'singularity' or recognisability, but also this generated 'sense' of the place. It is the set of associations and attachments between included (and excluded) materialities and sites or locales that generate a 'rootedness of belonging'. Or, as Massey (1999) observes: a place's "specificity (local uniqueness, a sense of place) derives […] from the absolute particularity of the mixture of influences found together there (1999:22).

In this way, places are not only porous, materialising ‘routes’ in and out the ‘relational unit’ by merit of materialities ‘gathering’ and ‘escaping’ as places are enacted in practice (Cresswell, 2014). They also materialise ‘roots’: they enact patterns of materialities that are repeatedly assembled into presence or absence and associated with specific patterns of appearance. In this way they generate ‘depth’ (Cresswell, 2014) to the ‘sense of place’.

This ‘rootedness’ or depth does not necessarily correspond to narrowness in its relations. Here, it is useful to point to two separate examples. Returning to STS study, and Knorr-Cetina’s (1999) work exploring the epistemic cultures of different laboratories, Knorr-Cetina (1999) characterises molecular biology laboratories in terms of their ‘small lifeworldly arrangements’. She outlines how materialities that comprise the experimental systems and configuration of the molecular biology laboratory practices enact a small, tightly localised set of foregrounded relations. It is these that give rise to, and - critically for this discussion - are experienced by participants as the experimentally focused laboratory. The ‘small lifeworlds’ enact a tightly focused, almost introverted sense of place generated through the associations accomplished through the small lifeworldly configurations and reconfigurations of materialities and meanings. However, by contrast, Massey (1994:155) notes that places can also generate a sense of place which is ‘extroverted’:

> “Instead, then, of thinking of places as areas with boundaries around, they can be imagined as articulated moments in networks of social relations and understandings, but where a large proportion of those relations, experiences and understandings are constructed on a far larger scale that what we happen to define for that moment as the place itself, […] And this in turn allows a sense of place which is extroverted, which includes a consciousness of its links with the wider world, which integrated in a positive way the global and the local.”

Indeed, Massey (1994) talks of a sense of place to emerge through ‘extroverted’ set of relations. Whilst the experimental ‘small lifeworlds’ enact experimentally focused, almost introverted relations; other performances – such as research performed through community discursive practices that entangle imaginations of future outcomes – are ‘conscious’ of their links in the wider world.

In conceptualising the sense of place this way, Massey (1994) also introduces a more broadly useful concept of ‘extroversion’ (or links with the wider world) through with which to consider material arrangements beyond the sociomaterial associations or ‘sense’ of place they generate. For example, as we encountered in Section 2.3, the way that research objects 'expand’ to enact broader societal expectations by

emphasising their links with wider imaginations of future use can be considered in terms of 'extroverted relations'. Indeed, in considering places as a relational unit (Knorr-Cetina, 1999), the heuristics of 'small lifeworlds' and contrasting 'extroverted relations' prove useful articulations through which to characterise the differences in the performances of relations with other materialities.

2.4.9 Theorising 'sense' in a 'sense of place'

Once again, whilst the notion that the set of associations and attachments exist to generate a recognisability or 'sense' of a place is largely agreed upon (regardless of whether such a sense is generated through small lifeworlds, or expansive and extroverted relations), the *way* these associations are addressed in broader theorisations of place is hotly debated.

There are two main axes of contention that have a bearing on how to understand place within this study. The first centres on the word 'sense' and the idea that the term 'sense' suggests social primacy in the creation of such associations. There are a variety of positions to be found in existing STS and sociological literature. Firstly, there is a social constructivist way of conceiving of the associations that generate a 'sense' of place. For example, Gieryn (2000) argues from a place of broad social constructionism. He asserts that it is *people* who create these attachments, thus a 'sense' generated about a place (and the materialities that enact it) *is* a primarily social act. Though it should be noted that Gieryn (2000) does concede that this is often in response to material agency. Secondly, at the other end of the scale, Latour (1999) eschews social primacy and argues for a materially led interpretation. He rejects any notion of a human-led 'sense' of place and argues that such associations between participants and places, or places and the materialities that emerge there, can be understood as 'tokens' or 'quasi-objects' (the intermediary phase between unmade things and made objects) that become 'networked' into being.

Meanwhile, adopting a more equal balance, sociomaterial scholars such as Hetherington (1997; 2000) eschew both social and material primacy, and instead prefer to discuss associations in terms of socio-material *entanglement.* This emphasises actions and materialities and privilege neither human nor non-human actors. In this sociomaterial vein, Law (2004a) theorises the associations of places with meaning - and the materialities with places - as *actions*. In the same way that imaginations and concepts can be materialised through the act of thinking, or imagining (Tutton, 2017), so too can the affective and subjective associations or accomplishment of a 'sense' of place. Correspondingly, the associations that

generate the sense, or ‘rootedness’, of a place are no less material in their articulation than other practical achievements (Woolgar and Lezaun, 2013). The ’sense’ of place can therefore be understood as another example of an apprehension (Law, 2004a) that enacts a flattened ontology and epistemology through practical achievement. They merely comprise another part of the sociomaterial apparatus generating reality (Law, 2004a:31,146). Indeed, in keeping with the wider sociomaterial sensibilities of this projects’ theoretical foundations (see Section 2.2), it is this conception of the ‘sense of place’ that this study adopts. Moving forward, any usage of the term ‘sense’ can be considered a shorthand, synonymous with the ‘practical achievement of sociomaterial association’.

Having resolved to understand the term ‘sense’ through its sociomaterial act of association and attachment, there still remains a second line of debate regarding the inclusion of human actor subjectivities. Specifically, the challenge of whether subjectivities of participants – such as notions of the self and affective experiences – are entangled in generating the sense or sociomaterial associations of place. Rather than the debate dividing different traditions of social constructivism, materialism, and socio-materialism, down different lines, the debate occurs *within* the traditions. For example, in the social constructivist scholarship, Löw (2008) and Casey (1997) suggest space and place can *only* be understood taking into consideration the role of perception – and thus the self – of the actor involved. Casey (1997) argues that place is embodied, and the experience of a place is inextricable from the ability to dwell within them. Meanwhile, Shapin (1998) and Gieryn (2000) represent another arm of social constructivism that gives little space to notions of perception and often dismisses the role of the ‘self’ as part of the process.

Similarly, in the materialist (and sociomaterialist) scholarship, debates on the role of subjectivities also split opinion. Callon (1986) and Latour (1999) both eschew the role of perspective, self, or use of the senses as ‘subjective’ philosophy. Callon (1986) prefers terms such as ‘interessement’ and ‘enrolment’ to describe the practices through which tokens or quasi-objects (attachments) of entanglements emerge. On the other hand, Haraway (1988) argues against this dismissal. She asserts that the material world is the result of multiple situated perspectives and subjectivities need to be acknowledged. Indeed, much feminist human geography and STS echoes this standpoint. For example, from the perspective of feminist human geography, Massey (1994; 1999) advocates a similarly inclusive approach to ‘sense’ as emergent through subjectivity. Elsewhere, Star (1991) observes that the world looks different if you start from the periphery of a network, rather than the centre. These scholars argue that retaining the notion of subjectivities and instead

accounting for them, rather than eliding them, provides a productive 'otherwise' window through which to explore the relationality of places that emerge.

In this study, I align to Haraway, Massey, and Star and advocate for an inclusion of the role of subjectivities in generating a sense of place. In the empirical chapters, I shall demonstrate why: participants' subjective and affective experiences with other potential human appearances – as well as comparisons with themselves and their own 'human' performances - frequently emerge in negotiating human appearances into presence or absence. Indeed, in line with Landecker's (2018) renewed call to consider the affective and the subjective in investigating scientific practice, acknowledging and accounting for the self provides a way to account for the subjectivities that my project participants draw upon and the 'feeling' to which they refer to when they account for where human enactments do and don't belong.

2.4.10 Taking place forward

So, what broader lessons can be learned from STS and Human Geography's engagement with notions of place to help generate the nuanced understanding of place required to better synthesise the empirical results?

The first point of learning is that place is not just a 'where' in space and time, but also a '*how'* in space and time: place is a process that gathers and performs. Cresswell (2014) offers us a useful working definition of place as: "a gathering of materialities, meanings and practices" (2014:5). Through this notion of 'gathering', place becomes much more than a 'location' where these components reside. As Law (2004a:104) outlines, place is the flux of multiple materialities and actions - including their normative associations and attachments - and the continual making and remaking of the relationships between them. It is through place as a process that the three features of place are inextricably connected: 'locales' (the material form of places) make 'sites' (locatable places); however, associations (the sense of place) also make locales. Place thus emerges as a 'relational unit' (Knorr-Cetina, 1999), enacted through their materialities and practices.

Through this continual processing of materialities, practices, and meanings, Massey (1994) argues for places to be understood as 'articulated moments'. However, perhaps it is Cresswell (2014:10), who provides us the most elegant way of thinking about place as a process. He elaborates as follows:

> "Places both gather and disperse. They collect things from outside and are thus constituted through their relations to the world beyond. But things are always also escaping place. Places, therefore, are in process. They are becoming and dissolving on a daily basis."

Cresswell's (2014) definition (and subsequent elaboration above) is sufficiently permissive to support multiple conceptualisations of space and time. It also integrates well with the literature from Section 2.2. This characterisation of place also supports the notion that multiple enactments of materialities can occur through multiple configurations of place (Jensen and Marita, 2015).

The second broader point of learning is that it is possible to theorise the 'sense' of place, its meanings, and cultural attachments (Knorr-Cetina, 1999) in ways that are commensurate with the approach of material semiotics. By flattening the ontology and epistemology into 'practical ontologies', it is possible to construe associations and attachments as actions, part of the materialities and practices engaged in producing reality (Law, 2004a). This enables us to better contextualise the way that participants associate the human with specific places.

The third broader point of learning relates to what place is not. Resoundingly across all the scholarship on place, the accounts - however varied - eschew the idea that place is merely a 'neutral container' acting as a backdrop for something else (Werlen, 1993). Every item of scholarship reviewed within this chapter – and indeed beyond – comprehensively rejects any reification of place along these lines. Places is not just a 'proxy' for the 'local' (Jessop et al, 2008). Indeed, Gieryn (2000) calls any use of place merely to 'bound' a unit of analysis in this way, "pseudo-places". Such 'pseudo-places' are quasi-realist appeals to reified and fixed places that exist regardless of what may - or may not - be performed through them. This propagates a logical positivist approach that was common from the positivists from Vienna and Berlin schools of rationalist philosophy. In pursuing an idea that place matters little, 'truth' becomes abstract, universal, and placeless. In short, any use of place as 'pseudo-places' puts us right back to where we began at the start of this section: in the 1970s, faced with refuting the logical positivist concept of 'placeless science'.

2.4.11 The significance of place, or 'what place does'

Finally, all that is left in this final part of this chapter is to provide the theoretical foundations for how and why the place of potential human appearances becomes a significant component to explore.

In short, places are powerful. Firstly, they perform work as a sorting and ordering mechanism (Cresswell, 1996; Gieryn, 2000). For example, in her work on different material enactments of atherosclerosis in Hospital Z, Annemarie Mol (2002) demonstrates how place can be used to sort and order materialities, especially ones that compete or conflict with each other. In Section 2.2 we heard from Pickering (1992; 1995) that the performative idiom generates materially different objects and research materialities. Having multiple different possible enactments, however, necessitates strategies to handle contrasts and conflicts. Section 2.2 stepped through some of the strategies to managing the multiplicity that Mol (2002) identified through her work in Hospital Z. Separating potentially contrasting and non-coherent enactments by place (something she terms 'distribution') is one of the common ways that ontological differences can be handled without collapsing multiple enactments into a singular performance. As Mol (2002) notes multiple different enactments may continue to co-exist, provided they "do not seek to occupy the same spot" (2002:88). Together the regional conceptions of space and romantic notions of complexity where 'everything has its place' from Section 2.4 enable a 'distribution' of materialities to places that enables the ontological differences and varying practical ontologies from Section 2.2 to exist in their multiplicity. Distinct 'places' emerge in which each of the material enactments can thrive (such as being in different sites in the hospital or appearing at different times) (Mol, 2002:112-115).

Secondly, through the process of sorting and ordering, places enact normative assumptions and expectations of what materialities and associations 'belong' where (Cresswell, 1996). As outlined in the Section 2.4.7 on the 'sense' of place, materialities are sorted and ordered in line with expectations about what is 'appropriate' to perform where. As cultural associations and 'social ordering' occurs, practical achievements of both associations with places and places with materialities, typically involve value judgements and implicit sets of sociocultural expectations about what does and does not belong. The more the sorting and ordering enacts normative assumptions and expectations, the more their repeated performances continue to entrench them as normative. This also creates opportunities of transgression for the materialities that do not fit (Bowker and Star, 1999). Such materialities, meanings, or practices can be considered 'matter out of place' (Douglas, 1966). Through the interplay between normativity and transgression, place emerges as a powerful consumer – as well as creator - of normative associations.

Thirdly and relatedly, places performing 'as a process' wield performative power (Massey, 1994; Agnew, 2011). When the material acts that generate associations between participants, materialities, and places are repeated, the normative

associations and attachments become entrenched (Cresswell, 2014). This then mediates further performances of place as a gathering of materialities, meanings, and practices. For example, Law (2004a) argues that realities grow out of repetition of 'right' and 'wrong' patterns and these emplaced presences and absences create and sustain an expectation, or norm of where particular materialities (such as human enactments) should appear which affects future sorting and ordering. In effect, the performance of these expectations extends or denies chances to other practices, materialities, and meanings that might 'jostle' (Hetherington, 1997) for inclusion. Correspondingly, place both creates - and consumes - normative patterns in a performative cycle, assumptions and expectations becoming further entrenched to create 'strongholds' of some appearances (Gieryn, 2000), whilst prohibiting others (Law, 2004a; Cresswell, 2014).

All three of these mechanisms are inextricable from each other. As Cresswell (2014:20) demonstrates in his summation of the significance of place:

> "At any point in time, a place is a particular combination of materialities, meanings and practices that encourages some connections and makes others unlikely. These elements that make up 'here' are, to be sure, likely to have come from elsewhere at some point in the past. This, however, should not distract from the significance of a place's history in the ongoing constitution of place in the present. The ways in which the vertical (rooted) and horizontal (routed) aspects of place are assembled, the ways in which the materialities, meanings and practices of place are gathered and the ways in which present places enable or discourage future places are all central to the politics of place. Power casts its net here."

2.5 Conclusion

In this Chapter, I have introduced and outlined the literature in the fields of STS and Human Geography that comprise the theoretical foundations and key concepts of this investigation.

I have drawn attention to material semiotic scholarship that elucidates the way that the 'things' and 'objects' of scientific research can be understood and how they inter-relate. This provides a conceptual foundation for how best to understand the research materialities into which human appearances emerge. I have gathered literature on three key sets of MSB research practices through which potential human appearances emerge. These include experimental systems; promises and expectations; and discourse practices. This helps better understand the arrangements of research materialities enacted in specific sets of practice. It outlines the roles and functions of objects and things in their material arrangements and in

doing so helps elucidate the work that human appearances perform when they are negotiated into presence (or absence). Lastly, I have summarised the different features of place and how they have been theorised in STS and Human Geography. I introduce some key aspects of how place can be understood and the work it can do, as well as the associative connections that are generated between particular materialities and the places in which they are performed. This provides a grounding with which to better interpret the spatiotemporal distributions of potential human enactment in the empirical results and understand not only *where* but *how* they are performed in relation to the places in which they emerge. This theoretical foundation equips us well to contextualise, analyse, and articulate the empirical findings that follow.

Before proceeding to the next chapter, however, there is one last matter of theory to address. This body of literature provides us with some useful terminology. Words do much of the theoretical heavy lifting of any argument, and it is important to be clear in their usage. Most of the terms I take forward as key concepts in this thesis have already been defined within the context of their discussion in this Chapter. For example, Jensen's (2010) 'practical ontologies'; John Law's (2004a) definitions of what counts as 'presence', 'manifest absence', and 'Othered absence'; or the Foucauldian understanding of discourse that includes material as well as linguistic practices. Other terms simply emerge in their common usage. For example, terms such as 'materialities', 'practices', or 'actions'; these remain legible in their everyday use without the need for elaboration. However, there are two key terms that underpin how potential human appearances are performed that remain open to multiple interpretations and usage across the social scientific literature. These are 'entanglement' and 'enactment'. My usage throughout this thesis is consistent with Woolgar and Lezaun's (2013) use of these terms. However, given the scope for nuance in their usage across STS, the last order of business in this chapter is to point to a clarification of their usage in Appendix 1. There, I clarify more explicitly how these terms (as well as some derivative terms upon which I also draw, such as '*potential* human enactments') are used moving forward to avoid any ambiguity in the chapters that follow.

Equipped with the theoretical foundations and terminology clarifications to make sense of the empirical findings, it is now to the considerations of methodology that we must turn.

Chapter 3: Methodological considerations

3.1 Aims, synopsis, and structure

The primary aim of this chapter is to elucidate the methodological approaches and considerations I have taken in pursuit of this investigation. Unpacking how the human appears in the context of MSB research is a topic that invites 'mess' (Law, 2004a). To handle such a topic, I designed and conducted a multi-site ethnographic study that explored four biomedically orientated MSB projects 'in the making' for their relationship with the 'human'. Over a period of 16 months, I followed the actors involved in the four projects and attended to a variety of project performances (Marcus, 1995). These included day-to-day experimental work, organisational activities such as reporting project progress to stakeholders and managing projects as part of a wider portfolio of research, and engagement with multiple communities. I generated data using a multi-method approach that included documentary sources and semi-structured interviews alongside participant observation. After reducing and coding data, I drew on the STS and Human Geography theory we have encountered in Chapter 2 - as well as elements of Critical Discourse Analysis that I outline later in this chapter - to identify and interrogate patterns of how the human appears in the context of MSB research practices.

This chapter comprises four main sections. Section 3.2 elaborates my general approach to the research and highlights some key elements of research design. I emphasise the reasons behind pursuing a multi-site ethnographic investigation, elaborate the design of the cases involved, and steer a course through some ontological and epistemological considerations. Section 3.3 outlines the research design activities for preparing to enter the field. I summarise the benefit of performing exploratory interviews, introduce the selection criteria for my case studies, and introduce each case in turn. Section 3.4 introduces the methodological considerations of entering the field and performing the fieldwork. I outline my approach to ethically engaging participants and provide detail of the core research activities I undertook. I also dwell on the matter of my own presence, and my research topic as a provocation to participants, before reflecting on my exit from the field. Finally, in Section 3.5, I introduce my approach to data reduction, coding activities, and my use of elements of Critical Discourse Analysis to elucidate themes relating to the human and the nature of its appearances. I conclude the section with a discussion on the ethical performance of writing and the necessary steps I have taken to reduce and linearise a complex set of materialities.

3.2 Elaborating an ethnographic approach

3.2.1 Elaborating the research approach

To deliver against my aim to generate empirical evidence and socially robust theory where none currently exists, there emerges a need for in-depth, real-time investigation into the complex materialities of MSB research. To conduct such an in-depth investigation, I adopted a broadly inductive approach. Inductivism takes as its basis that research starts with generating data and proceeds to generating theory[28] (Blaikie, 2010:18), a process that makes it suitable for under-developed areas of investigation. To generate the detailed and extensive data required for this investigation, I designed a multi-site ethnographic research approach. Ethnography can be hard to define. There are many overlapping ways the term can be construed, not least a considerable overlap with other qualitative methodologies. However, for the purposes of this investigation I followed Hammersley and Atkinson's (2007) characterisation of ethnography. They suggest that ethnographic investigation can best be described as studying participant actions and activities in everyday contexts. It gathers data from a range of sources (especially participant observations and informal conversations), follows an unstructured approach, focuses on a small number of targeted cases, and produces detailed descriptive content (Hammersley and Atkinson, 2007).

I also included two adaptations. Firstly, I expanded to a multi-site approach. MSB project activities span a variety of places including laboratories, scientific institutions, community conferences, and more. In recognition of these multiple places of performance - and their importance in my empirical findings - I pursued an explicitly 'multi-sited' version of ethnographic investigation. Marcus (1995) outlines this approach as 'following the actors' (by actors he means not only people, but ideas, concepts, documents, and much more) and leaving behind initial places of engagement to follow the actors wherever they go. Secondly, I also adapted the ethnography to include a multi-method approach (an increasingly common practice in contemporary ethnographies). I added documentary sources and semi-structured interview data generation activities. Including documents particularly assisted me in

[28] Traditionally an inductive approach advocates embarking upon such a journey without preconception. However, it should be noted that given the conceptual and the empirical are not considered separable domains, sensitising concepts are not only considered permissible, but ultimately inevitable (Jensen, 2014).

following actors across a more diverse range of settings. In Section 3.4, I return to the benefits of this in more detail.

Ethnographic investigation lends itself to immersive engagement. Indeed, as Scholl et al (2014:57) note, by focusing on the detailed practices of social life and the relations enacted in the materialities it shares a lot with Kwa's (2002) notion of baroque complexity that we encountered in Chapter 2 (see also Law, 2004b). It also allows for blurring the lines between description and analysis, focusing on the richness of situated and contextualised events. In doing so it enables 'thick description'. Schwandt (2001) outlines thick description as follows:

> "Thick description is not simply a matter of amassing relevant detail. Rather to thickly describe social action is actually to begin to interpret it, be recording the circumstances, meanings, intentions, strategies, motivations, and so on that characterize a particular episode. It is this interpretive characteristic of description rather than detail per se that makes it thick" (Schwandt, 2001:255).

In this way, ethnographic research gives space to each of the followed cases to generate their own data. Together, ethnographic features such as giving space to situated performances, deeply contextualising appearances, interpreting what is meaningful and what is not, and unpacking what is made present or absent and why, provide a strong, generative basis for my interrogation of an under-investigated topic.

3.2.2 Making the case for cases, and challenges of generalisability

Typically, ethnographic investigation adopts an 'open' approach to specifying the details of research design. It begins with an area of interest and the researcher follows where the topic takes them (Hammersley and Atkinson, 2007). However, there are some elements of design that are specified - and specifiable - early on. I designed these prior to entering the field. Perhaps the most important design decision was to identify the cases through which the study was to be conducted. Ethnographic investigation typically encompasses one (or at most a small number of) case(s) (Hammersley and Atkinson, 2007). This is not to be confused with formalised 'case study' methodology. Ethnographic investigation shares considerable overlap with more formalised case study methodologies (Hamersley and Atkinson, 2007:1), however, one critical point of departure is that for 'case study' methodologies, "theory development as part of the design phase is essential" (Yin, 2009:35). An (adapted) ethnographic approach, meanwhile, accommodates a more generative, and largely inductive approach, and is better suited to the focus of this investigation.

I chose to pursue four small, self-contained real-time MSB 'research in progress' projects as my cases of interest. I decided to study individual projects, as opposed to other ways of engaging with MSB research such as following a specific laboratory or an overarching SB institution, for two main reasons.

The first relates to the specific way that MSB research is organised in contemporary research. Projects are one of the key ways in which unfolding contemporary science research agendas are packaged, organised and governed (Felt, 2017). Indeed, projects are the underlying way that many of the large research organisations through which SB is delivered in the UK organise and govern their research, including the SB institution at the heart of this research. To deliver on its programme of work, the institution organises its research aims, resources, responsibilities, deadlines, and expertise (see: Bauer et al, 2018) into discrete projects, managed and executed by its member laboratories. It is not alone in doing so. The 'project' emerges as a relevant unit of both scientific and social scientific enquiry recognised at the micro, meso and macro levels of research more broadly (Vermeulen, 2015; Bauer et al, 2018), and in the UK MSB research landscape specifically.

The second reason for choosing projects as a unit of study relates to the ease with which they can be studied (at least in this investigation). Projects necessarily change shape, pivot direction, and fluctuate; and sometimes the people involved work across projects or beyond project work. This notwithstanding, projects still often retain a recognisable and legible core cluster of unfolding research activities and aims (Knorr-Cetina, 1999). This renders them "easily followed and offer a natural focus for observation" (Knorr-Cetina, 1999:20).

Projects being relevant to the UK MSB landscape and methodologically accessible, brings advantages over studying either SB laboratories as a case study or one of the larger overarching SB research institutions. In the case of the former, especially in the SB research institution at the heart of this study, few member laboratories *only* pursue SB research. Many have a diverse set of tools and technologies at their disposal and there exists a lack of discernible boundaries between SB and non-SB work within laboratories without the organising rubric of projects. This would render it more challenging (and potentially undesirable) to delineate 'SB' from 'non-SB' research within one laboratory without drawing distinctions based on projects. Meanwhile, in the case of the SB research institutions, these bring their own challenges. They may offer a clearer path to studying just MSB research, but they are not always a meaningful organising principle through which to study the full range of real-time SB research activities, especially when it comes to experimental

work delivered through member laboratories. Projects offer a solution to both these challenges.

In choosing to pursue projects as a unit of study, however, it is important to understand the historical context of how projects have come to dominate contemporary research and the role they subsequently play in the way science is performed. This has ramifications for how to best to understand the organisation of the empirical cases, contextualise them within wider governance structures, and understand the influence they exert on the materialities and practices they enact.

As part of that, it useful to note that projects are not the only way research can be organised. Whilst they are indeed a common way in which unfolding real-time MSB research agendas are packaged and organised, they are not the only way in which scientific research can be organised. According to Felt (2017), there are two broad 'logics' of scientific research: the logics of 'discovery' and 'delivery' (2017:53). Each has different temporalities, different ways of working, and different ways in which the research is structured and performed. Scientific work pursuing a logic of discovery is typically removed from administrative forms of organisation and focuses on producing enduring new knowledge. It often goes long periods without any visible output and forms the backbone of what could is often considered 'fundamental research' (Bauer et al, 2018). Meanwhile, scientific work pursuing a logic of delivery is often entrenched in administrative organisation, reporting cycles, and is based around regular 'short stories' of success (2017:61). It also often results in third-party funded research, focuses on 'applied science'[29] (Bauer et al, 2018) and is routinely structured into short-term projects that operate on (for example) five-yearly cycles of funding.

The delivery-focused, project-based ways of structuring scientific research have dominated many areas of science in recent decades. As early as 1934, Bachelard (1984/1934) put forward the idea that: "[a]bove the subject and beyond the object, modern science is based on the project. In scientific thought the subject's meditation upon the object always takes the form of a project" (1984/1934:11-12). Setting aside his apparent separation of the object and subject, Bachelard's observation foreshadowed the ubiquity with which the project has become associated with

[29] It should also be noted that an argument can be made that the 'capitalist' spirt in science has "all but obliterated the distinction between pure and applied research" (Hackett et al, 2017:748), whilst others argue science was never pure anyway (Shapin, 2010). It is not the subject of this thesis to resolve the debate, but it is worth noting the contention of this division. Indeed, synthetic biology is well documented as blurring comparable distinctions (e.g. see Kastenhofer, 2013b; Nordmann, 2015).

scientific research. In the last sixty decades or so, there has been a well-documented increase in ‘delivery’ based logics of scientific research, entangled with processes of industrialisation and bureaucratisation of research activities (Vermeulen et al, 2013). This has resulted in what has been dubbed the ‘projectification’ of contemporary science (Jacobsson and Jalocha, 2021).

Projects not only perform work as an organising principle, but they also exert influence on how the research materialities and practices are performed more widely. There is a slew of potential consequences of organising scientific research into projects that affect structural organisation but also wider concerns such as the experiences of the researchers involved (Fochler et al, 2016). Here I point to two examples[30]. The first is provided by Bauer et al (2018) (as well as many before them). They argue that projectification of scientific research does not sufficiently allow for individual or organisational continuity across such short and discrete packages of work. This is something we see played out in Section 4.4.5 where an argument could be made that projectification itself exacerbates the ‘othering’ of potential human appearances. Another example is elucidated by Felt (2017). She suggests that increased focus on ‘short stories’ of success (2017:61) prioritise delivery-based research over alternative models of research such as discovery-based science. She warns that this may lead to potentially missing out on longer-scale work that could ultimately contribute in alternative ways to longer-term goals and the grand-challenges experienced by society. Arguably this too is borne out too in the MSB landscape. Whilst SB institutions’ work itself has potentially far-reaching impact, the specific and measurable deliverables for the individual projects are limited to shorter-term goals capable of operating on administrative timescales.

It is beyond the scope of this thesis to debate ‘projectification’ as its own dedicated topic in the context of the findings of this investigation. Yet it is important to contextualise the history and role of projects as a reminder that the projects themselves may contribute to the way the research materialities and practices - including potential human appearances are enacted in practice - are performed and experienced. For more in-depth discussion of this topics see: Vermeulen (2015), Bauer et al (2018) and Jacobsson and Jalocha (2021).

[30] Whilst it is not included as an example here, perhaps it could also be argued that the increased bureaucratisation and projectification that contributes to a defined sets of measurable features also help make projects methodologically more discernible as an identifiable ‘unit’ of study thus also perpetuating their relevance in the social sciences.

In terms of number of projects to study, I decided to pursue four MSB projects. In that way, I could benefit from the informal processes of comparison inherent in the analytic processes (Gerring, 2004:347). The four projects I chose were also predominantly co-located (bar one). In this way, I could maximise my chances of encountering a diverse array of MSB actions and materialities whilst not overstretching my time and energy. I return to the specific selection criteria for the particular projects in the next section. However, for the remainder of this section I wish to dwell on the size of the projects I chose.

All the candidate projects from which I could choose were small in size. Indeed, they share many similarities to Knorr-Cetina's (1999) research into a series of small-scale molecular cell biology research projects at the Max Planck Institute group. There she described the projects she observed as being small, 'individuated', and often centred around single researchers (1999:216). Yet it is important to recognise, not all 'projects' are small; they can vary greatly in size (Vermeulen, 2010).

Since the 1950s, science has played an ever-increasing role at the heart of innovation and economic growth of the developed world (Agar, 2012). With this increasing role, the nature of scientific work - and the scale at which it operates - has also changed. In the case of the biological sciences, the increase of molecular biology in the 1950s and 1960s led to a changing scale of the biological landscape (Vermeulen, 2010), and in contemporary biology today there have been some impressive large-scale projects. Arguably the most notable of which is the Human Genome Project (Vermeulen, 2010; Hilgartner, 2015). Elsewhere, Knorr-Cetina (1999) offers us another example of a large-scale project: an experimental high energy physics (HEP) project at CERN. She shares her observations on the immense scale of that project - even during the length of her stay, single experiments had gone from involving "approximately 100 participants […] to 500 […] to more than 1,500 physicists from more than 150 collaborating institutes located all around the world […]" (Knorr-Cetina, 1999:20).

With these differences in scale, different project size affords different benefits. For example, large-scale projects enhance visibility and draw significant resources and attention. They can forge new communities and connections and influence scientific and public policy. Meanwhile, smaller projects reduce the risk of lock-in of research agendas, can be associated with greater personal satisfaction and control, and have increased agility (Vermeulen, 2010). Both have their benefits and there is no one 'archetypical' size of project. There are many factors that contribute to decisions about project size, duration, and organisational structure. These include subject

matter, research questions and research goals (Vermeulen et al, 2013). It just so happens that the projects at the SB Institute share more in common with Knorr-Cetina's (1999) molecular biology projects than large-scale, 'big science' projects.

When designing a study to use such small projects as case studies, the project size is a potential challenge to consider. It is feasible an argument could be mounted that the small size of the four projects offers insufficient opportunity to gather enough empirical evidence to defend any claims that are made. To these challenges, I point to Hammersley and Atkinson (2007) who remind us that a targeted approach with small and focused cases actually facilitates in-depth study (2007:3). More specifically, I counter any potential to project size on two further related counts.

The first is to point to the aim of this study. My investigation seeks to find patterns in how the human appears in the context of real-time MSB research practices in progress. This necessarily involves small, individuated units. Indeed, as Mol (2002) argues in her investigation into atherosclerosis in 'Hospital Z':

> "If one wanted to study, say angiography, they what kind of large place would one try to find? Sure, there are hospitals slightly bigger than Z, but one cannot study the workings and usages of an X-ray apparatus somewhere 'macro'. It is always 'micro', in a particular place. […]" (Mol, 2002:178)

More generally, she concludes:

> "The *size* of a field is of little importance to the theorist who does not try to map that field, but tries to discern patterns in it, modes and modalities of, say, coexistence (but it might be something else as world) …]" (Mol, 2002:181)

This investigation is not an epidemiology, it seeks to understand a situated relationship as it is being performed. As Mol (2002) poignantly asserts: "Adding up figures that come from ten or a hundred hospitals doesn't gives [sic] a *bigger* picture - it simply depicts something else" (2002:179).

The second rebuttal is that 'size' is a broadly unhelpful concept. We have already heard from Law (2004b), Massey (1999), Cresswell (2014) and more in Chapter 2 about the nature of places. They are a process, they are not bounded but a constant gathering of materialities, meanings and practices (Cresswell, 2014). If one conceives of projects as being performed *through* places and their practices - which contemporary STS traditions argue one must - then, projects themselves can entangle a vast range of people, practices, materials, and meanings into their

performance. They condense many more materialities into their performance than the experimental objects and the individual investigator.

That said, it is important not to dismiss any challenges to study size entirely out of hand. Considerations of number and size of cases do link with a broader debate about generalisability. When pursuing ethnographic investigation - even studies that address a handful of cases - arguments are made against its generalisability and representativeness (Hammersley and Atkinson, 2007:32). These include concerns of not being able to extrapolate meaningful data from one or a small handful of case studies (Collier, 1993; Blaikie, 2010:192; Bryman, 2015). Arguably this may be a logical fallacy; unless there are *known finite* populations, can anything be considered 'generalisable'? That rebuttal aside, there are two interlinked approaches this investigation takes to attempt wider applicability. Firstly, Hammersley and Atkinson (2007) argue there are different types of themes and categories in research. Whilst ethnography grounds investigation in the situated practicalities of every-day performances, it is possible to link them to broader analytical and conceptual categories. In this way, this study is not just about how the human appears in the specific context of these four MSB projects, it also makes a theoretical contribution. As I have introduced in Chapter 1 and expanded upon in Chapter 2, the themes emergent through this study relate to notions of materiality and practice, function, and place. These themes have broader currency outside the four projects. We return to these ideas in Chapter 7. Secondly, I aim to have provided sufficient thick description to the empirical chapters for other scholars to be able to evaluate the findings and themes for themselves. In that way, other researchers can evaluate if there is sufficient resonance in these pages to other forms of investigation.

3.2.3 An emerging set of sensibilities

As I designed this investigation, I engaged with a variety of research paradigms and traditions I thought might be useful to contextualise and make sense of the data to emerge. As my area of investigation took shape, it was clear that it corresponded to many of the central tenets of the 'material semiotic' tradition (see Section 2.2). For example, the 'physical' objects that are concretely apparent in the MSB research (such as human-derived biological materials), *and* the thoughts and concepts relating to the MSB practices (such as expectations of future human health application) are both 'enacted in practice'. Regardless of their abstract or concrete forms, both emerge as 'practical' achievements (Woolgar and Lezaun, 2013:326), performed into being through MSB research activities. They can therefore be treated similarly.

Treating ideas, concepts, and thoughts in the same way as physical objects affords equivalence to the array of MSB things and objects that enact and entangle human appearances. This approach therefore confers methodological advantage. It renders it easier and more symmetrical to identify and analyse how imaginations, expectations, and associations such as a 'sense of place', constitute realities. In rendering actions and concepts into materialised realities it also makes them more accessible to ethnographic investigation (Gad and Jensen, 2014). It is well suited to unpacking messy arrangements of relations. As Law (2004a) asserts: "(Social) science should also be trying to make and know realities that are vague and indefinite *because much of the world is enacted in that way."* (Law, 2004a:14). In looking for the way the human appears in the context of MSB practices, an approach that focuses on unpacking arrangements of relations becomes useful.

The alignment to a research paradigm and its traditions has implicit bearings on research approaches, assumptions, and theory; it shapes how the research is conducted (Blaikie, 2010:96). As such, before settling on a sociomaterial approach, I explored different paradigms through which this topic might best be considered. One contender was ethnomethodology. There is an argument to be made that a study focused on situated practices would benefit well from an ethnomethodological stance. Ethnomethodology has a strong focus on investigating practices (Garfinkel, 1967:11), specifically as situated, mundane and part of everyday life. In this way, it has a lot to offer this study. It shares several tenets with sociomaterial investigation, however, there are two key arguments that make material semiotic investigation more suitable. Firstly, ethnomethodology emphasises the importance of behaviour and activity, rather than 'action' more broadly. This can result in less attention paid to associations and the conceptual (Atkinson, 1988). Indeed, Gad and Jensen, (2014) observe it routinely shows "scant interest in the imaginations and conceptualizations of the actors whose actions they describe" (2014:713). Given many human appearances necessarily take the form of imaginations, this renders it a restrictive choice for my topic. Secondly, whilst it focuses on spatial and temporal dimensions (Lynch, et al, 1983) - a theme that resonates with this research - it tends towards orderliness. As we shall encounter within the empirical chapters, unpacking how the human appears in the context of MSB is messy, overlapping, and non-coherent. It relies on absence of the human as much as presence, and trouble attempts to neatly order it. Material semiotic sensibilities provided a better paradigm through which to tackle some of the complexity that emerges.

3.3 Preparing for the field

3.3.1 Early access and exploratory interviews

Whilst I was still evaluating the research design, I also conducted a series of exploratory interviews to better ground my ideas and understand what cases I might explore. As part of this process, I completed the University of Edinburgh's School of Social and Political Science's Ethics Review and was granted permission to enter the field. I then secured access to the overarching umbrella SB Institute (the Institute) where I would be conducting the research. The Institute (a pseudonym) is an umbrella organisation seeking to develop tools and technologies to build the biomedical capabilities of MSB. It operates as a master 'organising unit' for multiple workstreams of activity. As an umbrella institute, its research is performed through multiple locations, laboratories, and projects. I chose the Institute for three primary reasons, firstly it pursued SB research for biomedical applications. Secondly, it had sufficient MSB projects from which to choose. Thirdly, it afforded the benefit of leveraging existing connections and networks. Members of my Supervision Team had existing relationships with Institute and were able to act as gatekeepers to help me secure access.

In February 2018, I was granted official access to engage with the Institute and its participants. Whilst this did not replace securing consent for specific projects and individuals when the time came to enter the field properly, it allowed me to begin my engagement at an exploratory level. After I had secured access, I conducted exploratory interviews with six Principal Investigators of the organisation. These interviews took place over the period of three months at the beginning of 2018. Each Principal Investigator ran a different laboratory whose MSB projects also contributed to the Institute's portfolio of work. My primary goal was to better understand their MSB projects, determine what social dimensions they thought related to their work, ascertain how the human might relate to their work, and determine whether they might be a good fit for my research. In doing so, it would also allow me to refine my research design. In addition, I also conducted four further conversations with two Postdoctoral Researchers and two PhD students. These discussions were similarly designed to understand their projects from the views of early career researchers (ECRs) and any potential for cross-over of interests. These exploratory interviews and discussions proved useful on two counts. Firstly, they provided a clearer idea of the candidate projects from which I could choose and helped me refine the selection criteria I would eventually use to arrive at my four projects. Secondly, they afforded me some early ideas about how the human might appear in the context of MSB

practices, or more to the point, how it might not. In this way, the exploratory conversations provided me some empirically generated, early sensitising concepts. As already identified in Chapter 2, these early discussions also drew my attention to the likely need to attend to the absence of human appearances. It was rare for the human to emerge as a reference point in discussions of specific projects. Instead, they emerged through assertions that "there is no science fiction here" or not much "philosophical" discussion entangled with projects. As outlined in the Introduction, this shaped the types of questions upon which I sought to focus and contributed to the shape this thesis has now.

3.3.2 Case study criteria

I also conducted my own desk-based research alongside the exploratory discussions. With the findings from both these exploratory investigations, I devised two key criteria for the cases. Firstly, I chose projects that were relevant to biomedical (thus human) utility but had no direct involvement in creating applications for near-time clinical application. The reasons for this were two-fold. Biomedical relevance would maximise opportunity to engage with broader ideas, trajectories and expectations relating to human biology and human application. However, by merit of still being 'basic research' projects it meant they had not entered any 'translational' pipeline or pathway, they were still in the making. This was a core requirement to satisfy the gap in the STS literature, as illustrated in Chapter 2. Secondly, all four projects were chosen based on the types of outputs and products they sought to engineer. In the first instance, they were chosen to be examples of intentional, synthetic biology design. Synthetic biology is a heterogeneous field encompassing a range of perspectives, theoretical foundations, disciplinary backgrounds, and techniques (O'Malley et al, 2008). Arguably, there is no one type of research or project that can be considered 'typical'. However, choosing projects in line with the core principles of intentional design (Schyfter, 2011) sets them apart from projects that could conceivably be considered 'synthetic biology adjacent' by merit of similar tools such as CRISPR. In the second instance, they were also chosen because they entangled some use of human[31] biological materials (amongst non-human materials) and purposely designed and engineered novel, unfamiliar forms of being. This offered my investigation the opportunity to probe how the biological materials were

[31] Whilst the human-derived material creates an obvious opportunity for human appearances to emerge, mammalian material also troubles some of the same underlying categories (Pavone and Martinelli, 2015). As Franklin (2013:51) observes, epistemic goals and understandings of the human are made through "nested systems of comparable animal model populations" (2013:51).

performed in relation to ‘human’ biology as well as ideas of ‘the natural’. This was an area I was keen to explore.

3.3.3 Introducing cases

Following such selection criteria, I chose four separate mammalian synthetic biology projects[32] all encompassed by the Institute. I refer to these cases by anonymised identifiers: Projects D41, D42, D43 and D44. When it comes to the details of the specific cases, it is not necessary to understand in great technical detail. Appendix 2 provides additional contextualising information should it aid understanding. Instead, I summarise the headline points below and add additional detail in the empirical chapters as required.

Case 1: Project D41 - Programming Reaction Diffusion (RD) Patterns (or Turing patterns).

This project aimed to design and engineer particular types of patterns into groups of cells and in doing so, prove a set of theoretical principles. In 1952 the mathematician Alan Turing hypothesised a mechanism that could account for the patterning of cells into patterns such as stripes and spots on animal coats. This mechanism is called the ‘reaction-diffusion’ or ‘RD’ system. Project D41 uses synthetic biology tools and techniques to engineer new ‘genetic devices’ into host cells to attempt to mimic these RD systems.

Case 2: Project D42 - Programming multicellular organisation and communication.

This project aimed to design and engineer two systems that don’t occur in nature. Firstly, a ‘patterning system’ that could organise groups of cells into specifically designed patterns and arrangements, secondly a patterning system that could be adapted to become a ‘signalling system’. The signalling system would transmit signals from only some of the cells in the pattern to attempt to control nearby stem cells in a corresponding pattern. Project D42 uses synthetic biology techniques to engineer ‘genetic’ devices into the cells to use natural biological pathways in new ways.

[32] From this point forward, ‘case’ and ‘project’ can be understood interchangeably from a methodological narrative point of view. Typically, ‘case’ will be used when discussing research design and ‘project’ will be used when discussing the empirical observations of the projects that comprise the cases as they are organised and experienced in the field.

Case 3: Project D43 - Engineering light control into cellular patterning

This project aimed to design and engineer novel behaviour that doesn't occur in nature. It attempts to control the scattering and clustering of groups of cells using light as a stimulus. This project is a 'proof of concept' project and uses synthetic biology techniques to create the genetic circuitry through which to introduce and control the novel behaviour.

Case 4: Project D44 - Creating replica chromosomes

This project aimed to design and engineer a new version of a human chromosome, albeit a partial one. The project uses synthetic biology techniques to engineer particular DNA arrangements into host cells that will trigger the formation of the replica chromosomes. These then offer fine grained control to perform experiments that allow researchers to better interrogate the processes of cell division.

All four projects had been funded - at least in part (if not entirely, due to the complex nature of project funding) - by the Institute. They were also distributed across two separate laboratories. Projects D41, D42 and D43 operated through - and were subsequently also organised by - Lab 001 (the Garcia Lab, or GL - a pseudonym). Project D44, meanwhile, operated through - and was subsequently organised by - Lab 002 (the Meier Lab, or ML - also a pseudonym). In addition, the laboratories and the Institute also have their own 'parent' departments (in the case of the laboratories) or organisations (in the case of the Institute) whose priorities they also perform. This complex organisation sees each of the four case study projects enact the direct priorities of both the Institute and their respective laboratories, which in turn enact the priorities of their own parent departments. These relationships underpin the discussion in Chapter 5.

In terms of similarities and differences, all four projects share a range of methodological commitments, including working in cell culture and engineering novel behaviour or existing behaviour to perform in novel ways. In line with O'Malley et al's (2008) descriptors, they also all adhere to the 'DNA-based device construction' approach to synthetic biology. However, they also exhibit differences. Projects D41 and D44 are longer term projects with pre-existing histories, meanwhile Projects D42 and D43 are new, more self-contained projects. They also all have slightly different relationships to how they relate to nature. D41 and D44 seek to mimic natural behaviours synthetically, whilst D42 and D43 seek to introduce novel functionality *de*

novo (from scratch). I draw on similarities and differences when they become pertinent *in situ* int the empirical chapters.

3.4 Entering the field

3.4.1 Ethical engagement

Having already secured access to the Institute earlier in the year, in late 2018 I sought - and secured - agreement with the Principal Investigators (PIs) of the GL (Garcia Lab) and ML (Meier Lab) - Madelaine and Tomas respectively (both pseudonyms) - to engage with their laboratories as a site of research. After an introduction from the PIs, I also secured consent from individual participants with whom I would also be working with on the projects. It was vital to provide the project participants sufficient information about the nature of the study and prospective uses of data prior to their consent. This maximised the chances that consent was given freely and was an informed choice (Faden and Beauchamp, 1986). Appendix 3 and Appendix 4 provide a copy of the Participant Project Information Sheet and the Informed Consent Form. As my research started in earnest, I also adopted Murphy and Dingwall's (2007) approach that consent is both relational and sequential beyond the agreement at the outset. Any unusual or new types of circumstances that arose I would check my continued engagement was acceptable. By the very nature of ethnographic research, it was not always possible to secure up front consent in every setting. As such, I adopted an 'ethics in practice' basis for managing the additional cases that came up in a way that was sensitive to the situation. In most cases, this was a conversation at the first suitable opportunity.

3.4.2 Data generation activities

In terms of the data generation activities, I started in the Garcia Lab in late 2018 and in the Meier Lab early 2019. Engagement started with an informal meeting with each of the project leads to check they were happy to proceed that also allowed us to get to know each other. This was an expectation setting exercise and designed to generate some rapport. From there, when participants were ready, I began to follow them in their work. Given the projects were MSB research projects 'in the making', most of the early work took place in the respective laboratories.

Participant observation undoubtedly provided an unrivalled opportunity to start investigating how the human might appear in the context of real-time MSB research

practices. It allowed me sufficient time to ‘dwell’ within situated practices to explore actions, materialities, and discursive practices. In Section 1.2 we have already encountered some example practices in which real-time SB (and by extension MSB) research can take place. Methodologically, this translated into studying activities that included observing laboratory performances (as well as desk-based design work). It also involved conversational engagement across a variety of contexts that included ‘downtime’ such as going for coffee. This offered interesting opportunities to observe research reflections on their real-time activity, helping to contextualise my understanding of the real-time work ‘in the moment’ (including identifying what might be absent). I also attended some laboratory meetings. During all these episodes, I paid close attention to unfolding day-to-day discursive practices, experimental actions, relationship with biological materials, relationships with colleagues and other materialities, expectations, physical space, and the way the participants made sense of their projects. I also followed the actors to a variety of events where I was able. I attended multiple Institute meetings plus a handful of ‘organisational update’ meetings to stakeholders, and through these I observed project enactments of reporting, updating stakeholders, and observing the Institute as a community. Other in-person participant observation opportunities included an industry conference, a handful of public-facing presentations, a couple of guest lectures, and a small number of events targeted at non-specialist communities. Throughout such activities, I made copious fieldnotes on how projects were unfolding in real time through these different places, including notes on circumstances and settings. I also noted my own thoughts ‘in the moment’, and any circumstances that I thought might be pertinent during analysis. My own reflexive notes also became additional data items (Charmaz, 2007).

During my engagement I split my attendance across the two laboratories, the GL (Garcia Lab) and the ML (Meier Lab). As three of the projects were within the GL, I spent more time there than I did at the ML. Additionally, my attendance at each laboratory varied dependent upon other data generation and analysis activates I was conducting concurrently. Necessarily, I was also pursuing multiple other lines of investigation. These included following non-participant actors such as documents, gene histories, posters, repositories, books, articles, and more, out of the laboratory. I also performed transcription activates, data management tasks, and started analysis whilst conducting the data generation activities. During the peak of my engagement, I would spend a couple of days a week across the projects in the laboratory environment. The GL style of engagement was relaxed and permissive, I was largely left to my own devices and curated my own engagement. I could come and go and arrange my work as I saw fit. Meanwhile, ML’s style of engagement was

different. The experience was curated for me; in part down to reasons such as contamination issues and the team's other commitments. Whilst this style of engagement presented a 'limited' type of arrangement, the curation itself generated interesting data. It served to highlight what the project lead - Addison (a pseudonym) - thought might relate to my project interests, as well as how they viewed my work in relation to theirs. Where this becomes relevant in the empirical account, I pay attention to it *in situ*.

However, much can defy observation. Indeed, this investigation was as much about absence as it was presence. Consequently, I also included semi-structured interviews to generate additional data to secure participant views to add depth to my understanding of the human appearances (or lack thereof) in their real-time practices. Appendix 5 provides an example of an Interview Guide used for initial interviews with project leads early in the engagement. It was designed in line with a conversational approach, provided sufficient structure to support comparison of themes, but left room for interviewees reflect upon their work in the ways they saw fit (Mason, 2002). With each project, initial interviews were held near the beginning of my engagement. Their aim was to understand how the practitioners articulated their research in their own words, how they understood the human to appear in the context of their work, and to derive some early focus topics to explore during my investigation into real-time research in action. As the ethnographic investigation progressed, I scheduled follow up interviews when required, as well as multiple informal conversations. These later episodes also offered opportunities to probe some of the contrasting performances of human appearances I observed through other means.

In total, I secured in depth, rich interview data from ten participants. Across the two labs, they included two PIs (shared across the projects), three PhD researchers, one early career researcher, three mid-career researchers, and one laboratory technician. Several of these also had multiple interviews. Whilst seemingly small this represented the enacted realities of these projects. Again, I point to Mol's (2002) assertion that this is the nature of the MSB 'research in progress' enacted realities. In addition, these interviews did not comprise the sole basis of question-based data. It was well supplemented with many more conversations that entangled wider participants and actors across the Labs and Institute more broadly that were entangled as part of the broader project materialities and performances. Interviews lasted approximately an hour each but ranged from 35 minutes (this had to be split into two parts due to participant time constraints) to 1 hour 20 minutes. Each interview was audio-recorded and transcribed by me directly at the first available

point. Transcripts were offered to participants, but only one participant availed themselves of this offer.

I also drew on a wide range of documentary evidence. Latour and Woolgar (1979) and Myers (1990; 1996), amongst others, argue for the centrality of written outputs in laboratory work. Documents are crucial parts of project performance, and thus necessarily provide an additional way that the human is capable of emerging through MSB research in the making, as it unfolds. As outlined in Section 2.3, in this project I treated any discursive practice as a project enactment. This means that any documentary evidence through which a project was performed - whether as a short summary, a lengthier entry in a progress report, or a submitted thesis detailing the outcome of the whole project itself - became a real-time enactment of that project's SB research. As we explored in Chapter 2, discourse is not a means through which to get to a reality *behind* the discourse, it *is* the reality itself (Fairclough, 1995). Taking this view of documentary sources meant I generated a wide array of project enactments beyond just the places I could physically follow. Projects were enacted in grey literature such as a case for funding support, Institute annual reports, online portfolios such as websites, Lab brochures, and more. They were performed through scientific and technical literature, such as original research articles, posters, biology books, and more. Projects were also found in researchers' professional profiles, 'public engagement' materials, blog posts, podcasts, and more. Through this wide array of documentary evidence, the projects were discursively enacted. This provided data for me to investigate how the human also appeared (if at all) through these performances. I collected over 190 documentary sources (not including transcribed interviews, fieldnotes, or the c.320 photographs I had taken). In Section 3.4 I outline my approach to reduction and analysis for these documents.

Overall, the strength of these 'multi-methods' came from their combination and subsequent ability to generate a wider range of data than one single method (Bryman, 2015). Together, they maximised the ability to 'follow the actors'. Whilst they also generated a lot of data, I handled this through concurrent data generation and analysis where possible (Charmaz, 2007) and a robust data reduction method as outlined in Section 3.5.

3.4.3 Reflexivity and being 'out of place'

Throughout the data generation activities, I practised reflexivity in a variety of ways. Firstly, I made notes about my own experiences at every available juncture to incorporate into my analysis. I scribbled margin notes, 'notes to self' and recorded

voice memos on leaving events to capture first reflections. I also set out to improve my knowledge of synthetic biology techniques and projects to reduce too many power or knowledge imbalances (Bechofer and Paterson, 2000). However, despite my biological background, I was viewed by participants as a non-specialist in their field, especially at the outset. This brought with it advantages, not least some participants enjoying telling me all about their work at any available point. However, it also necessitated a high degree of reflexivity during analysis. For example, during some participant observation work participants performed their projects in ways that accommodated my presence as a non-specialist, narrating their work as though they would to an educated non-specialist. As we shall see in Chapter 6, human enactments and entanglements appear significantly more - and in different ways - when participants perform their projects in non-specialist communities and to non-specialist audiences, even if that audience is of one (me). As such, my presence encouraged an artificial increase in 'human' orientated discursive performances. As Law and Singleton (2005) remind us: "realities, messy or otherwise, are enacted into being" and as a result "we need to add that in part at least, such enactments take place in the practices of getting to know those realities" (2005:2). The task for reflexivity was to interrogate the circumstances of these performances and turn my non-specialist involvement into meaningful data. Participant observation, attending to peer relationships, and clarifying directly with participants helped me to calibrate my expectations to ascertain what was a non-specialist accommodation, and what was the way that participants discursively performed their work more generally.

I was also viewed as an 'outsider' – or matter out of place (Douglas,1966) – in the laboratories for two other reasons. Firstly, due to my methods; secondly, my topic. Regarding the former, my qualitative research approaches were of much interest to participants, especially in the Garcia Lab with whom I spent most time. In the middle of my research, I gave an informal presentation into my topic, my methodologies and provided some early thoughts about the way participants such as themselves had been making sense of the biological phenomena they worked with. I was curious if participants recognised how they worked in what I was saying. I was also nervous, wondering if my interpretation of their practices might be challenged. Yet, come the Question-and-Answer session at the end, I was surprised to find the entire session centred not on my findings (which were met with nodding of the heads) but my approach to subjectivity and managing bias. Questions flowed thick and fast, predominantly from those with whom the projects did not engage much: how did I manage bias when I interviewed people (Yusheng); had I considered using a different method such as surveys to "confirm" my interview results and eliminate bias (John); had I considered a strategy to consider pairing with another research to

“ensure objectivity” (John, again) After a twenty minute discussion on subjectivity, the possibility of ‘objectivity’, and ‘countering bias’ in the social sciences, Madelaine (the PI) good naturedly moved the conversation on.

My qualitative methods were not the only reason my research stood out. My topic itself was also provocative. As we will encounter in the empirical chapters, my topic investigating the circumstances of how, when, and where the human was entangled and in what ways brought with it strong normative responses during my data generation. These included assertions about where the human ‘belonged’ and where it did not. I talk about these themes during the empirical chapters of this thesis. However, methodologically, such notions of belonging also affected the way my participants engaged with my presence. As the increasing absence of human enactments and entanglements in the laboratory became clear (as discussed in Chapter 4), participants would worry - especially when it came to participant observation - that they had “nothing to show me” or could not help me given my topic ‘did not have much in common with their laboratory work’. Such anxiety required additional reflexivity on my part to manage participant attitudes to my topic. I set their minds at rest by explaining I was as interested in absence as much as I was in presence of any notions of the human and how it emerges as a reference point in their work. Additionally, it required work to overcome my own challenges of being made to feel (albeit not unkindly), a little ‘out of place’ in my own research. Here, I continually reminded myself that I was an active provocation for data generation. The very presence of my topic evoked normative expectations about when and where it is ‘appropriate’ to entangle human enactments and topics of discussion, and this was all grist to the mill.

3.4.4 “Just one more thing …”

Initially I had planned to be in the field for 9 months. It ended up being approximately 16 months elapsed (approximately 12 of those months active in the field). This included gaps in fieldwork and attendance at sites for a variety of reasons (such as Project D44 being “put on ice” whilst the project lead was away for a couple of months), as well as my own need to be away for a couple of months as my fieldwork was starting to slow down.

I had originally planned to leave the field in a particular way. I had hoped to provide a presentation to each Lab to conclude my work and share my findings and next steps. However, the more data I generated, and the more contingency and patterns that began to emerge, the more reluctant I was to leave the field. Working with ‘small

lifeworldly projects' (Knorr-Cetina, 1999), there seemed to be 'no good time' to extricate. Towards the end of 2019, after I had engaged with my projects around a year (for the ML lab closer to 7 months), I was forced to leave the field for family reasons. In early 2020, after a three-month break, I eased myself back into the field, but then the Covid-19 pandemic arrived in the UK. As we went into isolation, it was the second forced stop, and one that made me take stock of the data I *had* generated (of which there was a rich and comprehensive dataset), rather than data I still felt I wanted to generate. It was not the exit from the field I had planned, but it was decisive. I had a few follow up discussions over Skype - all of them informal and unstructured - to close some of my open conversations, but no formal presentation or meeting based exit as I had originally planned. People's priorities had changed and in practising reflexivity and ethics, it did not feel appropriate to demand further time from them.

3.5 Working with data

3.5.1 Data transformation, reduction, coding, and analysis

I started the processes of data transformation, reduction, coding, and analysis in parallel with data generation activities. This helped me calibrate the type of data I was generating as well as giving me a sense of workload and feasibility of following more actors into more places (Morse and Richards, 2002:117; Hammersley and Atkinson, 2007:36). My first step to analyse the data was to transcribe interviews, handwritten notes, diagrams, and other imagery (such as photographs), into Word Documents. In this way, I reduced everything to text-based inputs. This involved data transformation and some considerations of ethical data management. To maintain confidentiality and privacy, as I transformed documents, I removed personally identifiable information (PII). Once I had transcribed all interview data (and ensured successful backups) I also deleted the audio files from my encrypted laptop. In the cases of photographs, I obscured parts of images. In the case of hand-written notes and interview transcripts, I used coding conventions in line with the Economic and Social Research Council Framework for ethics (ESRC, 2015). When it came to the thesis itself to aid readability, I also converted identifiers for participants and organisations into pseudonyms (Wiles et al, 2008). I also changed some non-essential details of project activities and identifiers to preserve anonymity where possible. Such decisions were always made with careful consideration to whether it changed the integrity of the data or analyses; adjustments were not made if I considered that a risk. The scale of adjustments involved changing 'giveaway'

phrases unique to particular projects or particular names of tools that might be recognisable. All reasonable adjustments have been taken to preserve the anonymity and confidentiality of participants wherever possible, whilst retaining the balance of information required to support the central thesis.

Whilst I transcribed, I wrote early notes to myself, identifying themes, marking specific comments to explore further. These early steps gave me a feel for which data would potentially yield little reward. I had secured many documents through following the actors where a project might be enacted. I screened all the documents I collected for utility and potential themes. During this, I created a hierarchy of documents to 'park' and revisit periodically as my coding iterated. These were typically documents that 'alluded' to a project but made little effort to elaborate upon any of its project materialities. In this way, I reduced those that were largely peripheral into a 'parking lot'. At periodic points I reviewed themes against the 'parked' documents to ensure my themes were still robust in relation to what had been parked, and check the exclusions still made sense and that I didn't need to recall any (I rarely did). About 90 of the over 190 documents remained substantively useful and went into theme generation. The remainder continued to lend weight to the fact I wasn't missing any untrapped themes and served to underscore the patterns I was seeing.

These early steps also generated a 'feel' for my data and provided me some early draft codes through which to start the analysis. To perform the coding and analysis, I used the coding features of NVivo to code each data item. I started with some basic topic codes (Morse and Richards, 2002:116). Through an inductive process, I coded explicit or implied entanglement with the human across my data. This included appearances of human application, human knowledge, human biology, mammalian biology, physiology, provenance, phylogeny, human cells, human genes, human proteins, consumers, users, donors, sources, contributors, outcomes, expectations, project goals, and many more. They also included broader peripheral notions such as ethics, 'sci-fi' narratives, philosophy, subjectivities, error, creativity, curiosity, motivational episodes, compassion, and many more. As I developed a sense of the human appearances through this broadly inductive coding, I moved onto more analytic coding that allowed me to start to elicit some meaningful relationships from - and between - the data. To do this, I drew on some of the elements of Critical Discourse Analysis (CDA).

CDA is often difficult to define. There are many different variants of CDA (see Wodak and Meyer, 2009:29), and it is less a formal method and more a way to analytically

theorise. However, broadly speaking it can be understood as a way of analysing discursive practices that emphasises the fact that discourse practices are action themselves, rather than using them to get to a social reality *behind* the discourse (Fairclough, 1992). This is important. As I followed projects from place to place to unpack their performances, the aim was to use documentary evidence to understand the presentation or article as a project enactment in its own right. CDA is also particularly good at recognising the importance of absence and silence and how 'texts' and contexts are made through the same processes (Szymanski, 2016; see also Chapter 2). Flowerdew (2017) describes context as not something that is 'given', but that is made through a 'continual shunting between text and context' during the same processes. Some elements of CDA have been suggested to be out of step with STS, not least CDA's roots in rhetorical persuasion (Szymanski, 2016; Myers, 1996). However, when treated as a 'mode' of analytical thinking, it is possible to eschew the idea notions of classical persuasion rhetoric, and instead borrow the parts of CDA that remain relevant to the sensibilities that I outlined in Chapter 2. Specifically, I drew on its analytical categories that attended to the interrelatedness of human appearances with its other materialities. These included content ('intra-text'), structure and form ('inter-text'), and context ('context') analytic categories (Wodak and Meyer, 2009) and recognised that these were generated through the same processes. In this way, I built up a picture of the human 'appearances' through their relationship with the other project materialities with which they were inter-related. Over time, the topic codes iterated, or become aggregated into larger more encompassing themes. I refined the coding schema accordingly, and gradually clusters of patterns began to emerge. These eventually turned into the more defined relationships relating to inter-relatedness of human appearances, functional roles, and - critically - notions of place we find in these pages.

3.6 Writing patterns

3.6.1 The ethics of narrative

Hammersley and Atkinson's (2007) chapter on 'Writing Ethnography' opens with the following statement:

> "Writing ethnography is a key part of the entire research process. It is now widely recognized that 'the ethnography' is produced as much by how we write as by the processes of data collection and analysis" (Hammersley and Atkinson, 2007:191).

Writing is closely related to analysis and to reading, they argue, but it is also a way to create realities. As such, an author has a responsibility when writing (2007:205). It is this responsibility I wish to turn to in this final section of the Methodologies chapter.

Through an iterative process of ideation, and sorting and ordering themes, the structure of this narrative has undergone several restructures during its production. Once I had a good idea of my analytic patterns, their complexity, and the scale of the writing challenge, the next question was how to organise them to provide an account of how the human appears in the context of MSB. There was never going to be one way to provide this account. As we have seen in Chapter 2, the performance of project materialities, practices, and places are all inextricably linked, there would be no one 'right' way in which to temporarily disentangle them. As such, I took each theme and cluster of patterns and attempted a few in turn.

Initially, I started through the lens of the human materialities emergent through my data. Potential human enactments are entangled in three clusters of project materialities. These included imaginations of human health, application, and consumers relating to project goals, outcomes, and expectations; biological human enactments (such as physiology, phylogeny, or provenance) emergent through performances of biological materials; and human traits, behaviours, and characterisations emergent through practitioner performance. I began by ordering the thesis narrative through each of these clusters of potential appearances, identifying what counted as a human appearance, with an empirical chapter dedicated to each cluster. This placed the focus on the forms and types of humans that appeared. However, whilst it worked well to emphasise the types of human appearances to emerge, it gave inadequate space to the situatedness of practices through which they were negotiated. Critically, it also connoted that human appearances could be separable from each other. Human appearances emerge through the inter-relatedness of their materialities including each other. To risk reifying the human appearances as separable from either the situatedness of practices, or from each other was not a decision I was prepared to make.

Next, I attempted a structure that focused on the MSB practices instead. I linearly arranged project activities, starting the discussion with a chapter that focused on the organisation and institutional arrangements of projects. In the second empirical chapter, I accounted for the experimental design, build, and test (DBTL) practices. Whilst in the final chapter, I focused on project performances through wider communities. In each I identified how humans appeared, and what work they performed. This better accounted for the relations *between* clusters of human

appearances, it also better emphasised the situatedness of each of the different sets of practices. Indeed, for those reasons, it is not that dissimilar from the final chapter structure to follow. However, it did also give rise to a 'flow' of human performances 'morphing' from one stage of the project to the next. It intimated that what was counted as a human appearance in one MSB stage (such as experimentation) in some way, 'gave way' or 'translated' to the performance in the next stage (such as publication). This afforded the human appearances a continuity that does not reflect the enacted realities in the data. It also imposed an order and linearity to research that didn't exist during the making of the projects. Research is messy and simultaneous with multiple processes are executed at the same time. Simultaneously as experiments fail in the laboratory, practitioners prepare a presentation for the community, and their project is performed through an annual report. Project performances are discontinuous and occur in multiple ways across multiple forms at the same time. This narrative elided this discontinuity and multiplicity.

3.6.2 Putting the narrative to work

Eventually, the present structure emerged. The narrative in the chapters that follow performs a 'walking tour' of MSB project performances. Each stop is a temporarily stabilised 'place of project performance'.

During the use of place to structure the narrative, I follow two of Cresswell's (2014) articulations we encountered in Chapter 2. Firstly, that place is an ever-changing process (Cresswell, 2014:10):

> "Places both gather and disperse. They collect things from outside and are thus constituted through their relations to the world beyond. But things are always also escaping place. Places, therefore, are in process. They are becoming and dissolving on a daily basis."

Each of the places, or 'stops' on the 'walking tour' should be theorised as processes. They are constantly being made and remade, changing their shape and configuration (Massey, 1994). In this way, any stabilisation through which to create chapter boundaries is an artificial artifact of writing, it does not represent a reification of the place itself. Secondly, Cresswell gives us an indication of what to expect whilst interrogating each 'stop' on the tour, or 'snapshot' of a place (Cresswell, 2014:20):

> "At any point in time, a place is a particular combination of materialities, meanings and practices that encourages some connections and makes others unlikely".

Just as the places, or ‘stops’ on the ‘walking tour’ are temporarily and artificially stabilised, so too are the materialities, meanings, and practices assembled there. They are fixed in a snapshot of the ‘locale’ (Agnew, 2011). This is necessary to so we can interrogate a specific set of materialities, meanings, and practices that emerge. However, it should be noted that such stabilisation is for analytic and narrative purposes alone. It should not be taken as a reification that such a static assembly exists in the corresponding physical performances of these places.

In the tour, I introduce three places - or stops - along the way. We begin in the experimentally focused configurations of the Laboratory. From there, we move to the ‘organising units’ where projects are negotiated into existence and given direction as well as organisationally performed through grey literature and institutional structure. We then head to project performances in the Communities, firstly to some examples of specialist community performances and then some nonspecialist community performances. This is not a linear narrative of an unfolding project. We start in the middle of the projects, embroiled in experimental work in the laboratory. We then jump to early negotiations of the projects and visit ongoing structures and commitments of the Institute. Finally, we visit the different performances of projects as they participate in a range of their communities.

In each place, I unpack what - if any - potential human appearances are entangled, whether they are performed to presence or absence, the circumstances of enactment, and any other aspects of their relationship with their broader materialities and MSB practices. This narrative structure resolves the challenges of earlier structures. It emphasises the inextricability of human appearances from the practices that bring them to presence. It also amplifies some of the key patterns relating to particular ‘places’ of human appearance that were emergent through my data. That is not to say it is without challenges. Many of the human appearances in one place on this ‘walking tour’ appear in other places, there is necessarily some repetition and consolidation. However, the practices are always different, and the negotiations into presence and absence occur in different ways.

It should be noted that each of these places of project performance are also not mutually exclusive. As we have seen in Chapter 2, places can be assembled and performed differently through different configurations of materialities and relations. As we reach the empirical chapters, the reader will observe that laboratories make an appearance in each of the three empirical chapters. Under the conception of places as a process, laboratories enact different sets of practices and materialities dependent upon who and what is performing them. In effect, through differently

configured materialities, meanings, and practices, the laboratory emerges as three differently enacted places. For example, in Chapter 4 the laboratory is configured as a place of experimentation through which individuated project research is conducted. In Chapter 5, the laboratory emerges alongside performances of the Institute as an 'Organising Unit', performing as a place of project organisation where resources are mobilised, and project portfolios sorted and ordered. In Chapter 6, the laboratory enacts a community, a place of peer discussion, testing presentations, and team meetings to discuss projects.

The view that laboratories can enact different places and sets of practices is not new. Knorr-Cetina (1999) has already drawn our attention to the 'dual nature' of molecular biology laboratories in her work on 'epistemic cultures'. She groups community performances in with the 'laboratory as a whole' organisation, advocating for a dual nature of the laboratory. I merely separate the organisational work and the performance of the laboratory (and the Institute) as a community based on the strengths of differences in the practices and human entanglements that emerge through my data. At any given time, the laboratory can stand as a place of individuated project research, a unit that organises and structures projects, or as a community through which to perform and share them. Each enactment is significantly different, enacts a different 'locale' (and thus 'site') as well as brings with it different associations, attachments, and human enactments and entanglements. As we step through the empirical chapters, I introduce each performance of place further.

3.7 Conclusion

In this chapter, I have elucidated the key methodological considerations that planning, performing, and reporting this research has necessitated. In doing so, I have provided reasons for pursuing certain approaches and eschewing others. Specifically, I have sought to balance the aims of the investigation alongside the needs of my participants and myself as a researcher, as well as cultivate an adaptiveness and responsiveness to situations, data, and findings as they emerge.

As this chapter draws to a close, I would like to end with a short note on the significance of methodological decisions I have outlined. Methodological considerations are ethical considerations. Each of these decisions has a bearing on how the research is conducted. Whether that relates to how the study is designed, how the data is generated, or how the results are interpreted, analysed, and

performed for wider audiences (Hammersley and Atkinson, 2007; Charmaz, 2007; Blaikie, 2010, amongst others). When I opened this chapter, I suggested the research topic is one that invites ‘mess’ (Law, 2004a). The ethnographic methodologies I have pursued in this investigation are well suited to unpacking messy and contingent realities (Hammersley and Atkinson, 2007; Law, 2004a). However, they do not sit ‘outside’ the mess, seeking to disentangle it from ‘without’. Instead, they operate from ‘within’ the mess, becoming entangled in the materialities of MSB research in action themselves, crafting them into legible patterns and shape. The methods I have described here do not merely ‘describe’ social realities; they help to create them (Law, 2004a). In this way, methodological decisions are also political. They determine which realities get foregrounded and in what way and are ultimately co-constitutive of the account to follow. It is this understanding of the methodological decisions described here that we must take forward into the next part of the thesis.

Chapter 4: Assembling human absence through experimental laboratories

4.1 Introduction

The aim of this first empirical chapter is to provide an account of the way the human emerges in the context of experimentally focused laboratory performances. In doing so, I generate evidence of the ways in which human appearances emerge in the context of real-time experimentally focused laboratory performances. Throughout the chapter, I demonstrate that there are many potential human enactments entangled with the MSB project materialities. However, most are actively negotiated into absence during experimental activities and identified as 'belonging' elsewhere. The experimentally focused laboratory is therefore actively assembled – and performed – as a place of human absence. At every turn we encounter assertions that the human "doesn't come up" or "is not relevant". Where the few human enactments are negotiated into presence, there is a "time and place" for them to appear, typically at the periphery of day-to-day MSB experimental performances.

To generate this account and assemble the evidence, I step through three main clusters of project materialities with which potential human appearances are entangled. These include the projects' outcomes and expectations, the projects' biological materials, and the performances of the practitioners in the project themselves. Starting with project outcomes, I use interview data to demonstrate that project goals and potential outcomes can in theory implicate two types of potential human appearances: expectations about human health-related application (and the "users" and "consumers" they might implicate), and human physiology as knowledge objects. I then turn to participant observation and situated conversations to demonstrate that human health-related enactments of project goals are of little use to making sense of the research in the experimentally configured laboratory. As such, they are routinely negotiated into absence in favour of more useful and situation-specific goals. As part of that negotiation, these potential human appearances are often 'othered', located as belonging 'elsewhere' (such as "far in the future", or the remit of other projects or places of project performance).

Next, I turn to the biological materials. Using data from conversations and interviews, I identify three possible human enactments of biological materials that practitioners bring to presence when considering the 'humanness' of their materials. These

include performances of human provenance, phylogeny, and physiology. Once again, I use corresponding participant observation to demonstrate that each of these potential appearances serves little purpose in making or making sense of biological materials during experimental work. Indeed, they often actively conflict with enactments that *do* serve a useful purpose. As such, potential human performances of biological materials are predominantly negotiated into absence during experimental activities. They are rendered insignificant at best and incompatible at worst. Instead, they too belong elsewhere, othered to alternative places of performance (for example, “in the past” or “in nature”).

Finally, I turn to the performance of the practitioners themselves. Through a combination of interview, conversation, and participant observation, I elucidate a variety of practitioner performances that are identified by participants as specifically ‘human’ enactments. I then demonstrate there are strong normative associations with where such ‘human’ performances are negotiated into presence and where they are not. There emerges a “time and place” for them to appear that is typically found at the periphery of experimental laboratory performances (for example, such as “behind the design” or “at the outset”) rather than during the repeated day-to-day experimental tasks.

As I step through this investigation, I point to some of the patterns I observe relating to human performances. For example, I observe that human appearances are enacted in practice (Law and Lien, 2013) in conjunction with the other materialities with which they are assembled. I also note that human appearances that can perform a function are more likely to be foregrounded. Most noticeably, however, I observe that human performances are deeply entrenched in notions of place. Human entanglements and enactments are routinely located in space and time (“in nature”, “in the future” and more) with incompatible materialities held apart through distribution. At the same time, human appearances are also sociomaterially sorted and ordered as ‘*belonging’* to – or being associated with – alternative places of belonging. Through analysing the repeated spatial, temporal, and sociomaterial ordering of potential human appearances, I conclude that the experimental laboratory is assembled as a site of ‘human absence’.

4.2 Introducing what comes to count as a ‘laboratory’

Knorr-Cetina (1995) argues that laboratories are much more than a site to house experiments or a locale in which methodologies are practiced (Knorr-Cetina,

1995:43). She demonstrates that they are also a process. Specifically, they are relational processes that negotiate and accomplish alignment across the three levels of work organisation that Fujimura (1987) argues are involved with scientific activities (the experiment, the laboratory, wider social worlds). In Section 2.3, we saw that for projects to be 'doable', all three sets of activities need to be brought into alignment (Fujimura, 1987). Laboratories play a key role in accomplishing this by negotiating and renegotiating the way they are performed to accomplish alignment with both experiments, and the 'wider worlds'. To do this, some types of laboratories – including the biologically based laboratories in which I am interested - enact a 'dual-structure', or 'two-tier' system of organisation (Knorr-Cetina, 1999). Knorr-Cetina (1999) argues that the 'laboratory' can be understood as two separate places; one involved with individuated projects and experimentation, and one involved with organising projects together as part of a broader portfolio.

The first type of laboratory performance "fragments into projects associated with individual researchers" (Knorr-Cetina, 1999:224). The work centres around experimental labour and the laboratory is configured to support the individuated projects. Specifically, laboratory materialities, practices, and meanings are performed in such a way that renders each individuated project experimentally and technically workable. This experimentally focused laboratory is the type that the predominantly bench-based practitioners typically experience, and the one that comprises the subject matter of this chapter. The second type of laboratory is one that is configured and reconfigured as a coherent portfolio of projects requiring organisation, management, and socialising with wider structures and institutions. In that performance of the laboratory, projects are no less individuated, but the focus is on how the projects are managed as part of a laboratory acting as a "whole" (Knorr-Cetina, 1999:226). That type of laboratory enactment comprises the subject of the next chapter.

4.3 Potential entanglements and enactments

4.3.1 Entering the experimentally focused Laboratory

In March 2019, I entered the Meier Lab for the first time. At the time, the Meier Lab was experiencing contamination issues, and I would be unable to enter their Tissue Culture (TC) room where much of the work took place. As Addison (the project lead) met me in the entrance to the laboratory she was quick to assure me that she had given some thought to how our first session might work. I was instead to receive a

‘curated’ induction of what work went on in Lab 002 and she would point out things she thought would be of interest to my topic. The induction started with a brief introduction to the part of the building that comprised the laboratory. As we moved from the main laboratory along a corridor to the TC room, the walls were covered with posters, publications and articles pinned to noticeboards, printouts of papers on topics of interest, and flyers for upcoming conferences. As we walked, Addison reminded me of her research topic: to build a new type of replica human chromosome. This would be used by others in the Lab to study the process of mitosis (the process of chromosome segregation in preparation for cell division), a process she was sure to remind me was very important in human beings.

We came to a halt outside the TC room, and I peered through a glass panel in the door (the closest I would get that first day). Cell cultures are kept contained and separate from the rest of the laboratory in line with biosafety precautions and the TC room must remain sterile. The latter requirement at the forefront of Addison’s mind in the midst of a contamination problem, she apologetically asked me to stay put as she slipped inside to collect some samples she had pre-prepared for our session. Through the glass panel, I could see extraction hoods, microscopes, fridges, and two large incubators. On one incubator, a cartoon chicken, and the words “DT40” signalled its use for chicken cell culture (DT40 is a chicken-derived lymphoma cell line); the other sported a plain “Human Cells” label. I saw Addison collect a flask from the latter.

Back at Addison’s bench in the main laboratory, the cell culture flask sat in front of me, each cell within it containing an additional replica chromosome. She proceeded to tell me all about working with cell culture. She outlined how the cells behaved, the way they grew in adherent layers in these flasks, and what nutrients and essential elements they required. We discussed the protocols involved with culturing them (the art of “keeping them happy”) and how having cells in culture was like “having a pet or a baby”; they were “moody” at times but “you get a feeling” for how to manage them. I noted the ‘almost human’ way Addison talked about the cells.

We were deep in discussion, but I was acutely aware that we had still had not mentioned what the cells actually *were*; the emphasis had been entirely on how to work with them. I already knew from my own exploratory research that I was looking at human-derived cell lines but was interested by the lack of discussion. Eventually, I asked Addison to clarify. “They are a clone” she replied, expanding to add “they are

a fusion of HT1080 cells and HeLa cells[33]". Later on, I would learn that Project D44 has a limited range of cells it could use: HT1080 cells had amenable internal structures to accommodate the replica chromosomes, and HeLa cells have useful growing properties which made them well suited to particular experiments. In more recent Project D44 experiments, Addison was engineering unhybridised HT1080 cell lines. Critically, however, what was most important about these cell lines for Addison had not been where they had come from, nor what they were, but what function they served in the present. They were cells that contained replica chromosomes and enabled her to perform her experiments, they were performed as "replica chromosome containing cells" not through any reference to their developmental origins.

Eventually, we left the laboratory and moved into the office. Though not before a generous dose of bleach was administered to the cells on the way out (maybe not entirely *just* like "having a pet or a baby'). Without access to the TC room that day, Addison also wanted to show me how the HT1080 cells she and the team were currently working on might have looked under the microscope had we had access to the TC room. We huddled around her computer as she loaded the website for a biological materials database, the ATTC[34] (American Type Culture Collection). Addison navigated to the HT1080 record and the screen filled with microscopy images. She pointed out all the cellular features she explained she would have shown me in person. When we were done, the rest of the database record caught my eye. Prominently displayed in the General Information section was the following record of cell line provenance complete with donor information:

> Organism: *Homo sapiens,* human
> Tissue: connective tissue
> Product Format: frozen
> Morphology: epithelial
> Culture Properties: adherent
> Biosafety Level: 1
> Disease: fibrosarcoma
> Age: 35 years
> Gender: male
> Ethnicity: Caucasian
> Applications: This cell line is a suitable transfection host
> Storage Conditions: liquid nitrogen vapor phase

[33] HT1080 cell lines originate from human connective tissue samples. HeLa cells are derived from the carcinogenic specimens from Henrietta Lacks (see Appendix 2).
[34] https://www.lgcstandards-atcc.org

Addison seemed as curious as I was; up until that point she informed me she had been unaware of any information about the donor of these cells. This surprised me, but she offered two reasons that made complete sense. Firstly, such information was "not relevant at all" to the experimental work. It might be pertinent for projects involving a karyotype, she had mused, but it held no significance for her project, she just didn't need to know anything about its provenance. Secondly, Addison did not engage with databases such as the ATTC. As such, not only did she have no *need* to seek out such knowledge, but she also had no contact with repositories that might have informed her in passing. Instead, Addison and her team secured their cells from their collaborators (who send them master portions, or 'aliquots', in dry ice). They did not need to order in or look anything up online. We eventually wound down our conversation and I packed up my belongings to leave. As I did so, I reflected on what I had learned. Through the work I had already started with the Garcia Lab, I was beginning to identify certain patterns in the way that human appearances emerged during laboratory project performances. This curated experience had neatly consolidated them as outlined below.

4.3.2 Early reflections

Potential human appearances are implicated in three main clusters of project materialities. Firstly, they are entangled in the project goals, outcomes, and expectations through potential human utility or 'application' of what was being built. Addison was building replica chromosomes that would be used to study mitosis, a process that she had been sure to remind me was important to human beings. Secondly, potential human appearances were entangled by the biological materials themselves. From the incubator marked "human cells" to the provenance of the cell line represented in the ATTC database, it was clear that these were human-derived experimental materials. Thirdly, potential human appearances were entangled in the relationship between Addison and her cells. Through the material resistance of the cells to 'behave', both they and Addison entered into a relationship mediated through conceptual metaphors of human traits and behaviours. This renders the cells more legible; at the same time emphasising Addison's more human, affective side, getting a 'feeling' for her cells.

The day's experience had also underscored a second point central to this thesis. Potential human appearances may be *implicated*, but it does not mean they are actively materialised or practised into 'presence' in any meaningful sense. I reflected further on the conversation with Addison about the provenance of the HT1080 cell line. A 35-year-old male fibrosarcoma donor was definitely entangled by merit of their

cells physically being present in the flask; they were only available because of his donation. Some might argue that this donor was - in some way - represented within the flask that had sat in front of me (Landecker, 2007). However, this association or connection had not been brought to 'presence' in any meaningful sense during Addison's performance of Project D44 that afternoon. She did not know about the cell line provenance, and it held no significance for her and her team's work. A 35-year-old male may have been *implicated* through the availability of the cells in the flask, but in any *practical* sense, they were entirely absent from the enactments of the cells during the laboratory performance. Not only was it "not relevant", but the practices Addison used to secure cells also bypassed the need to engage with this type of information at all. Put simply, the donor had been actively *performed* into absence by the very way the project itself was practised. As we have seen from Chapter 2, this demonstrates the hallmarks of performing 'practical ontologies' (Jensen, 2010).

To get to the heart of the human appearances in the context of MSB projects is to account for how projects are practised through specific and situated performances. This is the task of the next three sections. I take each of the three clusters of project materialities where human appearances are potentially implicated and unpack each in turn. By the end of the chapter, I will have provided a comprehensive account of how the human appears in the context of experimentally focused laboratory based MSB research.

4.4 Negotiating project goals, outcomes, and expectations

4.4.1 "Nothing to do with human application"

It was late in 2018 when I bumped into Marek in an airport departure lounge. We were both on route to the same conference and at the time I had only recently been introduced to him. They were the lead on Project D41, the project to "mimic" the 'Turing patterns', or Reaction Diffusion (RD) patterns, found in nature (such as zebra stripes or cheetah spots). He and I settled into an easy conversation. In the tightly packed queue for boarding, we found ourselves discussing our respective projects. Marek explained their project in as much detail as an airport queue allowed; by return, I outlined my interest in how the human appeared in the context of MSB research practices. Not wanting to give too much away I provided little shape around what I might mean by the human in relation to the MSB practices beyond how people might think of or conceptualise the human in relation to their research. Marek

seemed genuinely interested and I was pleased. It had not been long since the Garcia Lab's Principal Investigator Madelaine had agreed for me to work with her Lab, and Marek's project was one of the ones in which I was interested. I enquired if he'd be interested in potentially working together and me observing his day-to-day work practices. He looked unsure and paused before apologetically suggesting, "I'm not sure how I can help. I'm doing basic research. I don't have anything to do with human applications". I was quick to reassure him I was purposely seeking out projects such as his, but this brief encounter and its rebuttal of an association with human application foreshadowed nearly every opening encounter I experienced hence.

4.4.2 Clarifying project outcomes and expectations

A couple of weeks later, Marek and I would clarify his project further. The primary project aim was to engineer a synthetic patterning system based on mathematical principles that Alan Turing had predicted. These principles had yet to be unequivocally proven in mammalian systems. Project D41 used synthetic biology tools and techniques to introduce new 'genetic devices' into host cells to mimic the processes that Turing predicted existed. This endeavour comprises the 'techno-epistemic object' of the research; a patterning system that mimics natural patterns. If this research were successful, the cells would organise into specific groups and patterns. Marek's engineered system was a way to test the hypothesis through a 'learn by doing' approach. Indeed, Project D41's project goals were two-fold. There was a goal of construction: to engineer a synthetic "patterning system". There was also a simultaneous goal of comprehension: a successful build would render 'known' the hitherto 'unknown' about whether Turing patterns worked in mammalian cells. Neither of these goals foregrounded human appearances. The first limited focus to "building tools" or "engineering systems". The second targeted the acquired knowledge to the reaction-diffusion mechanisms of specific molecular pathways. Specifically, a family of pathways termed 'Wnt pathways' that can be found across the animal kingdom as well as in mammalian (and thus human) cells.

As it transpired, the only way that the human did emerge was through reflecting on the broader expectations of the projects in settings that were distinct from his experimental work. Indeed, it was during interview that Marek acknowledged any engineered patterning system they built could "perhaps" - with a lot of further work - contribute to tissue engineering activities. It is only during these reflections that the potential future human outcomes emerge entangled with project materialities as an "ultimate goal". This not only changes the configurations of project goals to enact

longer trajectories, but it also changes the configuration of the research techno-epistemic objects (in Project D41's case, the patterning systems) to act as tokens of that future utility.

4.4.3 Implicating humans and reconfiguring the objects of research

In performing the projects in conjunction with their expectations in this way, there emerge two types of human appearances. The first appears in the form of potential future human applications. Specifically, these are imaginations of biomedical tools (such as more sophisticated patterning systems for tissue engineering or stable replica chromosomes for gene delivery). These count as 'human appearances' by the merit of their intended use, although there is little to no elaboration of any potential future users of these products. The focus remains on the research objects and their assumed technical trajectories unfolding down a linear pathway of translation.

The second type of human appearance is that of improved knowledge of human physiology. Physiology encompasses the function and structure of living things and the mechanisms of how bodies work from the organism to molecular pathways. As Kohl and Falk (2019) assert, in SB engineering practices "an application is an inherent part of the engineering approach, yet so too is a process of gaining knowledge. The 'investigation of biological phenomena' is an inextricable part of the intended objective" (2019:1). As projects make tools that can be used by other projects (such as Project D44's replica chromosome), there emerge expectations they will help generate more knowledge about human physiology (such as human mitosis).

4.4.4 Negotiating absence through insignificance and incompatibility

However, whilst participants acknowledge these broader trajectories, outcomes, and expectations of their projects during *interview*, the very nature of interview settings removes participants from the experimental materialities and practices through which their day-to-day work is performed. They offer participants places of reflection to consider a wider range of topics relating to their work. Indeed, performing the project materialities through potential human outcomes and expectations constitutes specific configurations of project materialities. It configures the patterning systems in a way that elides them as techno-epistemic objects of experimentation, instead emphasising them in ways that render them of potential interest to a broader array of people and social institutions. Through their relations with potential human

outcomes, the research objects become ‘collaborational things’ (Michael et al, 2005). However, in places of experimental ‘doing’, these configurations of research objects and the potential human outcomes and expectations they enact are barely considered at all. Indeed, any potential human enactments of outcomes are almost entirely negotiated into absence.

To illustrate this, we return to the Spring of 2019. I was set to follow Project D42 for a period of a few days to observe the routine activity of constructing plasmids. Like Project D41 (and indeed all the case study projects), Project D42’s project goals were two-fold. Firstly, to construct engineered systems capable of organising cells into a pattern and emitting signals in the shape of that pattern to nearby stem cells. Secondly, to learn about molecular and cellular physiology and its potential for configurability into novel arrangements not found in nature. In this way, Project D42’s techno-epistemic object is a set of ‘engineered patterning systems capable of configuring physiology into novel arrangements’. On this first day, I joined Rachel just as she had finished designing a plasmid that she needed. A plasmid is a small circular piece of DNA that acts as a vector to load (or ‘transfect’) engineered ‘genetic circuits’ into a host cell. Rachel was preparing the experimental conditions through which she would engineer the plasmid. As we sat at her desk, a schematic of her plasmid filled one computer screen and a ‘melting temperature’ calculator (to calculate some experimental conditions to melt DNA enough to open the strands of DNA) lay open on the other. She outlined the steps of the experiment. It would “isolate two separate sets of DNA from already existing devices”. Then it would “stitch them together” using a molecular cloning technique called Gibson Assembly (GA). If it worked, there should be only one possible outcome, Rachel pointed to the screen with the plasmid schematic: a “new device *de novo”*. That was the immediate goal for her work that week, and the corresponding expected outcome of the work.

Over the following days, laboratory life continued, and I followed. Rachel ordered in materials, isolated DNA fragments, performed PCR, tested the results, and started to grow colonies. During this period, she also stepped in to help a colleague and attended the weekly team meeting providing some perfunctory updates. As she went about her day-to-day laboratory work, not once were any “ultimate goals” or broader trajectories, outcomes, or contexts of eventual human utility brought to presence. Indeed, neither were the project’s own overarching goals (building patterning and signalling systems or learning about the limits of cellular adhesion). All the activities of the few days were focused on building the “new device *de novo*”. As we have already heard from Knorr-Cetina (1999), laboratories are processes designed to make scientific activities ‘workable’. They are predicated on the idea that objects do

not have to be taken ‘as they are’. This also applies to goals. Rachel’s work was targeted and focused. Through her day-to-day laboratory materialities and actions project work was performed entirely in relation to a series of short-term interim goals that comprised ‘device generation’. These interim goals organised and assembled the immediate outcomes and expectations through which to perform the experimental tasks. They included “isolating the DNA”, “engineering a plasmid”, “growing the colonies”, and more. In these arrangements and performances, there were no notions of human application nor human configurations of knowledge claims. In the laboratory, such human appearances were functionally insignificant. Correspondingly, they were ignored as insignificant, elided into absence.

Indeed, a key circumstance of whether potential human appearances are assembled into presence or absence is its ability to perform a useful function. Human enactments that prove useful are foregrounded, those that are not, are elided in favour of alternative performances that do. As Rachel herself explained, a lot of her research (like a lot of synthetic biology more generally) is “just biochemistry in the making”; much of it performed at the molecular level of “DNA and proteins”. ‘What of the main project goals then?’ I had asked. She laughed; she would settle for everything just to work she told me, echoing Rheinberger’s (1997) that experimentation is about repetition and recurrence, not overreaching and falling short (1997:75). We both fell silent.

Rachel was focused on the six vials she had just retrieved from the polymerase chain reaction (PCR) machine that held the DNA fragments of the gene of interest. I watched as she carefully loaded a dye into each vial that would later enable us to see the DNA fragments under UV light. I looked around. I could understand her point, there were no goals that seemed to make sense of the materialities of the laboratory or the project in that moment other than a successful next step in the protocol to make the new device. Even the project goals of creating ‘patterning systems’ felt a world away from the work to “isolate the DNA”. Rachel shook the vials, eyeballing how well they were mixing, and straightened up. She shifted her attention back to me. “As you can see”, she declared, “concepts of the human don’t apply”. She stalked over to the centrifuge to load the vials to ‘give them a spin to be on the safe side’. “But” she suggested - placing the vials inside the machine - “*if* you’re using PCR” (she nodded to the PCR machine a bench away) “[…] to amplify human induced pluripotent cells to differentiate - for example - *T cells* […] this is where [the human] comes into play”. Whilst we waited for the machine to spin down the fragments, Rachel elaborated on what she meant. Drawing on notions of translational application, she explained a researcher could culture cells, introduce

new sequences, and then “eventually introduce them back into the human” to use the engineered cells to “fight tumour cells.” *“This”,* she underscored, “is how the human appears”. She stopped abruptly and gestured around the laboratory at the apparatus that surrounded us, the prepared electrophoresis gel we were about to use, the centrifuge we hovered over. “I’m making tools” she concluded “not considering the human at all. We’re just making tools.”

4.4.5 Mechanisms of othering

Implicit in the enactment of biological materials as ‘tools’ is the notion of utility and function. A tool cannot be independent of its use (Strathern, 1991:39), each tool is designed to *do* something. In this way, Rachel and other participants can’t escape the idea of the tools they are making being used *for* a particular purpose. However, Rachel suggests her ‘tools’ are nothing to do with human application, or even human knowledge at this stage, they are instead designed to elicit a particular phenotypic response in a cluster of cells. They are tools to perform a particular function *within* the existing experimental systems. Within the laboratory enactments of project outcomes, ‘utility’ does not entangle broader trajectories and contexts such as ‘making designer tissues’, instead it relates to the functional use within the experimental systems themselves. In this way, human appearances do not emerge as the designated function of such tools. They do not form part of the ‘practical achievement'' (Woolgar and Lezaun, 2013) of experimentally focused practical ontologies (Gad et al, 2015).

Recalling the two types of absence Law (2004a) provides us in Chapter 2 (manifest absence, and ‘Othered’ absence), an argument can be made that imaginations of human application are still apparent through the laboratory performances, somehow ‘manifest’ in its absence through its negotiation as a recognisable context (Law, 2004a). Arguably, the fact that Project D42 was negotiated for on the basis of its potential human application and utility (something we explore in Chapter 5) could be a case for manifest absence, rather than an outright ‘othered’ absence. However, for such organisational performances to be negotiated into some form of context they would need to remain compatible with the other performances that were made present (Law, 2004a). This is not the case. Human-orientated future goals and outcomes are not only insignificant to the materialities and actions to hand during laboratory performances but are also (at times) incompatible with making projects ‘workable’ on a technical level. For example, Rachel suggests she is so focused on “facts” and what the “evidence tells you” that entangling anything else considered ‘opinion’ (such as the “wider implications of their work”) detracts from her focus.

Meanwhile, Maxwell suggests that entangling human outcomes as goals would compromise his ability to “remain objective”. He argues he might start optimistically seeing patterns that aren’t there and suggests that considering potential human outcomes of projects during experimental work is not only a distraction, but “unscientific”. Such human appearances do not ‘belong’ in experimental performances and are explicitly repressed, or ‘othered’.

There are two interlinked ways in which human appearances are othered by participants. Firstly, they are negotiated out of the experimentally focused project materialities. Secondly, they are negotiated into alternative places of belonging. Both acts are heavily entrenched in notions of place: both through associations made between potential human outcomes and the places themselves (the ‘sense’ of place, Cresswell, 2014); but also, through the spatial and temporal performance of a place. Here, Knorr-Cetina’s (1999) notion of ‘small lifeworlds’ (Knorr-Cetina, 1999) and Massey’s (1994) idea of ‘extroverted relations’ (see Section 2.4) combine to provide a useful heuristic through which to make sense of these othering mechanisms.

Participants perform their experimentally focused projects through tightly targeted, experimentally focused ‘small lifeworlds’. These small lifeworlds are strongly associated with specific material performances and actions. We have already seen Maxwell assert that performing human outcomes of projects are “unscientific” and they do not belong as part of the project materialities. Indeed, across the projects, potential human outcomes and applications are explicitly excluded, or ‘other’, to what is made present. Routinely, they only appear when a set of ‘extroverted relations’ are foregrounded, for example, through reflections in interview. This places potential human outcomes as spatially distinct – and distant – from the small lifeworlds of the experimentally performed projects. It is only when practitioners “step back” from their day-to-day work – such as during interview reflections - that they engage with the potential human outcomes of their projects. Invoking spatial rhetorical devices, Rachel, Addison, Maxwell, Zofia, and Deepti all referred to notions of human-orientated outcomes as “the wood” (c.f. “the trees”), drawing on notions of “zooming out” or “standing back” to gain visibility, or to “place [the work] in the big picture”. To engage with notions of potential human outcomes is to ‘distance’ themselves or ‘step outside’ their targeted, small lifeworld project materialities. Only then do practitioners engage with “the wood” not “the trees”.

As part of negotiating human entanglements *out* of their experimentally focused research materialities, however, many participants also simultaneously negotiate them *into* alternative places of ‘belonging’ through the same discursive mechanisms.

Indeed, Rachel provided an example of this in our second interview when she reflected on the potential of Project D42 and its capacity to contribute to a programme of work building synthetic versions of stem cell niches[35]. I was curious why she had not mentioned the synthetic versions of stem cell niches in any of our previous discussions. She offered the following explanation:

> "I haven't put it into those words before because that's like the holy grail and the ultimate thing, we're building step by step. I do not say 'building synthetic niches' because that is very far-fetched, holy grail goal, right? But I *am* laying foundations for that."

Here, Rachel both temporally and spatially distances potential human outcomes from her project performance by locating them elsewhere in space and time. She temporally distances the outcomes as the "ultimate thing", something she will not accomplish – it is too far in the future - but instead is instead laying foundations, and linearly progressing "step by step". Rachel is also pragmatic in her own involvement in such a programme of work. She is aware the "holy grail" goal is something that will be "someone else's project" in the future. Her time in the Garcia Lab as a PhD student is transient. As early career researchers (ECRs) move across projects and contracts, working on the same or similar overarching goals for any length of time is unlikely. These 'short stories' of success (Felt, 2017) are something that Bauer et al (2018) identify as part of the double-edged effect of increased projectification on scientific careers: whilst creating opportunity, one of the biggest drawbacks is that they don't allow for individual or organisational continuity across the work. For Rachel's individual role in enacting "holy grail" expectations, not only are they something she has to "stand back" to engage with, but it is also located "far in the future", "far-fetched" in terms of certainty, and ultimately belonging in a different 'time and place'. This small exchange stands symptomatic of a much bigger acknowledgement that projectification in the life sciences can not only change the performance of scientific research (see Section 3.2.2), but also affect the way that the real-time MSB research materialities and practices are configured, made, and made sense of in real-time practice. Though it sits outside the scope of this thesis to unpack 'projectification' in any great detail, an argument can be made that the organisation of the research into short-term projects might conceivably feed into, or at least exacerbate the 'othering' of potential human appearances by foreclosing any prospect of individual - or even Institute-level - continuity with the future human-related application goals (Bauer et al, 2018).

[35] We return to discuss these further in Chapter 6. In this chapter it suffices to know these are a useful feature in regenerative medicine and could be a huge leap forward in generating realistic human organs.

Such spatial and temporal distancing of potential human outcomes and expectations can be found across the four project performances. The acts of both othering and locating potential human appearances elsewhere are also inextricable from normative associations and attachments between the potential materialities and the places they do or don't belong. Indeed, participants position potential human outcomes and trajectories as spatially distanced, 'belonging' to the remit of "science fiction" not 'science', or temporally distanced through projects being "nowhere near" that stage, "if ever". They can be loosely elaborated, for example, potential human outcomes located 'far in the future' (Marek, Zofia, James, and more), 'decades away' (Addison, Tomas), or 'out there' accompanied by a lofty hand wave to some place beyond the laboratory walls (Maxwell). Meanwhile, other distancing is more specific, locating potential applications into alternative physical settings such as 'in the clinic' (Maxwell), 'working with patients' (Deepti, Rachel), or more specifically identified temporalities such a matter of 'decades'.

Whether loosely or more specifically elaborated, or spatially or temporally distanced, what they all share however is a commitment to underlying notions of three-dimensional, regional space (Law and Mol, 2001), and linearised notions of 'clock time' (Adam, 1990) (see Section 2.4). Both regional notions of space and linear notions of time enable participants to hold human appearances as distant – and distinct - from the experimentally focused laboratory. In the case of spatial separation, regional geographies present 'alternative settings' "outside" or 'beyond' the laboratory as separable and distinct from the laboratory. Meanwhile, in the case of temporal separation, potential human appearances are designated to 'out there' futures that are temporally displaced down the linear line of time, held distinct and separate from the present day (Adam and Groves, 2007:28). Spatially, temporally, and socially, most human appearances are actively assembled out of the laboratory.

Throughout the projects performed through experimental laboratories, potential human appearances in relation to project outcomes and expectations have negligible function and are routinely elided in favour of more useful interim experimental goals. In configuring the project materialities into small lifeworlds that exclude, or 'other' many of the extroverted relations, human appearances are assembled into absence and held as distinct – and distanced - from the laboratory performances, sorted into alternative places of belonging. Correspondingly, laboratories enact a place of absence in relation to potential human outcomes of projects. As we step through the rest of this chapter, we start to see how other human enactments and entanglements

are similarly othered and held apart. It is to the performance of biological materials that we turn to next.

4.5 Negotiating biological materials and systems

4.5.1 "Not really what I would call human"

"Sure, they come from the human: it looks like a dog, it barks like a dog, but is it *really?"* Rachel had mused in conversation one afternoon. We had been discussing their human embryonic kidney (HEK293) derivative cell lines. She was engineering them to become signalling cells but had cast doubt on how 'human' she really considered them. "So, sure I mean they're '*human*'" - she deployed a sarcastic use of air quotes - "but they've been cultured so long in the lab that … they don't really *behave* like human cells. […] So they are not really physiological, they do not really reflect anything that we see happening naturally, physiologically *in vivo*".

Whether cell lines, genes, proteins, or resultant engineered components came to be considered as 'human' was never a yes or no answer. There was no 'settled ubiquity' to be found, no definitive ruling on a 'generalised human biomaterial subject[36]. Any conclusions were always subject to qualifications, uncertainties and 'hedges' (Lakoff, 1973). As various participants explained, 'yes', their cells derived from the human, but 'no', "they're not really what *I* would call human" (James); "they're not *human* human" (Marek); they "don't resemble anything in nature" (Addison). What emerged as "human" became a 'matter of degree' or resemblance (Rosch, 1971). Biological materials such as cells were evaluated through performances that drew on a number of criteria. Rachel summarised the common ones as follows:

> "I mean if you define 'human' based on genetics, [the cells] definitely are. Or cytogenetics, they definitely are. If you focus on this idea of the human as an organism […] they've been out of the organism so long and cultured and they're so paraphysiological that yeaaaaaah [pulling a face and waving a dismissive hand], they're definitely not."

4.5.2 Entangling humans

[36] I draw inspiration from Landecker's (2007) term "generalized human or cellular subject" (Landecker, 2007:165), adapting it to encompass more than just cell culture. Landecker introduces this notion of a generalised human or cellular subject in the context of HeLa cells where they had such "settled ubiquity" that they were taken for granted as standing in for a 'generalised' human subject (2007:165).

Indeed, through discussions such as these, there emerge three main ways human derived biological materials can *potentially* enact human performances into presence.

The first relates to their provenance ("sure, they come from the human"). We have already encountered this appearance in our earlier induction in the Meier Lab in Section 4.3. Provenance enacts the lineage from original organism to experimental sample. In doing so, it entangles the 'original' humans from whom the material was derived. Typically, these original humans emerge situated at the start of a technological process as "donors" or "sources". The sources - if not known to the individual practitioners themselves - are at least a matter of record as we saw in the case of HT1080 cells and the 35-year-old fibrosarcoma patient. Where the link is not known, the donor might emerge as a generalised version of "a human". Provenance is not unique to cellular biological material. Genetic material also has a provenance. For example, one of Project D43's genes of interest had sequence information available that had been derived from "95 human individuals representing 27 different tissues" (NCBI, 2021). In this case, donors to large scale sequencing initiatives such as the Human Genome Project (Hilgartner, 2015), or - over the subsequent years - patients whose genetic polymorphisms were biopsied and their tissues also sequenced and submitted (anonymised of course) to various databases (Landrum et al, 2016). Provenance can provide a direct connection with the original human source.

The second way biological materials can potentially enact human appearances relates to phylogeny. Whilst provenance traces the lineage of the biomaterials to individual sources, phylogeny emphasises the similarities and differences of biomaterials in relation to a broader evolutionary lineage or record[37]. A phylogenetic designation sorts and orders by resemblance. It brackets together genetic similarities and differences across organisms, species, and populations, designating members that share similarities to particular taxonomic categories within a broader phylogenetic tree (Bowker and Star, 1999). It is entrenched in evolutionary history, but also resonates in the present through shared membership to a group of similar individuals. Setting aside the nuance between the myriad definitions of species, the common use of phylogenetic designations can be thought of as a 'species' designation. As with any designation, the act of using it makes it so. Any cell line,

[37] The two types of human appearances are related, but they are not synonymous. All instances of donor humans in the case of these projects can be considered members of the human species, or human organisms. However, not all instances of human organisms, or species across the projects can be considered as donors or source humans.

gene or material designated as ‘human’, whether through informational database performances or practitioner utterances (such as Maxwell referring to genes as “human variants” or “human genes”), correspondingly materialises a human enactment.

The third way biological materials can potentially entangle human appearances is through human physiology. As already described, physiology elucidates the ‘typical’ structure and function of living things and covers myriad biological processes. What participants designate as ‘typical’ or ‘physiological’ differs. Deepti offers a health-based interpretation of human physiology (“basically [it] means everything is working as it’s supposed to be”). Other practitioners offer a more naturalistic based interpretation (“natural processes, *in vivo*”). Some just refer to it loosely as “normal” development. As with phylogenetic designations, designations of a ‘physiologically human’ (or not physiologically human) biological material are based on sorting and ordering resemblances through comparisons with an exemplar. If a comparison is favourable, the biological materials enact human physiology into presence. If it is not, it renders it into absence.

4.5.3 Negotiating resonance through physiological similarities

When I began fieldwork, I had anticipated spending much time disentangling the different ways these three biological ‘pillars’ of human enactment might be negotiated and debated during laboratory work. However, there emerged very few instances where this was the case. Most of the time, human enactments of biological materials were largely insignificant to the laboratory performances.

Addison did provide me with one illustration where human enactments and comparison perform a valuable function and were therefore foregrounded through experimental performances in the laboratory. Although the broader trajectories and expectations of human application and knowledge are routinely ‘othered’ during laboratory performances (as seen in the previous section), projects must still be performed in a way that keeps future human applications and knowledge a possibility. The requirement for ‘human applicability’ originates through organisational project performances to create alignment with broader societal priorities, it is not an experimentally driven requirement. As such, we return to this in Chapter 5. Nevertheless, the requirement does guide the configurations of the experimental work through which to deliver them (Eames et al, 2006). Biological systems must at least be human ‘applicable’ to align to the commitments made during organisational performances of the projects.

Human applicability can be accomplished in two ways. Firstly, by designing project experimental systems that are sufficiently *similar* to physiological human behaviour so that they might tell us something about endogenous human behaviour. Secondly, by designing experimental systems that are sufficiently *compatible* with existing physiological human behaviour that they could integrate with - and be used as tools within - endogenous human bodies. Project D44 aims to be sufficiently similar in the first instance, with an eventual view of being sufficiently compatible *should* the replica chromosomes ever become therapies. For Addison, the experimental design requirements therefore come down to a balance between how much the experimental system is: a) reproducible; b) something that practitioners can handle; c) a system that she (jokingly) suggests means they "don't have to kill people to study their chromosomes"; and d) one that is representative of what's "really happening in the human body". The first three considerations are required to render the experimental system 'workable' in the laboratory. The fourth is required to retain sufficient "resonance"[38] (Rheinberger, 1997:225) to applications or knowledge of interest to wider people and social institutions to make the experimental system – and thus the project - 'workable' in wider scientific communities and beyond (Fujimura, 1987; Clarke, 1998). It is this fourth requirement that enacts comparisons with human physiology as part of the experimental design. Addison elaborates below:

> "So the question is, we are taking a cell line, we are knocking in a gene, we are knocking down other genes. […] So *how* is this system then- if I go to a conference and I say 'oh, I find out that my [replica chromosomes] in this cell line, this does that', people can then argue 'but how is this system … close enough' … representative to what is really happening."

To ensure sufficient similarity to in her experiments (and ultimately be able to argue her work amongst her peers) she evaluates her replica chromosomes against imagined exemplars of physiological chromosomes to ensure that: "if you zoom in, if you go to the molecular detail, you study something that happens the *same* in your system as in the human". Here, performing exemplars of human physiology to presence serves a real-time, useful function to align her experimental systems to nature, and thus validate her project's ability to generate useful insights. There are, however, two considerations to keep in mind. Firstly, these calibrations and negotiations are infrequent and episodic: they are addressed early on in design and

[38] Whilst Landecker terms this resonance 'continuity' (2007:175), Rheinberger's term 'resonance' allows for the understanding the resonances are contingent, multiple and always discontinuous and transient, even if some emerge as long lived (2007:225).

once a decision is made, unless it is challenged (which also gets resolved quickly), they cease to become an active consideration. After the comparisons to human physiology are made, they become black-boxed into the design decisions and elided from view. Secondly, such comparisons to endogenous human chromosome physiology did not make the replica chromosomes themselves physiologically human, merely 'sufficiently similar' to accomplish resonance with physiological systems and thus ensure 'human applicability'. The designation 'human' was the preserve of the 'natural', or endogenous chromosomes.

4.5.4 Insignificance and lack of utility

The more I observed of day-to-day project laboratory performances, the more I realised enactments of experimental biological materials as human themselves were quite rare. When it comes to performing biological materials, any potential human appearances they might entangle are largely insignificant to the laboratory performances at hand. This insignificance was highlighted to me most keenly in discussion with one participant as they explained their decision for changing their expression host. The participant began by explaining: "[t]he HEK cells are kidney, monkey; whilst the MDCK cells are kidney, dog". At this point, I had paused, not quite sure how to frame the challenge (recall, HEK cells are human derived cells, not monkey derived). Sheepishly, I asked, "you say monkey, are they not human embryonics?" There followed another pause, then the participant started to laugh. "Oh my god, maybe I'm doing something wrong, saying something wrong. Aaaaah, terrible!" they cried. They proceeded to explain their mistake. Their experimental work was about the cellular signalling pathways *within* the cells, specifically a signalling pathway known as the Wnt3A pathway, not the cells themselves. The Wnt family of pathways is one of the most conserved pathways in evolution and it can be found in a huge range of organisms. Their project required a mammalian cell line to provide them a sufficiently sophisticated system to study. However, whether those cells were derived from a human, monkey, or dog was insignificant to the way their experiment was performed in the laboratory. They echoed Addison's earlier assertions that the provenance of cell lines was just "not relevant"[39].

4.5.5 Practising practical ontologies

[39] Here, it should be noted that the participant was also a seasoned researcher, albeit relatively new to cell culture at the time.

However, human enactments of absence extend beyond merely not knowing - or misremembering - the human provenance of a cell line. Such enactments are *actively* and knowingly negotiated into absence because of a lack of significance. They are actively elided from practical achievements, or practical ontologies.

One lunchtime, Maxwell was designing a genetic construct he hoped would accomplish a specific phenotypic response in his cells. He had identified a gene of interest (GOI) and needed its genetic sequence information to enable him to design an experiment to cleave a copy from an existing cellular genome. At his computer, he navigated to a global database of genetic information (the NCBI[40]). As Maxwell keyed in the name of his desired gene into the search bar ("MET"), a list of results returned, all characterised by their organism context. Amongst the results, there was his 'homo sapiens' GOI:

> Organisms: Homo sapiens.
> Lineage: Eukaryoata; Metazoa; Chordata; Crainiata; Vertebrata; Euteleostomi; Mammalia; Eutheria; Euarchontogilres; Primates; Haplorrhini; Catarrhini; Homindae; Homo.

The NCBI database contains a huge amount of molecular data. Its repository dedicated to genes alone contains 1.65 billion genetic sequences. Handling such a vast set of information necessarily requires a standard way of sorting and ordering biological information. The most common approach to such large-scale curation needs utilises phylogenetic systems based on organism (provenance) and species designations (phylogenetic) (Leonelli, 2012:224). Such organism and species designations serve a valuable sorting and ordering function. Not only do they surface genetic sequences in relation to their own developmental origins, but they also create resonance with the myriad other samples, specimens, data records and digital representations with which they share a designation. In this way, it offers a classification system that is legible for a diverse set of scientific communities (Leonelli, 2012) as well as being relevant to biomedically focused repositories (such as the NCBI) by making accessible the relationship of various gene to human biology, and the families of genes related to particular human disease pathologies. Here, Maxwell's MET gene enacted not only its own developmental lineage into presence, but also its wider 'extroverted relations' to the broader evolutionary context and myriad other genetic sequences.

[40] National Center for Biotechnology Information (NCBI): https://www.ncbi.nlm.nih.gov

We return to this resonance and integration into wider community performances in Chapter 6. However, whilst such evolutionary and developmental enactments perform a vital function *within* such shared scientific communities (Leonelli, 2012), they have little significance in the specific laboratory practices of the four MSB projects. Indeed, laboratories are explicitly predicated on the idea that any number of materialities can be configured and reconfigured into objects that are more suitable and 'workable' for the project work (Knorr-Cetina, 1995), they are a 'technology of intervention' (Hacking, 1992). In a previous discussion about his human-derived cells, Maxwell had already told me that his experimental work was: "nothing to *do* with looking at the cells" and was instead all about demonstrating "*control*". Here, he demonstrated that his experimental work also had little need of the gene's potential human enactment either. At a blistering pace only achieved by well-rehearsed familiarity, Maxwell ignored all the potential evolutionary links, biomedical information about the multiple human cancers related to this gene and navigated to the 'reference sequence' of the MET gene's record. He opened a digital copy of the sequence information and turned to his second screen where a sophisticated genetic software programme lay open. This software already contained many of his other project materials including plasmid designs, other gene sequence files, diagrams, annotations, and more.

At this point, Maxwell's computer screens presented an interesting contrast. On the left-hand screen was the digitalised human gene within the NCBI database, contextualised through its place in the broader evolutionary record and entrenched in information about its biomedical importance. On the right-hand screen lay open Maxwell's own project-specific 'scrapbook' of digitalised gene sequences, DNA segments, RNAs and more, all contextualised by their utility to Maxwell's experimental activities. There was not a species designation in sight. Instead, what related these fragments was how they related to each other, not their evolutionary relationships. These were the relationships that served a useful function for Maxwell, not those born of their phylogenetic and provenance origins. As Maxwell, imported the MET gene sequence into this new set of situated materialities, it became an uncomplicated and unproblematic 'technical object' (Rheinberger, 1997), finding a new home amongst the small lifeworlds of plasmid designs, primer sequences, promotors, reporters, other gene sequences, and more. I would later find its developmental origins buried in metadata, but as Maxwell confirmed, the human enactments of the gene served no useful function. Instead, it simply became performed as "Met" or "c-Met" (this gene can also be found in 363 other jawed vertebrates so its human derivation could not be assumed), "scatter factor", the "GoI"

(gene of interest), an “insert”, a “sequence”, or other relational and more practically useful enactments.

This small episode stands representative of a wider practice across laboratory performances. Across all four projects, biological materials (both physical and digital) are gathered into the laboratory from an array of wider scientific infrastructures. Through the laboratory performances they are configured as specific ‘materialities situated in practice’, or practical ontologies (Jensen, 2010; Gad et al, 2015). Rarely did these ‘practical ontologies’ enact human performances. The overwhelming majority of performances of biological materials ‘other’ any potential enactment of human provenance, phylogenetic designation, or physiological characteristics. This othering is not only because they served negligible useful purpose or function in the experimental performances, but also because they were often incompatible with alternative enactments that did serve a useful function. Where different potential materialities jostle for attention in the laboratory performances (Hetherington, 1997), different enactments of the experimental components are often in competition with each other. To foreground one is necessarily to prevent another.

There are two types of biological material performances to emerge more useful than human ones. The first is a ‘functional’ enactment of biological materials. This is where performances of biological materials - and the systems being engineered as a result - foreground molecular functionality and phenotypic behaviours. For example, instead of ‘HEK cells’, an experiments’ cell lines are performed through the functionality which has been engineered into them. For example, “cdh1s” or “cdh3s” (HEK cell lines engineered to express the cdh1 or cdh3 adhesion gene), of “feeder cells” or “receiver cells”. Such performances foreground the new functionality to not only differentiate them from each other, but also establish the relations between them and situate the experimental component through terms that have meaning in the broader set of experimental materialities and actions. Early on, I had enquired of one participant why he did not refer to his as HEK cells and he had looked confused. It wasn’t about the HEK cells, he had told me. That meant nothing to the experiment. ‘Sure, they’re adherent cells, and naïve cells, that’s useful’, he had patiently explained, but the experiment was about the functionality being engineered into them, why would he make sense of the cells through a lineage that served no purpose in their laboratory performances when there were more meaningful differentiators and identities?

The second useful enactment is production related. These emphasise methods and means of production. Sometimes this can be more useful than functional

performances, especially during experiments with multiple conditions tested simultaneously. For example, a single cell engineered cell line ("cdh1s") might have produced multiple clones for testing. Under these circumstances, the performances that emphasise components by their functionality ("cdh1s" or "cdh3s") is sufficient. Instead, the biological components emerged as "Clone 3", "Clone 7" and "Clone 11". This foregrounded the methods of their production through which to differentiate and 'relate' them. Elsewhere a clone might be taken forward into a new line of experiment as stabilised cell line itself. In doing it becomes "A17"; for example, Project D44's 'A17' cell line stands for Addison's 17th experiment. This discursive performance brings to presence more than just the successful clone, but the practitioner and the experimental attempt as well. This type of enactment situates it into the context of other experimental attempts, the wheelhouse of Addison's contribution, and stands as a token for what worked and what didn't. As Knorr-Cetina (2001) observes: each biological performance does not enact some 'essential' or 'universal' identity, but instead emerged as "[…] a way to punctuate the flux, to bracket and ignore differences to declare them as point to an identity-for-a-particular-purpose" (2001:193). I would add to this, 'within-a-situated-set-of-materialities' if it didn't make for such an unwieldy adaptation.

These functional and production related 'practical ontologies' also extend to the way that biological materials are processed and stored. Inside freezers, project biomaterials were grouped together and stored in relation to the "Ghosts of projects past", ordered by older project components as "libraries" of parts (genetic devices, components, 'modules'). Fridge shelves were organised by materials belonging to specific practitioners and projects, and boxes and boxes of vials in the freezer were labelled in terms of the functional components they contain. There are some exceptions to functional and production related modes of sorting and ordering. Recall the two incubators from Lab 002, one for DT40 chicken cells and one for human cells. In these cases, the cells *do* entangle a human performance whilst in the incubators; they require 37 degrees for incubation and the chicken cells require 39 degrees. Labelling the incubators in terms of what differentiates them (the different origins of cell lines) acts as the quickest way to differentiate the two sets of experimental conditions. However, such enactments "by design and habit, tend to fade into the woodwork" (Bowker and Star, 1999:34). Participants instead focused on the *function* such a label performs (differentiating incubators), rather than any identity work that might be performed through its content.

4.5.6 Characterising absence

Once again, there emerge two interlinked ways in which human appearances are othered from the laboratory. Firstly, they are negotiated out of the small lifeworlds of the experimentally focused laboratory; secondly, they are negotiated into alternative places of belonging through extroverted relations. Both actions are again entrenched in notions of place: both the 'sense' of what belongs in specific places and their spatial and temporal dimensions. Routinely, potential human entanglements are negotiated into absence through a range of spatial and temporal discursive devices in line with the normative assumptions and expectations associated with places' 'social spaces' (Agnew, 2011).

For example, specific donor or source humans (such as the 35-year-old fibrosarcoma donor of the HT1080 cell line) are near-universally performed as belonging to the past. The donors, or the generalised human organism they stand in for, are identified variably as "the origin", "the source", "where [biomaterials] came from", or the "background" of the cells. These associations form part of the extroverted relations (Massey, 1994) that typically only emerge when 'stepping back' to consider the broader dimensions of the four projects. Such discursive performances distance real-time project materialities from discrete periods of time in the past - "ages ago" (Rachel) or "back in the 1970s" (Maxwell) – where cell lines were "derived from" their original donors. In doing so, these performances continue to draw on linearised conceptions of time as 'clock time' (Adam, 1990) where it is possible to hold different temporalities as linearly ordered and distinct along a 'temporal line'. These terms not only create a separation between the biological materials and their originating contexts, but they also strengthen associations of human donors and sources as belonging in the past. The human provenance enactments of biological materials relate to a distant past, rather than having currency or being a matter of consideration in real-time project performances.

Elsewhere, biological materials designated as phylogenetically 'human' are othered in different ways. They are often othered to areas of spatial adjacency, to be found in the resources of the wider scientific community (such as the NCBI database) from which participants can 'gather' what they need ready for reconfiguration and utility in the laboratory. In line with Cresswell's (2014) assertion that places gather and disperse, participants talk of "ordering in from", or "downloading from" such databases and repositories. In much the same way that donors of cell line technologies are designated as belonging in the past, repositories are positioned as spatially distinct places in the present, useful with which to intermittingly secure project components for reconfiguration through the small laboratory lifeworlds, but ultimately places that are separate to the laboratory. This also continues to draw on

notions of ‘regional’ space where human appearances can be distributed and held separate from any potential competing enactments (Law and Mol, 2001).

As outlined above, there do emerge some human appearances amongst the comparisons with endogenous human physiological exemplars and differently labelled incubators. However, any such enactment is either fleeting (in the case or comparisons) or rendered invisible through routine (as is the case for incubator labels). Instead, there emerge many more instances where potential human enactments of biological materials are othered. Against the overwhelming negotiation of potential human performances into absence from the laboratory, the occasional (and often overlooked) human enactments of project biological materials barely register in the associative connections and attachments generating a participants’ ‘sense’ of the experimentally focused laboratory. Nearly all potential human enactments of biological materials are seen as belonging to “natural” settings: “*human* human” biological materials are those found “in nature”, or ones that can be considered “endogenous” (within the organism). The distinction between the ‘engineered’ – or the ‘technical’ - and ‘the natural’ is often invoked here. Human enactments of biological materials are associated with ‘natural’ realm therefore incompatible with the laboratory as a technology of intervention (Hacking, 1992). As James told me, the biological materials are “not *really* human” because “they do not reflect anything that we see happening naturally”.

As with the potential human enactments and entanglements of project outcomes, the potential human appearances relating to project biomaterials have limited function in the small project lifeworlds. They are typically elided in favour of more useful functional and production-related enactments and are thus performed as distinct and ‘other’ to experimentally focused laboratories. Through repetition of experimental labour and laboratory configuration, project performances enact the experimentally focused laboratory as a place of absence in relation to any performance of specifically *human* biological materials.

4.6 Negotiating human practitioners: “there’s a time and a place for that”

4.6.1 Introducing practitioners

The final cluster of project materials through which potential human entanglements emerge encompasses the performance of the practitioners themselves. As outlined

in Section 2.3, it is not the intention of this work to explore practitioners *qua* practitioner performances *per se*. However, as we shall see in the following section, certain practitioner performances are an inextricable circumstance of how *other* human appearances emerge. As Rheinberger (1997) notes in Section 2.3, practitioners are cast in "inextricable relation" with their experimental objects, comprising part of an "ensemble of changing interactions" (1997:226-227). As part of that ensemble of changing interactions, practitioners can – and do – enact human performances, 'adapting' to themselves as human and foregrounding qualities considered 'uniquely human' (see discussion of Knorr-Cetina (1999) in Section 2.3). There are two key clusters of practitioner performances that emerge as human enactments. There are those that are valued positively: such as curiosity and its related notion of motivation; and creativity and its related trait of innovation. Then there are those that are valued negatively: these include fallibility, error, and the catch-all notion of 'subjectivity[41]'.

4.6.2 Negotiating the "ensemble of changing interactions" through curiosity and motivation

One of the first human practitioner performances to which I was introduced was that of positively valued enactments curiosity and related episodes of motivation. During the very first semi-structured interview I had with Maxwell, I had asked him what came to mind when he had thought about the human in the context of his work. He had underscored the importance of the "very human" trait of curiosity early on:

> "[B]efore you go into the experiment, there is definitely a human element involved. Because if Madelaine wasn't passionate about finding or demonstrating this concept that she had, or this idea, […] if I wasn't passionate about executing it, you wouldn't have a human element. I don't think any robot would think 'let's find out this answer'. The fact is you have a human behind the design of these experiments. Because without that, you wouldn't have curiosity. Because for me that curiosity is such a human thing. […] Why would I even bother with an experiment if I wasn't curious about the answers, that's very human to me. That's very basic".

Indeed, during my engagement with the study participants in the laboratory, nearly every practitioner demonstrated performances of curiosity in one form or another. From the almost excited design of experiments to the perplexing experiments yielding unexpected results and the curiosity (and frustration) driving practitioners

[41] 'Subjectivity' is an actors' category. It is not the remit of this thesis to interrogate their use and experience of 'subjectivities' instead to account for the enacted realities. However, it should not go unacknowledged that there is plenty of STS literature eschewing many of the notions of subjectivity that emerge from participants. Some of this is covered in Section 2.4.9.

towards answers. Curiosity provides a useful function; it catalyses action and is intimately linked to motivation (Sarukkai, 2009). It is often the 'unknown' that engages participants and keeps them motivated in projects. Participants are generally passionate about finding out if their techno-epistemic object (Rheinberger, 1997) can be made to work. As Rachel attests, it is the drive to see *if* something can be made to work that gets her out of bed each morning.

In the 'ensemble of changing interactions', practitioner enactments of curiosity and motivation are also intimately associated with other potential human appearances. A few months on from our first interview, Maxwell experienced a run of problematic experiments. One evening, whilst waiting for some immunostaining procedures to complete, he told me he drew on notions of potential human-related outcomes of his project to help. Here we encounter just one of the many inextricabilities of human practitioner performances with other human appearances. "So, I think I use the human [impact of this research on society] to motivate myself" Maxwell had explained. "Because one of the reasons I've remained-, I stay positive throughout the [troubles he'd been experiencing], is I have this very good ability of going back at the end of the day and seeing the big picture and then telling myself 'why am I doing this'. And it's never …. ". He paused, trying find the right words before starting again. "Right. A lot of people go home like '*why* am I doing this?'" he mimicked a plaintive tone. "But no. For me, it's like 'why am I *doing* this?'" He leaned forward assertively stressing his point. "It's a very objective question." It turned out that Maxwell was genuinely motivated by wanting to contribute to something worthwhile with his work. Accordingly, this gave him the drive to keep on with his problematic experiments and sparked the curiosity in how far he could take his patterning system. The repeated confounding results were made bearable through a mix of motivation, curiosity, and the drive to do something good.

4.6.3 Negotiating materialities with human enactments of creativity

Meanwhile, Rachel draws our attention to a second set of positively valued human-adapted practitioner enactments. In her first interview, she extolled the importance of enactments of creativity and the closely related innovation:

> "You've *got* to be creative, and that's a lot of synthetic biology, it's being creative. Because a lot of synthetic biology is you engineer *novel* things, whether you change what is already there and you change them in a novel way - that's one part - or the other part is you visualise a function of what you want a cell to do, you visualise and you engineer it to try to make it happen. There's a lot of creativity involved […]"

She went on to underscore her case by casting it into conversation with the 'central dogma' that scientists must be 'objective'. "It is partially true, and it's partially bullshit" she had declared. "It's true because that is the ideal of how we operate as scientists. *However,*" she emphasised, "we are not robots, we are *human* and – so, you *need* to have some creativity!"

Across the projects, human practitioner enactments of creativity routinely emerge and in doing so also perform work. Specifically, they too catalyse action. As Tomas reminds us, it is a "fundamental researcher goal" to "do something never done before". For example, in one episode, Madelaine, Maxwell, and Lewis set about devising a particularly creative solution to enable Project D43 to take microscopy images (requiring light) without disrupting their need for exclusively blue light. In other examples, Madelaine and a former colleague Abhishek had been inspired by a chance encounter with the separation of oil and water, making Madelaine wonder whether it might be possible to build 'phase-separation' patterning systems (those that ultimately underpin Project D42). Creativity and innovation mix with curiosity to catalyse action.

In materialising action, however, creativity and innovation also bring to presence specific material outputs, or practical ontologies. They are constitutive of specific configurations and experimental systems that become materialised as part of a practical achievement (Woolgar and Lezaun, 2013). For example, the replica chromosomes of Project D44 owe their existence to the creativity and doggedness of Tomas who engineered the precursors to Project D44 himself to circumvent a series of challenges he and his colleagues experienced in adequately investigating endogenous chromosomes. Motivated by the inaccessibility of their biological materials and curiosity in finding the answers, he and his colleagues sought to provide a solution to their problems by making their own chromosomes. As Rachel notes above: "you visualise a function of what you want a cell to do, you visualise, and you engineer it to try to make it happen". Human enactments of creativity and innovation generate realities; as Law and Lien (2013) observe, realities are enacted in practice.

Yet it is not human enactments of practitioner performances alone that combine to materialise these realities. The biological materials discussed in Section 4.5 emerge as co-collaborators in this process through the enactment of their own potential human entanglements. For example, one of the reasons Project D42 can be so creative in its patterning systems is because the HEK293 derivative cell lines it uses are *not* sufficiently 'human' to be regulated in their experimental usage as tightly as

other human biological materials (such as stem cells or patients' own cells). Through foregrounding their non-human physiological performance, they enable a greater remit of creativity. As Rachel explained that no-one seemed to care about engineering cell lines technologies:

> "There is less of an interest in cell lines, editing cell lines. Because a cell line is essentially a bunch of cells that have been immortalised one way or another […] nobody even cares if you play with them, so there's not, they're not many ethical implications, or - you know - big time effects of playing with such kind of systems".

In this way, the extent to which human practitioner enactments of creativity emerge is inseparable from the non-human practical ontologies of biological materials. Human -derived cell line technologies performing in ways that sidestep being treated as a 'regulatory object', or even an 'ethical thing' (Michael et al, 2005), actively co-constitute the scope for creativity and innovation with the experimental systems.

4.6.4 Negotiating "unscientific" human enactments into absence

Not all practitioner performances in these inextricable ensembles foreground such positively valued human-adapted practitioner enactments. I soon encountered some of the more negatively valued human-adapted performances that comprise project materialities in the laboratory. Across all four projects there emerges a group of closely related negative human enactments including "subjectivity", fallibility, and "human error". These are the performances of practitioners that are considered "unscientific", examples of "bias", or simple "errors". Multiple participants associate error and fallibility with human enactments, yet they associate success with "good science". As Rachel succinctly summarises: "when something goes wrong, I think 'Aaaargh, Rachel!' When something goes right, I think that was a good experiment". Meanwhile Madelaine and Maxwell are both very aware that human practitioners see patterns where they may not exist. "This is why we use maths" explained Maxwell, "[…] to your eyes it looks different, and you *want* to believe it's different. Even during the analysis, you want to *romanticise* what you did in the lab". The examples of fallibility, subjectivity, and errors attributed to human-adapted practitioner enactments are legion.

To mitigate such potential risk of human enactments, there emerge a variety of strategies to assemble "unscientific" human enactments into absence. For example, in her role as a Lab Technician, Deepti spends much of her time performing highly technical work. She prefers to keep focused on the matter at hand, focusing on the "little answer you're looking for" enough to keep her attention and sufficient

motivation to prevent the slips in attention that lead to error. Rachel has a theory that practitioners are actively trained out of engaging with potential human outcomes and other extroverted relations of their projects:

> "In order to become a researcher you need - we do not care about opinions, it's only *facts*. The facts, the *evidence* tells you want there is to be told. Researchers are horrible because they need to train their minds into trusting and relying only on the evidence that they lose that wider-, the, the balance of it with being philosophical and thinking about the wider implications of their work.'

In line with this idea of training negative human performances out of the laboratory, Maxwell explained to me how imperative it was to him to separate thinking about potential human outcomes of their project whilst performing experimental work:

> "If I [thought about the human], my whole PhD training is wasted. My whole *science* training is wasted because the whole point of science is to – or rather the whole point of conducting an experiment – is to be objective about it. I don't want to bring in any sort of biases […] So you just have to be-, you know, you have to leave all this human element that you see – if you're working on the human – to the end, when you've actually *done* your job. And *then* think about it. […]"

To 'leave all this human element to the end', Maxwell likes to talk to colleagues whilst they work, others listen to music.

4.6.5 A "time and place" for human practitioner enactments

Through these observations and conversations, it is increasingly apparent that there are many normative assumptions about where human-adapted practitioner performances are acceptable and where they are not. These normative associations centre on there being a "time and place" (Rachel) for human-adapted practitioner performances. Once again, we see human appearances entrenched in spatial and rhetorical discursive practices. Episodes of curiosity, creativity, innovation, intuition, motivation, and similar human appearances are located or 'placed' by participants into specific experimental stages, tasks, and physical locales. As we saw in Section 2.4, place is a common mode of sorting and ordering by 'distribution' (Mol, 2002:88). Contrasting material performances can be designated to different places of performance to hold any non-coherence apart and potential conflict apart. These again draw on notions of clock time (Adam, 1990) and corresponding regional performances of space that can be mapped out in three dimensions.

In one discussion, Rachel pondered on the “fine line” between productive subjective and affective practitioner performances and the negative ones and where they emerged. When it came to the experimental activities at the bench, she was unequivocal:

> “…[y]ou need to be unbiased, you need to be as objective as you can be and very logical. You cannot start making make-believe stories, you need to rely on your data because your data are records of facts. And facts are the *only* things that matter. For example, if I am handling a new cell line and it’s not behaving well, or it’s dying […] and I need to logically be able to delineate and diagnose. I cannot say ‘ah I feel it’s because of that’. What does it mean ‘I *feel’*? […] If I confidently *feel* that this thing is or should behave this certain way, that’s more like dogmatism and I’m relying too much on my emotions.”

Yet, when it comes to making experimental design decisions and innovating solutions to problems, Rachel argued the counter claim:

> “On the other hand, you need to have a sense of feeling, where, you know ‘if I put *this* with *that*, in that experiment, could it work?”

Rachel goes on to advocate for “intuition” and “playing around with” options and configurations, designing systems and assays to establish productive lines of experiment. Here, Rachel rationalised these competing performances by designating them to the different spatial and temporal parts of the experimental work. Whilst designing experiments, “a sense of feeling” is a productive human enactment to be foregrounded. Conversely, whilst performing and analysing experiments, a sense of feeling is not considered productive. In this way, we find evidence to support the assertion that when it comes to potential human appearances at least, notions of subjectivity and the self make key contributions to the sociomaterial associations of human enactments to places of belonging (see discussion of theorising ‘sense’ in Section 2.4.9).

Multiple participants mirror this distribution of expectations. As we can see from the quotes and observations encountered already, curiosity, creativity, and positively valued subjectivities and affective experiences are valued “before you go into the experiment” or “behind the design”. They emerge during “conceptual work”, “when making experimental design decisions” or in the activities of designing assays to probe potential lines of experimentation. Often episodes of creativity are to be found at the computer, drawing together connections between different functionalities, and taking bits from preceding projects. Innovation, meanwhile, can be found enacted in the collaborative discussions between colleagues attempting to troubleshoot challenges of apparatus limitations or unpredictable results. Creativity and curiosity

can also be found outside the laboratory, in the process of observing oil and water on a concrete floor sparking an idea for Madelaine and Abhishek's *de novo* patterning systems. What all these share, however, is placement into the spatial and temporal margins of experimental work: "*behind*" the design, "*before*" the experimental work, or "when you've actually *done* your job". Human enactments are rarely positively 'placed' into the technical experimentation work. As Maxwell asserts:

> "Bringing the human element into the technical bit of science would be a mistake. It's ok to do it before, when you're trying to design it and fund it. And it's ok to do it afterwards because you're trying to place it in the big picture. But during the experiments, no. It never occurs to me. Or rather, if it does, I try to take it out!"

Together with the desire to eliminate negatively valued human enactments, these expectations generate – and repeatedly entrench – an exclusion zone of human association at the heart of the bench-based experimental activities.

4.6.6 Combatting inextricability and complication through distribution and othering

Yet this spatial and temporal distribution of human appearances is not quite as clear cut as normative expectations for these project materialities, and practitioner behaviours would indicate. Given the inextricability of human practitioner performance from each other, other human appearances can complement – or complicate – each other.

Deepti, Addison, and Maxwell, all tell me that over time working with cell cultures, you see how they respond and "get a feel for how they grow". Experiencing experimental systems through subjective and affective means whilst working with them at the bench can indeed be productive, especially during episodes of troubleshooting or unpredictability. For example, when confronted with unruly experimental systems or results confounding expectations, participants tended to renegotiate their relationship with biological materials not only by emphasising their own human-adapted traits and affective experiences, but also by drawing on conceptual metaphors through which to render unpredictable biological performances 'legible' (Szymanski, 2018). Cells "refuse to grow", or "won't do as they're told". At one point, Maxwell joked that their HEK cell expression hosts were "very moody" and had "bad attitudes", concluding that "HEK cells are a bit stupid". Yet, setting his character assassination aside, Maxwell adapted his behaviour in line with these conceptualisations to productive effect. The likes, dislikes, attitudes and emotions of biological materials all used to render legible unpredictable and unfamiliar performances, help practitioners react sensitively, and navigate the

practitioner – biomaterial relationship on to more familiar territory. Human enactments are central to these behaviours. Indeed, Waytz et al (2010) identify that such behaviour not only renders objects more understandable, but also more predictable. Yet such behaviours are often apologetically dismissed as *ad hoc* transgressions with claims of "I know I shouldn't" made in regard to treating experimental systems in such ways (Maxwell).

Here, the inextricable human performances become subject to strategies to elide them from view where they are transgressing norms and 'do not belong'. Assembling any implicated human appearance into explicit absence, or othering, through explicit repression emerges as a core tactic amongst practitioners. As Maxwell explained, if he caught himself thinking about potential human outcomes of his work at the bench "I try to take it out". Human enactments of subjectivity and self materially constitute how other human materialities become associated with particular places. Zofia, Deepti, and Marek all intimated similar approaches. For example, returning to Maxwell's assertion that he uses the potential human outcomes and impact of his work to motivate himself, Maxwell was quick to caveat that he only considers them when he has finished the experiment.

> "And it is *only* during that time, *I* feel – and that's how I work as well – I introduce the human element, or the outcome and say 'what is the impact on society'. […] [a]nd sometimes it doesn't, it still doesn't come into account, because that's probably one experiment in a series of experiments without which it would be immature [sic] to conclude anything as an impact".

Yet repressing imaginations of potential human outcomes – or other inextricable human appearances - comes with consequences. In repressing a complicating human appearance (such as potential human outcomes of projects), participants can simultaneously repress productive or complementary human appearances that perform a useful function. For example, repressing reflection on potential human outcomes of projects, and othering them from the small lifeworlds, necessarily also others the motivational work they perform. As Addison explains there can be weeks or months that experiments might not work, or she can't see the light at the end of the tunnel whilst writing a publication. "But I think the problem is that we kind of focus so much in like this little problem [gesticulating a tiny amount], this little experiment that has to work, then you kind of lose the big picture". In this way, even human appearances that perform a valuable function in experimentally focused laboratory project performances can be elided from view if they contradict normative expectations of practitioner behaviour.

In previous sections exploring the human appearances entangled with project outcomes and biological materials, human appearances enact limited useful function. They are therefore typically elided in favour of more useful enactments. Correspondingly, they are performed as distinct and 'other' to experimentally focused laboratory performances. In this section, however, the human enactments of practitioners complicate this relationship. Human enactments *do* perform useful functions, they can help materialise innovative experimental configurations, catalyse action, improve understanding and legibility of experiments. Yet, there still emerges a specific "time and place" where such human enactments 'belong'. These tend to be performed at the periphery of the laboratory activities, rarely "the technical" experimental work at the bench. With such inextricability to other human appearances, here the repression of potential human enactments of practitioners only confounds the absence of other potential human appearances.

4.7 Assembling the experimental laboratory as a place of human absence

Throughout the chapter, we have routinely seen project participants discursively (both physically and linguistically) negotiate human appearances into places of 'belonging' that are often 'other' to the experimentally focused laboratory. Firstly, in relation to project outcomes. As most participants attest, their experimental work has "nothing to do with human application". Instead, potential human appearances are othered to alternative temporalities such as the future. In other cases, such outcomes are relegated to both other temporalities ("end of the day") and to a different, "unscientific" spatial realm. Secondly, when it comes to biological material performances, most human enactments are othered to alternative 'natural' or 'endogenous' places, such as "in nature" or in the "human body". Even when human appearances are associated with the experimentally focused laboratory – as is the case with some of the positively valued practitioner human enactments – these are often restricted to a "time and place" that operates at the periphery of experimental work: "behind the design" or "at the end, when you are done with your work". The vast majority of "the technical" work attempts to eliminate human performance.

This process of designation or sorting and ordering is underpinned – and thus brings to presence – underlying concepts of regional, or Euclidean notions of space (Law and Mol, 2001). As outlined in Section 2.4.5, the basic premise of regional space is that places correspond to regions in space, are durable, and can be geographically mapped. This, however, leaves no room for the possibility that places are constantly

changing, and shifting in time, composition, and space. At the same time, the designations are also enacting notions of clock time (Adam, 1990), a spatialised, abstracted notion that results in a linear view where pasts, presents, and futures are all situated sequentially along a linear 'line'. Similarly, this leaves no room for the alternative performative conceptualisation of time, where the past, present, and future are all created and recreated in a present (Adam, 1990:39). Human appearances are instead imagined as belonging to distinct and separable segments of time.

The persistent enactment of clock time, regional space, and designation of potential human enactments to specific places in space and time is emblematic of a romantic approach to materialities and complexity. Here it is useful to recall Kwa (2002) and Law (2004b)'s account of romantic complexity from Section 2.4.5. They argue that romantic approaches to the complexities of material arrangements designate different materialities as 'belonging' to different spaces and times. Everything has its place. It is these associations and attachments that afford specific and separable places their distinctive characteristics (Cresswell, 1996; Agnew, 2011).

Through consistent and repeated processes of othering, enactment of potential human appearances is positioned as insignificant at best - and incompatible at worst - with laboratory performances. As outlined in Section 2.4.8, these sociomaterial acts of associative connection (Law, 2004a) generates a set of attachments or 'sense' of the laboratory in relation to human appearances. The laboratory emerges as a place of human estrangement. These normative associations about what does and does not belong continue to configure the types of materialities that are performed to presence there (Cresswell, 2014). There emerge patterns of 'right' and 'wrong' human entanglements and enactments (Law, 2004a). Through repeated use of place to sort and order (Gieryn, 2000), these patterns of human appearances further entrench the norms, expectations, and value judgements that gave rise to them, deeper 'rooting' in the 'sense of place' and mediating performances of human materialities moving forward. Whether in relation to the imagined human outcomes of projects, the potential human enactments of biological materials, or the "very human" performances of practitioners themselves, the experimentally focused laboratory is assembled, performed, and perpetuated as a place of human absence.

4.8 Conclusion

In this chapter I have interrogated the experimentally focused laboratory performances for how the human appears. In doing so, I have produced an account of not only what human entanglements and enactments emerge, but how they emerge, the circumstances under which they emerge, and the work they do through their performance. In doing so, I have characterised how experimental laboratories emerge as places of human absence. This account takes the first step in building the empirical evidence we shall return to in Chapter 7. Additionally, it has furnished us with a robust understanding for how absence can be negotiated. Starting an investigation into an object of investigation by exploring its absence presents a methodological and narrative challenge. However, what is made present is dependent upon what is made absent (Law, 2004a; Hetherington, 1997) and this chapter has tackled this important aspect of human entanglement and enactment head on. This provides early access to valuable knowledge about the mechanisms through which absence and presence are negotiated that will enrich our understanding of how presence is made (and the trade-offs that occur) as we move forward. As we step through the other two empirical chapters dedicating more of their focus to what is made present, the knowledge acquired in this chapter about how the mechanisms negotiating presence also negotiate absence will help provide a richer understanding of the discussion to come.

And so, armed with these empirical findings and accompanying insights, it is to places of real-time MSB research organisation we turn next.

Chapter 5: Negotiating human orientation through 'organising units'

5.1 Introduction

Not all places of real-time MSB research are actively negotiated into places of human absence. Indeed, places of project organisation and management – places I term 'organising units' – explicitly foreground a specific set of potential human appearances through their performance The aim of this second empirical chapter is to provide a short and targeted account of the way the human emerges in the specific context of these organising unit performances. In doing so, I generate evidence of the ways in which human appearances emerge in the context of real-time MSB research as it is performed through places of organisation. Throughout the chapter, I demonstrate how a subset of potential human appearances is assembled in ways that emphasise project connections to notions of human health. Reviewing a range of organisational activities and institutional arrangements, I unpack how organising units not only enact a human presence, but also generate a directionality and orientation to their human enactments. In doing so, I conclude that organising units emerge as places of 'human orientation'.

To produce this account, I narrow my focus to an interrogation of two main clusters of project materialities (potential project outcomes and expectations, and the performance of project biomaterials) for how they work together to perform organising units as places of 'human orientation'. Through a synthesis of documentary evidence, participant observation, and data from semi-structured interviews and informal conversations, I analyse how the four case study projects are performed as part of organisation and management activities. This includes local practices within organising units (such as membership meetings and reporting) as well as activities that engage with distributed institutions (such as negotiating funding and priorities with Policy Groups and Research Councils).

I demonstrate that during organisational project performances, appeals to human health emerge as a core part of the promises and expectations made in relation to the potential project outcomes. Through these promises we routinely encounter two types of human enactments: imaginations and expectations about human health-related translational trajectories, and human physiology as a knowledge object. Promises encompassing both these types of human appearances perform work as

‘guiding visions’ that have ramifications on real-time research (Eames et al, 2006). Specifically, their appearance helps accomplish alignment between societal priorities and scientific programmes as well as mobilise resources. They also generate direction, a sense of momentum in the present, and an ‘extroverted’ orientation to imagined futures and broader applicability of work.

Next, I examine how organising units enact biological materials and their potential human appearances. Using a similar synthesis of evidence, I argue that biological systems (and the materials that comprise them) are valued for their biomedical relevance and performance as tokens for the potential human health-related outcomes. They emerge not as ‘techno-epistemic objects’, but instead perform work as ‘collaborational things’ (Michael et al, 2005). Indeed, organising unit performances of biological materials tend to emerge as tokens of future human utility contributing to potential future human health-related trajectories; or tokens of broader human applicability, telling us something about endogenous human biology beyond the experimental systems themselves. These biomaterial performances elide other potential human appearances entangled with biological materials such as human-specific provenance, species designations, or physiological enactments. In doing so, a clear hierarchy emerges amongst the potential human appearances entangled with MSB organisational materialities. Those enacting past or experimentally focused biological performances ‘submit’ (Mol, 2002) to those associated with future human health outcomes or wider human applicability.

As I step through the organisational performances of MSB projects, I continue to observe additional patterns relating to human performances. For example, I observe that human appearances performing a useful function are typically foregrounded, and human appearances can both complement and complicate each other’s appearances. Most significantly, however, I observe yet more evidence of human appearances being entrenched in notions of place. Firstly, organising units are associated as places where human enactments ‘belong’ and perform valuable work through their presence. Human appearances are not only associated with these performances, but they are also actively expected here. Secondly, the types of human appearances that emerge enact an ‘extroverted’ orientation towards future human health related outcomes and broader human applicability. They therefore enact a far broader, ‘extroverted’ (Massey, 1994) set of relations into presence. Through these performances, they do not merely enact a presence; they enact an orientation to the extroverted temporal and spatial human appearances. In this way, I conclude that organising units are performed as places of ‘human orientation’.

5.2 Introducing ‘organising units’

5.2.1 Organisational structures

An ‘organising unit’ can be understood as the organising body through which the four MSB projects are delivered, organised, and managed. In this way, projects and organising units co-constitute each other. Projects are only capable of being materialised with – and through – the organisational resources and equipment of their organising units. Meanwhile organising units are only capable of being materialised through the individuated projects and experimentation that comprise them.

In Section 4.2, we encountered the idea that the laboratory operates a ‘two-tier’ system, or ‘dual-structure’ (Knorr-Cetina, 1999:226). The first type of laboratory is configured in ways that enable the successful experimental performance of projects. This was the subject matter of Chapter 4. The second type of laboratory is configured and reconfigured in ways that enable the successful organisation and management of the projects as a coherent portfolio of work. Individuated projects are managed as part of laboratory that is acting as a “whole” (Knorr-Cetina, 1999:226). Specifically, the laboratory materialities, practices, and meanings are performed in such a way to enact the laboratory’s overarching research themes (not just an individual projects’ themes), anticipate future directions of work, initiate new projects, and negotiate resources. It involves balancing research themes, providing direction to projects, motivating teams, and managing the operational requirements of projects; all in the ‘here and now’ of unfolding MSB research. *This* is the laboratory that operates as an ‘organising unit’, typically managed by the Principal Investigators.

These laboratories operating as a ‘whole’, are not the only organising units associated with the case study projects. In Section 3.3.3, I introduced the case study projects as being funded (at least in part) by the specialist synthetic biology Institute. The Institute is also configured to manage an array of projects into a coherent programme of work. This time, however, the member projects do not belong to a single laboratory, instead they span multiple laboratories; what unites them is their use of specific SB techniques. The four case study projects enact membership to both their organising laboratory *and* the Institute. Whilst there is much overlap between the activities of the two organising units and what they offer the project, the Institute is broadly responsible for co-ordinating the ‘what and when’ of projects

(such as negotiating project aims, making funds available, and providing oversight and direction), whilst the laboratories are responsible for managing the day-to-day 'what and how' of the project work.

During these activities, organising units perform projects as real-time discursive enactments. These complement the experimental enactments of Chapter 4 to generate an additional set of real-time MSB research realities (Fairclough, 1992). Bacchi and Bonham (2014) remind us that discursive enactments are both rhetorical and physical in their manifestation (see Section 2.3.3). We encounter both during organising unit performances. Rhetorically, projects are performed through grant applications, departmental brochures online, and a miscellany of annual reports, strategy documents, and job adverts that are circulating. Physically, projects are performed through the institutional arrangements of projects into workstreams, as well as organisation of meetings, events, strategy sessions, attendance at conferences and more.

To begin this Chapter's exploration into human appearances in the context of MSB organising unit performances, we turn out attention to one of the Institute's rhetorical enactments of the projects: the important activity of negotiating the projects into being and how work done in 2014 still continues to sustain and frame research projects in real-time.

5.3: Negotiating a 'Case for Support'

> "Mammalian SB holds vast promise in diagnostics, to provide tools to identify and rapidly interrupt disease." (Case for Support, 2014:1)

5.3.1 Promising human health-related outcomes

Long before the experimental lives of each of my four case study projects either began (D42 and D43) or became explicitly configured into 'mammalian synthetic biology' projects (D41 and D44), their organisational lives were already being negotiated through a series of activities between the Institute's Leadership Group and a collection of UK Research Councils. In 2012, David Willets (the then UK Minister of State for Universities and Science) announced that the UK could be "world-leading" in synthetic biology technologies (Willets, 2012) and over £100 million had been made available to support a new initiative, the 'Synthetic Biology for Growth Programme' or 'SBfG' (BBSRC, 2012; BBSRC, 2013). This initiative was

managed through a combination of UK funding bodies comprised of the Biotechnology and Biological Sciences Research Council (BBSRC), Engineering and Physical Sciences Research Council (EPSRC), and the Medical Research Council (MRC). In 2014, the Institute's Leadership Group produced a 'Case for Support' to fund a sizeable programme of SB work through the SBfG's available funds. The proposal centred around creating a new SB organisation (the Institute) with an ambitious plan to realise the 'full potential' of MSB in relation to biomedical tooling and application.

Running to twenty pages, human appearances were in abundance throughout the report. By way of framing the opportunity available, the proposal outlined the "vast promise" that SB (and by extension MSB) technologies offered in human health-related fields, declaring the "time is now right for mammalian SB to become a key enabling technology for advances in biotechnology, medicine and for addressing biology in new ways" (Case for Support, 2014:1). To illustrate this claim, the proposal highlighted a combination of existing research and future areas of opportunity in relation to human health. Arguing how SB and MSB could improve diagnostic capabilities and identify and interrupt disease, it listed possibilities of engineering cells to produce biologics, manipulating cells to explore epigenetic influence, and creating synthetic circuits and control systems capable of improving stem cell biology and regenerative medicine. Seeking to insinuate the Institute as part of this landscape, the Case for Support outlined a set of work packages that promised to improve biomedical tooling and applications in line with the 'health and wealth' opportunities of the wider SB field.

When it came to proposing individual projects for the initiative, the Case for Support assembled these potential human-health related opportunities as part of its proposed projects in the form of the 'long term possibilities' or 'ultimate goals' of projects. In doing so, the projects enacted a link between the experimental project outcomes and wider social priorities and opportunities. For example, Project D42 was performed in relation to its potential contribution to regenerative medicine:

> "Tools to allow mammalian cells to be engineered so that they can thrive in specific synthetic environments and provide niches for, for example, stem cell programming, would boost regenerative medicine, at first for research purposes and later for production and clinical use." (Case for Support, 2014:14)

Meanwhile, Project D44 was performed through its potential contribution to interrupt (and even 'correct for') disease:

> "The availability of [replica human chromosomes] that can be induced to form in any desired cell type, that can carry extremely large amounts of DNA and that can be "cured" from growing populations of cells provides unique possibilities for the correction of defects and for engineering predesigned complex traits." (Case for Support, 2014: 7)

Indeed, in relation to Project D42, the Case for Support elaborated the experimental systems proposed before concluding: "the long-term possibility of integrating synthetic transcriptional control with signals from a synthetic niche would potentially allow the directed design of human tissues". Here the proposed outputs from Project D42 were described as a "synthetic niche", something we saw in Section 4.4.5 Rachel had described as a "very far-fetched, holy grail goal" and something for which she considered her project as merely laying foundations. Throughout the entire 20-page document, these human-health related outcomes and opportunities underpinned the case to fund the Institute.

5.3.2 Early reflections

When I first analysed the Case for Support, I had been spending much of my time in the experimentally focused laboratories. This provided a lens of comparison to my initial review. I was surprised by the extent of the differences between project configurations negotiated into presence in the Case for Support and those I was experiencing in the experimentally focused laboratories. The proposal was filled with promises about the proposed projects' human-health related outcomes. Schyfter and Calvert (2015) offer a working definition of the promises made in SB as "rhetorical statements about what the field can deliver and what it will become if supported appropriately" (2015:363). As part of those rhetorical statements, human-health related project outcomes were emphasised (or "dialled up" as one participant described it) to paint a positive picture of potential project outcomes and what the Institute could achieve. As such, project performances explicitly enacted broader materialities, temporalities, and health related opportunities as part of their performances; they enacted 'extroverted relations' (Massey, 1994).

This contrasted starkly with the small lifeworld arrangements (Knorr-Cetina, 1999) I had been observing in the experimentally focused project performances. Indeed, by 'condensing' (Law, 2004a) these extroverted relations into places of organisation, there emerges a 'human orientation' to the project performances through the continued enactment of the rhetorical statements not witnessed during experimental laboratory configurations. Potential project outcomes that had been routinely excluded from the laboratory for being 'too far in the future', or - in the case of its

complicated relationship with practitioner motivation - “bad science” if allowed into the laboratory, become a central part of the ongoing performance of organising units. Whilst experimental laboratories actively assemble future-orientated human appearances into absence, organising unit performances actively assemble them in ways that not only enact them into being, but do so through extroverted relations that places them in an imminent future, generating an orientation to potential human outcomes (or ‘human orientation’ for short). The rest of this chapter unpacks the practices through which this occurs in more detail to better understand these instances of human appearance.

5.4 Assembling human-health orientated outcomes to negotiate value and resonance

> “Synthetic biology is being applied to gain insight into human health and disease and transform medicine and healthcare” (Institute Website, 2022)

5.4.1 Performing humans

The human-health related outcomes central to not only the Case for Support, but a wider array of organisational performances, bring to presence two types of potential human appearances. The first appears in the form of human health related translational opportunity. For example, generating patterning and signalling systems that could potentially “boost regenerative medicine” and “extend the capabilities of tissue engineering”. Another example includes developing screening tools that could help “identify potential chemotherapy agents”. Rarely are the areas of opportunity elaborated any further into specific, packaged applications (such as designer tissues, or gene therapies for monogenic diseases). There is also little to no elaboration of any potential future users or consumers of any future applications. The ’humans’ that underpin the concept of ‘health’ remain black-boxed. The potential appearances count as human by the merit of their intended use, but the focus remains on the technical trajectories; need and desirability are largely assumed, as Maxwell demonstrated when he unquestionably explained “everything does translate into the human eventually”.

Once again, we know from Kohl and Falk (2019) that as well as pursuing potential health related applications, the investigation of biological phenomena also forms an inextricable part of SB research. Indeed, as part of the organisational project enactments in this study, promises are also made to improve human-health related

knowledge. This gives us the second type of human appearance, that of human physiology as a knowledge object. Typically, these knowledge objects are performed to presence as loosely defined areas of epistemic opportunity (such as improved understanding of developmental biology, or better understanding of chromosomal segregation) rather than specifically detailed gaps.

Both these types of potential human appearances lack physical realisation. They are prospective, and therefore necessarily only emerge as imaginations of potential outcomes rather than outputs physically accomplished. Yet it should be noted that their presence as imaginations makes them no less real or useful. They remain practical achievements (Woolgar and Lezaun, 2013), part of the organising units' practical ontologies, precisely because they serve a useful function in the present.

5.4.2 Negotiating 'doable' problems and resonance with societal priorities

Projects need to be 'doable' for them to gain traction and become viable research initiatives (Fujimura, 1987) (see Section 2.3). In Chapter 4, we already saw how participants negotiated their projects and experimental systems to be *technically* 'doable' through 'workable' materialities and practical ontologies (Jensen et al, 2010). However, projects also need to 'align' - or resonate - with the larger 'social world' beyond their own experimental work (Fujimura, 1987; Clarke, 1998). The potential human-health related outcomes of the case study projects play a key role in negotiating this resonance.

Indeed, the imaginations of human-health related outcomes that emerge through promissory rhetoric and expectations of the future can be considered 'guiding visions' (Eames et al, 2006). Guiding visions perform work in the present in four main ways (see Section 2.3.2). The first is by enacting imaginations of possible future worlds in ways that connect the priorities and expectations of the 'social worlds' with the priorities and promises of the projects' 'experimental worlds'. This creates mutually agreed upon agendas out of shared priorities (Eames et al, 2006). Taking Project D42 as an example, the "holy grail goal" of 'synthetic niches' to enable "directed design of human tissues" is insignificant to the success of experimental work. However, it *is* significant to the alignment of that experimental work to broader societal priorities and opportunities. Performing Project D42 through its potential human-health related outcomes generates resonance between the promises of the experimental worlds and the priorities of wider extra-scientific communities (Clarke and Fujimura, 1992:8). As Rachel herself points out whilst evaluating the way her

project is organised - albeit partially tongue-in-cheek - “what other than sex-, I mean the human, sells?”.

Secondly, this resonance and shared agenda stimulates resources and support as demonstrated by their centrality in the ultimately successful case of the Institute’s Case for Support and ongoing work today. In 2014, the Institute was funded by the BBSRC, EPSRC and MRC, and the UK Research Council’s SBfG Programme. Visions that relate in some way to ‘human health’ have been a dominant frame for the life sciences for decades. Since the 1970s, research into diseased (and healthy) bodies were as generative of scientific research as the military had been in the preceding decades (Agar, 2012:435). Results from life sciences research were increasingly widely reported, and there emerged a raft of social and technical advances that increased scientists’ capabilities in the field. These included the advent of recombinant DNA technologies, increased privatisation of molecular biology projects (the ‘biotechnology boom’), a reorganisation of the pharmaceutical industry into ‘giant multi-national’ corporations (‘big Pharma’) and a trend towards information technology and automation inclusion in the life sciences (Agar, 2012:426-443). Under such influences - and catalysed by a ‘sea change’ of priorities since the end of the cold war (including President Nixon’s ‘war on cancer’) - the Life Sciences became “the working world of sustaining human health” (Agar, 2012:466).

Synthetic biology follows in the footsteps of this well-worn tradition. In 2012, the UK Roadmap for Synthetic Biology was published (SBRCG, 2012), and amongst its 34 pages, it provided an overarching vision for the areas of opportunity in which it was interested. First and foremost, this included notions of health, wellbeing, and prevention of disease:

> “Potential applications of synthetic biology arise wherever biological systems play a role, or could play a role in the future. Fields of increasing interest at individual and societal levels include well-being (such as prediction and prevention of diseases, personalised healthcare, improved lifestyle, employment), security (including food, water and energy security) and sustainability (meeting the challenges of managing natural resources, reducing dependence on non-renewable resources and finding ways to mitigate climate change” (SBRCG, 2012:6)

This is not just the case for the SB-specific Institute and its Case for Support. Madelaine provides us another example of the utility of emphasising project outcomes in relation to her laboratory’s SB projects. She convivially suggests that emphasising the “medical links” of the Garcia Lab projects such as “building artificial kidneys for regenerative medicine purposes” is useful for stimulating interest and

funds. In the UK there is high demand for kidney transplants, in part driven by a shortage of viable organs and protracted waiting times. As several members of the Garcia Lab note, there is a pressing need to find ways to address these shortages, whether through repairing damaged kidney tissue or assembling new kidney tissues or organs through 'directed design'. The latter is of particular interest to the fields of regenerative medicine making it an attractive proposition for funding agencies to support.

Such health-related imaginations are not just about individual or societal wellbeing; they are also about wealth[42]. Across the SB policy literature, health discourse has been increasingly accompanied by political and economic discourse regarding SB's value at the intersection between biotechnology and engineering (Kearnes, 2013:455). Indeed, the SBUK roadmap outlines that "[a]s synthetic biology starts to play an increasing role in medicines and healthcare, it is becoming possible to assess the global scale of the future market, at least in the near future". It estimates that "€5bn may be added to the European bio-economy by 2025 from ongoing research activities" (SBRCG, 2012:7). Imaginations of human-health orientated project outcomes not only negotiate alignment to these health priorities, but also resonate with wealth priorities.

5.4.3 Setting direction and generating momentum

The utility of human health-related outcomes in negotiating shared agendas and resonance with wider societal priorities and using those to stimulate resources can best be described as 'collaborational work' (Michael et al, 2005). Potential human health-related outcomes tease open and catalyse interest from a variety of different collaborators and institutions around the same areas of health (and thus wealth) opportunity. In doing so, they generate productive material arrangements of structural support and interested parties. However, there are also two additional useful functions they enact that is better described as epistemic work.

Firstly, the potential outcomes provide direction and meaning to the parties and projects involved. They shape research in line with shared commitments and agendas, prioritising potential directions and trajectories to pursue. Secondly, and simultaneously, they generate a sense of momentum for the 'way things are going' in the field more generally (Eames et al, 2006). For example, the human health-related

[42] This sees SB follow in the wake of other biotechnologies such as stem cell therapies and regenerative medicine practices that emphasise both 'health and wealth' deliverables (Franklin, 2013:6).

outcomes promised in the Case for Support emerge renegotiated into the context of experimental project enactments as project 'aims' or 'ultimate goals'. It is these promises that materialise the requirement of all four projects to connect to human health-related outcomes in some way. For example, in Section 4.5.3 Addison explained the requirements of her experimental systems and how she could not modify her replica chromosomes too much because they still needed to be "representative of what's actually happening" in endogenous human chromosomes. It is that resonance with existing human biology that enables Project D44 to contribute useful knowledge about the way human chromosomes work and potentially end up as viable additional chromosomes in human cells in the future. Only through negotiating a balance between technically workable replica chromosomes and sufficient similarity to endogenous human chromosomes can Project D44 continue to deliver on its broader human health orientated commitments.

In conjunction with both their collaborational and epistemic work, the imaginations of human health-related outcomes also act as the basis for sorting and ordering institutional arrangements of the organising units themselves (Schyfter and Calvert, 2015:378). Research projects are characterised by - and sorted and ordered into – workstreams based on the types of potential human-health orientated outcomes they might enable (in line with the logic of delivery discussed in Section 3.2). For example, the Institute has three 'research' workstreams[43] into which the research projects they comprise are arranged. There emerge several ways in which the research projects are organised, but one of the more prevalent is through their potential outcomes. Projects that have potential biomedical outcomes (such as the regenerative medicine boosting Garcia Lab projects) are organised into a workstream aiming to deliver "non-clinical biotechnological applications". Meanwhile, projects that have clinically focused – or near-future clinical – outcomes and applications are grouped into a workstream aiming to deliver "medical applications". A third set of projects focused on building tools and technologies that could be used by other workstreams (such as the Meier Lab's replica chromosomes) are organised into a "tooling" workstream.

Institutional arrangements such as these are repeated through an array of discursive performances. They can be found replicated in physical form, such as in the frequent stakeholder update meetings or strategy days where project presentations are physically grouped and structured in meeting agendas in line with their outcome-

[43] There are also other work packages for initiatives such as RRI and standardisation that do not form part of the "Research" workstreams.

orientated workstreams. Similarly, they can be found replicated in rhetorical performances grouping project enactments in annual reports, all-Institute updates, and other grey literature such as promotional material, portfolio websites, and more. Bensaude-Vincent (2013:23) argues that human-health orientated outcomes emerge as an "integral part of the technoepistemic culture of synthetic biology", I include structural organisation as part of that culture. During these enactments, human health-related project outcomes are repeatedly reinforced to generate an enduring and directional 'orientation' towards human outcomes as part of the organising unit project performances.

5.4.4 Characterising 'human orientation'

It should be noted that the enduring performances of orientation to human outcomes does not lead to uniform human appearances. There does exist some variation between the organising units in the way that such 'human orientation' is performed. One axis of variation operates around the types of human appearances that are foregrounded. Different organising units tend to emphasise different types of human appearances. Synthetic biology emerged at a time of "increased pressure" on academics to generate research impact (Meckin, 2016:234). Therefore, Institute guiding visions and promises foreground human health related outcomes that "deliver impact". These can include human-health related knowledge outcomes (if they can be coupled to potential biomedical contribution or novel productive collaborations) but most often they foreground potential future human health-related applications in their visions. Conversely, the laboratories that act as an organising unit - 'organising laboratories' - take a different approach. In both the Garcia and Meier Lab project performances, the focus on 'delivering impact' is tempered by an increased focus on the epistemic value of better understanding hitherto unknown aspects of human physiology beyond making synthetic biology products. As Madelaine apparently once had pinned on her laboratory noticeboard: "Science is like sex. Sure, it may give some practical results, but that's not why we do it." For Madelaine, the 'medical links' of her projects are "almost accidental".

A second axis of variation is in the way human health-related outcomes are elaborated. They are elucidated in terms of the areas of opportunity they enact rather than specific outputs. Imaginations of human-health related outcomes can emerge as 'territory' based opportunities, for example, opportunities to "build and exploit synergies between synthetic biology, stem cell science and regenerative medicine" (Institute Annual Report, 2018). Alternatively, they can appear as 'epistemic domain' based opportunities, such as better understanding "how centromere chromatin is

assembled, organised and dissembled during mitosis" (Meier Lab Portfolio, 2020). Finally, they can emerge as 'biomedical capability' based opportunities, for example Project D44's replica chromosome offering "new mechanisms for screening" (Institute Annual Report, 2018).

As already identified, human health-related outcomes nearly always enact loosely elaborated outcomes in the form of 'areas of opportunity', rather than specifically elaborated *outputs*. Eames et al (2006) argue that 'vague' guiding visions are left open during agenda building to afford "interpretive flexibility" that makes it easier to accomplish consensus (2006:367-368). Elaborating in too much detail can be unproductive and creates opportunities for roadblocks, challenges, and obstacles (Michael et al, 2005). Martin and Turkmendag (2021) cite Fish (2015) when they suggest biological research linked with health applications can be considered a 'moral-technical imaginary'. Coupling projects too concretely with health outcomes opens opportunity for contestation of normative judgements they enact. As Rachel would tell me, she tended to keep her potential project outcomes loosely elaborated when talking to stem cell scientists; her naïve cell line technologies would not be suitable for clinical application nor long-range outcomes. Keeping elaboration loose allows interested parties latitude to interpret the opportunities through their own institutional priorities, cultures, and priorities, whist avoiding elucidating of details that could otherwise foreclose productive collaborations.

Enacting human-health related areas of opportunity over applications also shifts where human appearances are discursively located. No longer are they "far in the future" at the point of translational application. They still emerge through 'extroverted relations' (Massey, 1994), but instead, they emerge entangled with spatially and temporally 'imminent' areas of *opportunity*. Despite ambiguity in relation to eventual outcomes, focusing on areas of opportunity rhetorically foreshortens the associations with potential human-health related outcomes. Repeated performance of organisational performances generates a temporal ambiguity and sense of 'imminence' to the potential human health related outcomes. For example, in the Garcia Lab Research Briefing (where her project portfolio is summarised), Madelaine declares the Garcia Lab uses: "organ culture, molecular biology, bioinformatics, synthetic biology and stem cell techniques to investigate mechanisms of tissue self-organisation, for basic science and for regenerative medicine". Here, both basic science and regenerative medicine emerge as present-day areas of opportunity.

Such a focus on human health related outcomes is not restricted to performances of project outcomes. It also applies to the way that the biological materials and outputs are performed to presence. It is to these we turn to next.

5.5: Instrumentalising biological materials and systems

> "New developments that use any kind of biological matter are seen as significant to human life, even revolutionary, because they (1) introduce a new therapeutic product, which affects humans by changing their health possibilities or longevity, or (2) suggest the same is true of human beings and bodies" (Landecker, 2007:224)

5.5.1 "Everything is human oriented inherently"

On the Institute's website, the opening line that introduces the Institute's approach to their research activities announces: "[The Institute] is building a capability in the design, construction and testing of synthetic components, integrated into the cellular host, to produce useful outputs in a robust and predictable manner". It then proceeds to list some examples of the types of tools upon which the Institute focuses (tools for cell-engineering, construction of DNA, and more), and draws attention to how these tools will not only advance understanding of biology but also generate products for commercialisation in line with its vision to improve healthcare and medicine.

These few short lines stand representative of many of the organising unit appearances of biological materials and systems: they focus less on the composition of the systems and more on human health-related outcomes they enable. As Madelaine explained, organising unit stakeholders (such as funders) are typically more interested in the 'why' of projects and what they can achieve, rather than 'what' of what is being built.

Rachel echoed this emphasis on the 'why' in her reflection of the SB field more broadly:

> "[W]ith synthetic biology […] we make a novel tool in terms of err, a synthetic protein, or a receptor system, that […] we can use it to … I don't know … elicit certain responses in cells. Why do you want to do this? Because you want to study something. Well, what is it that you want to study, something that will probably have a biochemical or biotechnological application? Even if you are playing in bacteria, and you say 'oh we're using synthetic biology to create metabolic pathways in order to you know gain certain, I don't know […] compounds or pharmaceuticals or whatever […] why do you want to do- use this? Because it has a purpose that fits the human.

> Pharmaceuticals are going to be used in humans, biotechnological outputs are going to be consumed by humans, therefore everything is human oriented inherently."

Indeed, there is nothing valuable about biological components *per se* (Birch and Tyfield, 2013). Instead, value and meaning comes from their relations with other components within their situated materialities (Jensen, 2010; Gad et al, 2015). In experimentally focused Laboratories, objects derive their value from their contribution to the experimental investigation (Rheinberger, 1997) (see Section 2.3.1). However, in organising unit performances, biological materials are instrumentalised through their 'extroverted' sets of relations; they enact value through their contribution to social priorities and longer-term human health related outcomes.

During organisational performances, project biomaterials are instrumentalised in ways that foreground them as 'tokens' of project outcomes in two ways. Firstly, by emphasising their relations with potential human-health related outcomes (thus demonstrating their human utility). Secondly, in ways that foreground their similarities to human biology through shared membership to the same grouping of 'mammalian' biology (demonstrating human applicability of any findings).

5.5.2 Practical achievements of human utility

The 'practical achievement' (Woolgar and Lezaun, 2013) of human utility is accomplished in three inter-linked ways.

Firstly, as we have seen, their organisational enactment rhetorically foregrounds associations with potential human-health related outcomes during project summaries. This entangles imaginations and expectations of desired futures into their biomaterial performances. Madelaine gives us another example when she summarises the Garcia Lab projects in relation to what they are designed to achieve:

> "[I]n order to test current theories of tissue development and to exten[d] the scope of tissue engineering, we are using synthetic biological techniques to program cells to generate designed (non-natural) patterns and forms, driven by artificial genetic modules."

During these enactments, biological materials are typically elaborated in relation to expectations and imaginations of the work that they do, rather than their own composition. This occurs through both the short summaries of projects (which arguably have little room for elaboration of any type), but also the more technically

detailed accounts of biological systems. For example, the following account of Project D44's replica chromosomes in the Institute's Case for Support elaborates on technical details that help better demonstrate their utility:

> "We will also create DNA arrays designed to assemble pericentromeric heterochromatin, to which other chromatin modifiers can be targeted. By assembling different combinations of these arrays, our plan is to create stable replica chromosomes in which both the kinetochore chromatin and the adjacent pericentromeric heterochromatin can be altered at will […] so that genes can be efficiently inserted *in vivo* if desired." (2014:6)

Secondly, biological materials are rhetorically performed to presence through a raft of engineering discourse[44] that explicitly frames them as "enabling technologies". This also generates a future orientation to their performance. From organisational documents to presentations to organising unit meetings, project biomaterials are routinely performed to presence as "tools", "toolkits", "synthetic control systems", "genetic circuits", "epigenetic tools", and more. These are then necessarily coupled with notions of utility (Strathern, 1991): they are tools *for* something. Specifically, they become tools for either 'territory' based areas of human health-related opportunity, such as improving regenerative medicine; or 'biomedical capabilities' based areas of opportunity, such as improving screening diagnostics. This engineering discourse streamlines complexity of the biological systems, eliding their experimental and biological lives in favour of what they *do* (O'Malley, et al, 2008:61).

Thirdly, biological materials and outputs are often performed as 'collaborational things' (Michael et al, 2005) (see Section 2.3.2.). They establish links between projects and potential collaborators, and in doing so, consolidate the rhetorical performances of utility through physical, institutional arrangements. For example, across the Institute's literature ranging from the Case for Support to routine updates and Annual Reports, the "tools" and project "outputs" from one project are performed to presence in relation to the way that other packages of work within the Institute can leverage them. They are not only rhetorically performed as 'enabling technologies', but they are also materially performed as such. For example, Tomas' replica chromosomes have been used by at least two other Principal Investigators as a method to deliver large amounts of DNA into a cell (one of its core capabilities) to help other projects in pursuit of their own human-health orientated goals. Elsewhere,

[44] Performing SB biological materials through engineering discourse is a well-documented phenomenon. It is not the aim of this thesis to further findings in this space. However, for further reading, please see Balmer and Hereman (2009), Hellsten and Nerlich (2011), McLeod and Nerlich (2017). These scholars - amongst others - write comprehensively of SB's metaphor usage, especially relating to its ethical dimensions and consequences.

Rachel also made some of the tools produced as part of Project D42 available to another non-synthetic biology project in the Garcia Lab. Some of this "tools" helped Lewis in experiments designed to better understand human kidney behaviour.

Expectations and imaginations of the future human-health related outcomes of project research objects are enacted in practice, and in doing so biological materials become tokens of their future utility.

5.5.3 Practical achievements of human applicability

As outlined in Section 2.3.2, not all expectations and imaginations of 'extroverted relations' are enacted through future temporalities. Some relate to the 'representational scope' of the biological materials and what they are seen to 'stand in for'. A biomaterial's "representational scope" describes the "extent to which researchers see their findings as applicable *across* organisms" (Ankeny and Leonelli, 2011:8). Organising unit performances of biological materials and systems enact a 'practical achievement' of human *applicability* through emphasising their representational *scope* rather than their representational *targets*. In this way, when not being performed as tokens of human utility, project biomaterials are performed in ways that broaden the epistemic domain and enact their applicability to stand in for endogenous human biology in the present.

Typically, this emerges through the rhetorical classification of biological materials as "mammalian". Across the organising units' discourse, project biomaterials and outcomes can routinely be found summarised as "mammalian systems" (when talking of project outputs), "mammalian cells" (when detailing the cellular hosts of biological systems), as well as "mammalian organs" or "mammalian tissue development" (when invoking future trajectories). "Mammalian" biological materials foreground their membership to a shared group of biological organisms encompassed by the phylogenetic category (class), '*Mammalia*'. As outlined in Section 4.5.2, phylogeny emphasises the similarities and differences of biological materials in relation to the evolutionary record. A phylogenetic designation sorts and orders by resemblance of shared features, it brackets together genetic similarities and differences across organisms, species, and populations (Bowker and Star, 1999). Consequently, members of this 'class' share significant similarities. In this way, performing biomaterials as mammalian designate their behaviours and findings as also being applicable to endogenous human biology by merit of belonging to the same shared category of biomaterials. In this way, it enacts the 'epistemic domain' based opportunities of potential human-health related outcomes.

An argument can be made that the emergence of mammalian phylogenetic designations simply acts to group similar materials via a collective term, without additional meaning. For example, each of the case study projects encompass a variety of biological material, including human-, canine-, and murine-derived cell lines as well as an array of other mammalian biological derivatives (such a donkey serum, mouse antibodies, and many more). Collectively, these can – and are – referred to through their collective phylogenetic class, “mammalian”. However, the significance stopping there can be refuted on two counts. Firstly, not all enactments of “mammalian cells” or “mammalian systems” correspond to collectives of biomaterial performances. Project biomaterials that could be performed in the singular (for example, the canine derived patterning systems in Project D43) are routinely designated as “mammalian” rather than “canine”. Secondly, as Madelaine explains, the significance lies in what the cells can tell us about potential human biology more broadly, not just those specific cells. As she posits in one of the Institute’s introductory texts on the matter: “Why - at less than 4% of the animal kingdom do mammals dominate biological research?” Answering the rhetorical question, she explains that because humans are mammals, research on mammalian systems provides important insight that is useful for medical research, as well as “satisfying our own curiosity about our own human condition”. Elsewhere, she would similarly explain that mammalian biology systems (mouse, rat, human, amongst others) are “biomedically relevant”, capable of interrogating “fundamental physiological mechanisms and pathways, from single genes to complex behaviour, relevant to normal human function and how disruption of these mechanisms lead to disease” (Garcia Lab’s Departmental Overview, 2019). ‘Mammalian’ signals a wider reach of value than just its use as a collective term.

5.5.4 Hierarchies of human appearances

During organisational activities, practical achievements of biological materials through their extroverted relations of future human utility or broader human applicability, foreground the same potential human appearances identified in Section 5.4.1. These include the loosely elaborated human-health related areas of translational opportunity that they enable (such as boosting regenerative medicine or extending the capabilities of tissue engineering). They also include the endogenous or natural human physiology that emerges as a knowledge object (such as better understanding of human chromosomal segregation). As potential project materialities jostle for enactment (Hetherington, 1997), foregrounding this set of material performances necessarily negotiates other potential enactments into absence.

Specifically, organising unit project performances ‘black-box’ (Law, 1986; Latour, 1999) research objects’ experimentally focused biological composition, behaviours, and complexities. They black-box the performance of the biomaterials as a ‘representational target’ (Ankeny and Leonelli, 2011). Recall from Section 2.3, the representational target are the biomaterial features for which experimental claims can directly be made. This means that functional and production-related enactments encountered in experimental laboratory performances (“clones”, “expression hosts”, “transgenes”, and more) as well as potential human appearances (such as those that relate to their provenance, specifically human phylogenetic designations, or physiological comparisons with endogenous human physiology as a result of their lineage) are typically elided from view. For example, in the case of the Garcia Lab projects, performing the biological materials as “mammalian systems” elides the specifically human developmental origins of some projects in favour of shared characteristics with wider mammalian systems in the present. As multiple participants explain, provenance alone does not guarantee human utility or applicability; cell line technologies especially have been mediated so much, they’re “not *really* what I would call human” anymore. What emerges is a hierarchy of potential human appearances.

Potential human appearances that emphasise human associations through past temporalities such as lineage are elided in favour of those that emphasise human associations accomplished in the present or future, such as comparison of shared membership to human-relevant phylogenetic class (mammalian) or connections to humans in the future (through translational areas of opportunity).

These hierarchies operate along spatial and temporal dimensions, but also – once again – in consort with normative assumptions, expectations, and sociomaterial associations of materialities with places. What potential human appearance is prioritised over another is once again inextricable from the ‘sense’ of what materialities belong in what places. Specifically, organising units prioritise enactments of biomaterials in relation to future temporalities and extroverted spatialities. Human utility is accomplished through associations in the future, and human applicability is accomplished by membership to similar classifications in the present rather than by through its past derivation that ‘have no place’ in future-orientated performances. Potential human appearances such as past human donors, enactments of human derivation, or human phylogeny as performed through lineage are subordinated to potential human appearances associated with future health-related outcomes or wider applicability to human physiology through synergies

created in the present, rather than shared in the past. What emerges is a narrow enactment of human appearances associated with the future temporalities and extroverted spatialities in the present, rather than past temporalities, or experimentally and biologically focused performances in the present.

There emerges a clear hierarchy to the potential human appearances entangled with biological materials. Those associated with immediate biological performances 'submit' (Mol, 2002) to those associated with wider human health outcomes. Mol (2002) offers 'submission' as one way that multiple competing enactments of project materialities can be reconciled (see Section 2.2.6). Submission involves a hierarchical approach to sorting different possibilities. Unlike the separation of competing enactments via othering to different locations we encountered in Chapter 4, submission sees different objects sorted in line with local hierarchies, only the dominant remains visible. This results not in human appearances being 'othered' to an 'out there', but instead, elided in their entirety. Submitting to more useful (but still human) appearances that negotiate value and alignment to societal priorities, instantly others human enactments of lineage and developmental origins into the flickering 'absence' of fire space (Law and Mol, 2001).

The process of submission to separate competing material enactments (Mol, 2002) has two immediate consequences on the project materialities that are enacted in practice and the places that are generated through them. Firstly, 'submission' narrows the visibility of potential human entanglements. Despite an array of potential human entanglements related to biological materials (ranging from original donors of biological materials to imagined future consumers of products to emerge from using them), the focus on human health narrows the potential 'human' enactments to a small subset of future-orientated or spatially extroverted, biomedicalised, and translationally focused human appearances. Othering by submission denies visibility to alternative enactments (such as human provenance, donors, developmental origins, and more); they do not re-appear in alternative places of belonging, distributed elsewhere, they merely cease to form part of the performance. In this way, there emerges a 'unifying narrative' of human health-related orientation that becomes associated with places of organisation. Project outcomes and project biological materials combine to enact a broadly coherent, singular narrative (Mol, 2002; Law, 2004a). Indeed, as Rachel attests, when it comes to organisational performances, "everything is human orientated inherently".

Secondly, submission keeps the focus of human enactment on the organising unit performance itself. In experimentally focused laboratories, practices of 'othering'

routinely negotiated potential human enactments of biological materials both *out* of the laboratory and *into* alternative places of belonging. As such, this led participants to experience human appearances as being distributed elsewhere, 'out there', 'in the future', 'in the past', or 'in nature'. It created 'routes' (Cresswell, 2014) out of the laboratory, anywhere but *in* the laboratory. However, othering potential human enactments (such as human provenance of research objects) during organisational performances subordinates them to more useful enactments, those left behind are merely negotiated out of view in line with performances of 'flickering' fire space (Law and Mol, 2001). The process is one of simple replacement, rather than re-distribution. There emerge no 'routes' out through which human appearances escape. Instead, organisational units remain as places that enact human appearances, just a *curated* set of appearances pointing 'forward' and 'outwards'.

5.6 Assembling organising units as places of human orientation

Through this brief and targeted account of the entanglements and enactments of human appearances in the context of organising unit performances, I have unpacked how organisational performances generate specific associations with a small set of future-orientated human appearance. Specifically, I demonstrated how organising units emphasise the extroverted relations of projects and their connections to a variety of human health-related areas of opportunity. I also showed how biological materials were also performed to presence in relation to these potential human health-related outcomes, rather than in relation to their own experimental or biological lives. In doing so, I have also consolidated some of the key features of human entanglement and enactment we encountered in Chapter 4.

Specifically, we have seen that human appearances continue to be enacted in practice (this time through the extroverted practices and materialities of organising units), their appearance continues to depend on the functional utility they afford the practices through which they emerge (this time, performing work as 'guiding visions' or performing biological materials as 'collaborational things'), and how different potential human appearances can either complement – or in this case complicate – their performance. In the case of organising units, one competing human appearance 'submits' to another to sidestep the challenges of multiplicity. In performing this hierarchy, organising unit performances emerge as places of explicitly 'extroverted' and future-focused 'human orientation'. It is on this notion of orientation – and how this enacts particular performances of place into being - that I wish to dwell before moving forward.

Like the experimentally focused performances, organising unit performances of the four MSB research projects continue to enact a romantic approach to complexity (Kwa, 2002) (see Section 2.4.6). Both Kwa (2002) and Law (2004b) argue that romantic imaginations of complexity designate different materialities as 'belonging' to different spaces and times. Everything has its place. This chimes with project participant behaviour. Several participants routinely pointed me to organising unit performances of projects as being a 'place' where the human emerges. In this way, as outlined in Section 2.4.6, the repeated use of place as a mode of sorting and ordering entrenches norms, expectations, and value judgements about where human enactments belong (Cresswell, 2014). Organising units *become* associated as places of human orientation.

However, as also demonstrated throughout this chapter, there is only a narrow selection of human appearances that 'belong'. These human appearances are those associated (whether directly or indirectly) with human-health related outcomes and are predominantly characterised by performance through imminent areas of opportunity. Primarily focusing on areas of opportunity rather than elaborating eventual outputs 'elongates' the present (Michael, 2000:33), contributing to the sense of imminence of human outcomes. It performs a present pregnant or 'dilated' (Meckin, 2016) with purpose and opportunity that may - or may not – lead to physical realisation of human health related outputs as successive project work unfolds. This performance enacts a different conception of time than linear 'clock time' (Adam, 1990). Instead, it chimes with the performative time put forward by Adam and Groves (2007) where there is only ever the present and that the future is made through an unfolding series of 'presents' until such ideas are actualised into physical being (2007:28). Futures under this conception of time are always 'in process' (Adam, 1990), and are correspondingly represented by a series of "future presents" (as opposed to distinct and distanced 'present futures') (Adam and Groves, 2007:28).

We have already seen in the preceding account that materialities that emphasise opportunity and 'unfolding' contributes to the temporal ambiguity and sense of 'imminence' afforded to human-related project outcomes. However, combining this temporality with the regional notions of space (coupled with flickering notions of fire space), and romantic notions of complexity, we also see how present human appearances enact a *spatial* immanence. If futures unfold in the present temporality, then they are also experienced as 'unfolding' *into* adjacent territories, capabilities, and epistemic domains. Anything that does not fit is simply rendered into absence in line with ideas of fire space (Law, 2004a). There emerges not only a temporal

orientation towards unfolding futures, but also a spatial orientation to encompass broader areas of opportunity in the present. Through these enactments of potential human appearances, organising units are assembled and experienced as places of human *orientation* that unfold in both the spatial and temporal dimensions of place.

5.7 Conclusion

In this chapter, I have interrogated the performances of organising units for the how the human appears. Like the preceding chapter, I have produced an account of not only what human appearances emerge, but how they emerge, the circumstances under which they emerge, and the work they do through their performance. This has involved a different set of materialities, practices, and meanings associated with human appearances. It has also produced a performance of organising units characterised by their association with human-health orientated outcomes. In providing this account, this chapter continues to build the empirical evidence required to address the research questions in full in Chapter 7.

Additionally, this chapter has provided an interesting point of contrast in relation to the mechanisms of othering and how they contribute in real terms to the places that are made. In Chapter 4, we encountered othering to alternative places of belonging, this contributes to the enactment of place as linearly temporally ordered and regionally spatially ordered: everything had its place, even if that was placed elsewhere. Here, we encounter one potential human enactment simply ‘submitting’ (Mol, 2002) to another. Section 5.5.3 demonstrates the real-time effects of this strategy of othering by denying ‘routes out’ (including into the past and back into the future) and consolidating focus on the human appearances that do emerge. Different strategies to manage tensions amongst human appearances and multiplicity of potential human enactments contribute differently to how places are experienced not only in sociomaterial associations, but also spatial and temporal performances.

Chapter 6: Integrating human contexts and presence through communities

6.1. Introduction

Human orientation is not the only way in which human appearances are enacted into presence. Across an array of community performances of MSB real-time research, multiple human appearances are assembled into both manifest absence (context) and explicit presence. The aim of this final empirical chapter is to provide an account of the way that these human appearances emerge.

There are too many configurations of community performances for this chapter to be exhaustive in its coverage. As such, I take a different approach in the pages that follow compared to the two preceding chapters. Specifically, I focus on the key patterns that emerge across a range of community performances, rather than focusing my attention to one or two targeted sites. To help assemble meaningful patterns, I characterise communities by whether they can be considered 'specialist' or 'non-specialist and account for patterns in potential human entanglements and enactments in line with these characterisations. In the first half of the chapter, I focus on performances of the MSB real-time research performed through specialist communities. In the second half of the chapter, I focus on performances of the research performed through non-specialist communities. I generate evidence of the ways in which human appearances emerge in both and argue that potential human appearances emerge differently dependent upon the type of community through which projects are performed.

Specifically, I demonstrate that in the case of specialist most potential human appearances are negotiated into absence, but they are not 'othered' absence (Law, 2004a). Instead, I argue that they are negotiated into 'manifest absence' – that which is absent but remains relevant to, or implicated in what is made present (Law, 2004a). Potential human appearances are performed into manifest absence as 'context'. In this way, they help integrate the research performances into the wider practical ontologies of the community writ large. I also demonstrate that occasionally, more explicit human appearances do emerge, but where they do, they tend to be performed into the periphery or ancillary parts of the research materialities such as metadata, or background information. Through these performances, I demonstrate that specialist communities emerge places of peripheral and manifestly absent

human context. Meanwhile, I demonstrate the reverse is true in the case of non-specialist community performances. Potential human appearances are also performed to help integrate the research into the wider practical ontologies of the non-specialist community as well, but these ontologies routinely include human appearances. As such, during the project performances in non-specialist communities, human appearances not only permeate nearly every aspect of the MSB research performance, but they are also performed as explicitly belonging in these places of performance. Through these performances, I demonstrate that non-specialist communities emerge not only as places of presence but integrated human inclusion.

To generate this account and assemble the evidence, I draw on a combination of interview data, informal conversations, participant observation, and documentary evidence, across the communities. I first turn to specialist communities. I interrogate three key clusters of project materialities and practices: those relating to the project outcomes, goals, and expectations; working with biological materialities; and how the practitioners perform themselves. I argue that across these three different clusters of project materialities, human appearances emerge in a combination of presence and manifest absence, configured to establish alignment with the communities to which they belong and demonstrate the significance of the project work. Across all three clusters of materialities, I argue that human appearances serve a useful function to help align and integrate the project into the broader community but do so in line with a series of conventions and normative associations that sees them predominantly enacted during the 'periphery' of project performances. This occurs either through inference to a manifestly absent 'context', or by negotiation into parts of the project performance associated with opinion or interpretation rather than evidence. These include Introductions and Conclusions, or the metadata characterising journal articles. In this way, human appearances emerge to provide significance through 'context' but are located as distinct from the central "scientific" focus.

Next, I turn to non-specialist communities. Once again, I step through the same three clusters of project materialities. This time, I demonstrate that human appearances are routinely negotiated into explicit presence throughout the project performances. I demonstrate that human enactments not only serve a pivotal role to negotiate the significance of project work for these non-specialist communities, but also to 'accommodate' the scientific narrative for the less familiar audiences. In doing so, I demonstrate that across all three clusters of project materialities, human enactments emerge much more explicitly and consistently across all parts of project performances including Introductions, Conclusions, descriptions of experimental

systems, the experiments' effects or outcomes, and more. Through the non-specialist community performances, human appearances are almost systemic in their appearance, and – critically – expected to be so.

As I step through these accounts, I draw attention to some of the patterns we have come accustomed to seeing in the empirical accounts of other chapters. I especially pay attention to community performances and their material configurations. In a departure from concluding with assembling a characterisation of place, I conclude the chapter by assembling a juxtaposition of two types of community performances to compare the different way that material arrangements emerge, the complexity they generate, and the material form of the places they enact. This combines with the evidence I consistently gather during the rest of the chapter to generate more evidence for how human performances are routinely located in space, time, but also their material relations.

6.2 Introducing communities and their complexities

> "And finally, synthetic biologists explicitly see themselves as building a community as well as a technology." (Calvert, 2013:178)

6.2.1 Building communities

There are three main types of communities with which my project participants engage. Firstly, both the Institute and the organising laboratories operate as small, localised communities of expertise and support. The Institute performs work as a small, localised community[45] focused on MSB techniques. Meanwhile the organising laboratories perform as small, localised communities focused on their own specialist interests. In the case of the Garcia Lab, tissue engineering and developmental biology; in the case of the Meier Lab, chromosomal assembly and segregation. Both these communities run a variety of meetings, events, and resources for their membership. These include face-to-face activities such as Lab meetings, Institute meetings, retreats, and occasional team-building and social events. They also include digital resources such as newsletters, email updates, and other useful communication channels designed to bring together their membership. Through such

[45] The member Laboratories that comprise the Institute are not all physically co-located; however, they are within the same local area and continue to meet in person (during non-pandemic working conditions). In this way, they can still be considered localised.

activities, members can learn what other members are doing, discuss their own individuated projects, and receive feedback from peers.

Secondly, project participants also engage with a range of distributed, wider scientific communities. These include the broader synthetic biology community, and a selection of traditionally disciplinary scientific communities. For example, Addison and Deepti engage with the cell biology community; meanwhile, Maxwell, Zofia, Madelaine, and Marek all take an interest in the developmental biology community. Membership to these types of communities is typically practised through publication, and episodic attendance at conferences where participants showcase their work and network with potential collaborators. It is through these activities – especially peer review publication - that projects' scientific claims are argued and validated (or refuted) as knowledge.

Thirdly, project participants are also encouraged to engage with a wider array of non-scientific communities and audiences[46] as part of their real-time research. The Meier Lab is particularly active in its "public engagement" with Addison and Tomas often involved with various initiatives, including engaging with schoolchildren to demonstrate science-in-practice and guest speaking on podcasts. Meanwhile, in the Garcia Lab, Madelaine, Marek, Maxwell, and Zofia, often engage in a variety of different community endeavours. Collectively, the Garcia Lab projects have been performed to wider audiences such as special-interest groups, the listenership of several podcasts, and other assorted groups, varyingly to stimulate interest, and – at times – to entertain (Davies and Horst, 2016).

6.2.2 Characterising communities

When it comes to accounting for the human entanglements and enactments of community performances, a productive way to characterise the varied communities is by their relationship with the subject matter under discussion. Specifically, how much 'specialist' knowledge they already have about the projects' research topic. Specialist knowledge can be considered pre-existing knowledge that helps an individual engage with, understand, relate to, and evaluate the topic in question. At one end of the spectrum, the small, co-located and localised communities such as

[46] Here a distinction must be made between engagement with a community and engagement with broader, more diffusely gathered publics. A community involves a degree of active engagement and participation from a particular segment of society around a shared interest, often on an ongoing basis through regular meetings or subscriptions services. Meanwhile, if there is ad hoc engagement with a broad cross section of society, often through one-off events, this typically falls under engagement with publics.

the organising laboratories can be considered archetypal ‘specialist communities’. Their membership has a high degree of pre-existing specialist knowledge of the other members’ research. For example, many members of the Garcia Lab are well versed in each other’s projects by merit of working on similar topics, using similar experimental systems, and helping each other troubleshoot. Meanwhile, at the other end of the spectrum, communities with little pre-existing knowledge of MSB research, cell biology, or developmental biology amongst their membership can be considered ‘non-specialist communities’. They lack the level of pre-existing knowledge to be able to adequately engage, evaluate, and understand the topic without ‘accommodations’ being made to the project performances (Fahnestock, 1986). An example might include a group of schoolchildren learning about synthetic biology.

There are three important clarifications to characterising communities in this way. Firstly, the term ‘specialist’ or ‘non-specialist’ is one that is given to individual community members; it is they that entangle the potential pre-existing overlapping knowledge on the subject matter, not the overarching community body. Communities take on the term based on the composition of their membership[47]. Secondly, ‘specialist’ and ‘non-specialist’ designations are roles, and archetypal roles at that. They are not an inherent identity, nor are they fixed. A specialist can become a non-specialist (and vice versa) at any given time as subject matters and topics under discussion develop and shift. There is no hard boundary that designates any given community as either always ’specialist’ or always ‘non-specialist’, the designation is instead established at the point of project enactment.

Thirdly, the archetypal roles of specialist and non-specialist should not be conflated with scientist and non-scientist; they are not synonymous. There can be great diversity in scientific communities and not all scientists will be specialists in particular topics. MSB itself is an interdisciplinary field, filled with diverse backgrounds, disciplinary traditions, theoretical perspectives, and more (O’Malley et al, 2008; Schyfter, 2011). Such heterogeneity of knowledges, practitioners, and approaches, renders it impossible to assume shared knowledges and perspectives[48] across the scientific community writ large (Bazerman, 2000; 2013). Conversely, not all non-scientists (or non-traditionally conceived of ‘professional’ scientists) can be

[47] Any label of specialist or non-specialist applied at the level of the community henceforth is given upon that assumption. It is not the intention of this term to reify community knowledges beyond that of their membership.

[48] Similarly, not only can specialist knowledge not be assumed, but neither can a shared interest. As one participant scoffed when asked about attending meetings encompassing *non*-mammalian synthetic biology: “It’s all bacteria, or plants, what use is that to me?”

considered non-specialists. For example, there is a ‘DIY Bio’ movement where amateur scientists, artists, or even self-taught novices are carving out a niche for themselves as specialists under the remit of synthetic biology (Calvert and Frow, 2013).

6.2.3 Performing projects

With these clarifications in mind, across both specialist and non-specialist communities, there are an array of activities through which projects are performed. They emerge through journal articles, posters, presentations, podcast episodes, interactive meetings, demonstrations, and more. Sometimes, a single project forms the sole focus of a community performance (for example, an original research article detailing the work of a project). Other times, a single project contributes to a wider discussion encompassing multiple other projects (such as Marek discussing the Garcia Lab projects to introduce MSB to a broader audiences). The important thing to recall from Chapter 2 is that these discursive enactments are not a means through which to get to a reality *behind* the discourse, they *are* the reality of the projects themselves (Fairclough, 1992). In this way, MSB research performances are enactments of specific project content, discursive practice (the ways the content is performed), and enactments of sociomaterial practices through which discourse is performed.

With these characterisations of communities and projects in mind, it is to two different performances of Project D41 - one predominantly specialist the other predominantly non-specialist - that we now turn to demonstrate just how differently projects can be performed through different communities.

6.3 Negotiating different community performances

6.3.1 “Now I have convinced you that Turing Systems are quite interesting, what are we doing?”

One Thursday morning, I was sat watching Marek give a 15-minute presentation on Project D41 to the membership of the Institute’s Parent Organisation during one of their routine fortnightly gatherings. The Parent Organisation comprises MSB practitioners, broader non-MSB SB practitioners, and a handful of social scientific members. The membership present cannot be considered wholly specialist in Marek’s area of research, but many shared a significant overlap in SB

understanding, biological perspectives, and a familiarity with the themes of the Institute more broadly. It can be considered a predominantly specialist community.

Marek's presentation to his SB colleagues followed the standard pattern of reporting project progress to peers that I had come to expect from attending many of these meetings. Broadly presentations to (predominantly) specialist groups comprise three parts. Firstly, a brief overview of conceptual principles and existing work in the area, as well as the contribution the researcher hoped to make. Secondly, a substantive discussion of specific experimental systems and work in progress; this always formed the meat of the discussion. Thirdly, a look forward to next steps and where the researcher intended to take the work. In line with this convention, Marek opened the presentation with some history of the project. Through a discussion of the theory that Alan Turing had postulated about reaction-diffusion mechanisms and animal skin patterns, he outlined the conceptual principles of his project and how he sought to validate the existence of Turing Patterns in mammalian cells. Marek noted that amongst other fields, developmental biologists like himself were interested in Turing Patterns. "Why is that?" he posited before answering. "Because if we want to engineer patterns, we need to know how [patterns] self-organise". This was the extent of his justification; he had not then explained why he might want to be engineering patterns in the first place. Nor had he explicated how knowing more about the patterning systems might contribute to engineering patterns. Any significance to this statement was left to inference amongst the membership. I made a note to follow up.

Marek then moved on to try to interest the group in the nature of the scientific challenge. He summarised some of the work from other fields interested in these reaction-diffusion mechanism, including other developmental biologists, computer simulation, and even robotics. He described the nature of the challenge, the fact that the patterns had been proven in some systems but still not others and outlined how it piqued the curiosity of a diverse set of scientists for a variety of reasons. "Now I have convinced you that Turing Systems are quite interesting" Marek concluded, "what are *we* doing?" A slide appeared on screen with a schematic of the synthetic biology system Marek had designed in conjunction with Madelaine and Abhishek. The presentation had moved into its second part.

Over the next 8 or so minutes, Marek elaborated the technical details of the research. He detailed his experimental design, the biochemical pathways he was engineering, and talked about his most recent set of experiments at the level of molecular functionality. At no juncture did he link any of his day-to-day work to

potential human-health orientated utility or outcomes, neither did he perform any of his biological materials and systems in ways that entangled their human provenance, phylogeny, or physiology. Whilst the labels of his slides confirmed he was in fact using HEK293 derivative cell lines, his corresponding discussion focused firmly on the level of engineering pathways, ligands, transcription factors, and 'target genes'. The only clarification about the cell lines came early on to ensure the wider group of synthetic biologists (including plant and bacterial synthetic biologists) knew Marek was using "mammalian cells". Finally, he concluded his discussion with a summary of his upcoming focus. This centred almost entirely on troubleshooting a particular challenge he was facing. Turning over for questions and comments, Marek received a smattering of feedback, including some comments relating to the challenge Marek had described. The last group member to offer advice clearly excited Marek. "Can we talk?!" he had asked as he returned to his seat. He had managed to make a potentially useful connection amongst the community.

6.3.2 "Great, but what about biomedical applications?"

In contrast, I will now transport us across town to a function room above a pub for a contrasting community performance. About 20 people gathered one wintery evening on the promise of pizza, clutching drinks in their hands waiting to learn more about MSB research. Marek had been invited to engage with a small community of individuals who shared an interested in fostering discussion of synthetic biology. The community membership comprised both non-scientists (including a couple of artists and a designer) and scientists (some of whom were synthetic biologists) but few with familiarity with Marek's area of expertise. This community could be considered predominantly non-specialist. Marek had agreed to talk about his MSB work; not only in relation to Project D41, but also some of the other projects ongoing in the Garcia Lab.

This 15-minute presentation continued to broadly follow the same three-part structure we saw in the previous example. Marek opened his talk by introducing the differences between synthetic biology and mammalian synthetic biology and providing a brief overview of some of the work ongoing in the MSB field. He took the audience on a brief journey through some of the novel and innovative techniques that MSB initiatives (in general) had been investigating in the last year. He highlighted work that he had personally done on another project to engineer pharmacological drugs as triggers for cellular behaviours, he informed them of other work in which he was involved in the Garcia Lab to use light as a stimulus to control cell behaviours, and - to the delight of the audience - other projects he knew of using

smell as a potential stimulus to control cellular behaviour. With his journey through the senses – an accessible way to introduce the use of different triggers - he generated a sense of novelty around the MSB systems he described.

Marek then turned the group's attention to the second part of the presentation and provided some details of his experimental work. He introduced his work on Project D41 – and that of Alan Turing - to elaborate some of the "clever things" that MSB techniques could enable in more detail. Indeed, for the next 2 or 3 minutes, he pointed out the pathways that he was engineering, explained how far he had got with his research, and how he hoped it might tell us something about patterns 'in nature'. During this part of the presentation, Marek provided some molecular detail that perhaps only the specialist members amongst the audience could fully follow. However, it was not long before he disrupted this technical part by turning to the audience to declare: "everyone always says 'great, but what about biomedical applications?'"

From my position in the audience, I could see a nodding of heads. Marek then moved to the third and final part of his presentation. Here, he outlined next steps in terms of longer-term trajectories for Project D41 and other 'basic research' projects for how they could eventually be useful for biomedical application. He explicitly stepped through how controlling cellular mechanisms meant fine control over tissue engineering and intimated how projects such as his could be combined with other projects (also ongoing in the Garcia Lab) to produce sophisticated combinations of patterning. He summarised how such research could be used to engineer more realistic organoids for diagnostic and screening tests, and perhaps even eventual kidneys - whose shortage was a real problem. When Marek had finished, the floor was opened to questions. The first hand shot up. "What are the advantages for mammalian cells over non-mammalian?" someone asked from the back. Marek's answer was immediate: 'for advancing human and therapeutic synthetic biology' he summarised, "it is the obvious way to go" he added. The next question came in from the organiser. "Taking from science fiction, what amazing or awful future do you see?". Marek thought about it, then offered a utopian example. One of diagnostics where you could tell from the toilet if we had any diseases and be able to fight it, before adding animatedly, "and become young forever!"

6.3.3 Comparisons and reflections

Through this retelling, it becomes clear there are some significant differences between the performances. Three differences stand out the most. Firstly, the aims of

the two performances were significantly different. In the case of the presentation to the Institute's Parent Organisation, Marek was there to inform the group about his project, share his conceptual and technical work, and to receive some (hopefully useful) peer feedback. Conversely, the purpose of Marek's talk in the pub was to engage and promote discussion, but also to entertain. Secondly, the way Marek negotiated the interest and attention of the two groups differed. In the case of the first presentation, Marek attempted to negotiate interest through the nature of the scientific challenge and the way he sought to address it. This was a story about novel approaches to an unresolved topic of scientific enquiry. Meanwhile, in his second talk, he negotiated interest through appeals to the novelty of MSB research and its eventual biomedical application. Thirdly, and at the heart of what follows in the rest of this chapter, there were more explicitly foregrounded human enactments and connections during Marek's non-specialist community performance than there were in the (predominantly) specialist performance.

As I compared these two episodes, I was reminded of Marek's assertion in the Airport departure lounge that his work on Project D41 didn't "have anything to do with human application". Whilst that certainly was the case for his presentation in the predominantly specialist community, in the pub function room surrounded by individuals from varied backgrounds, Marek's project enactments were performed in ways that rendered them inextricable from human application and outcomes.

6.4 Contextualising projects in specialist communities

6.4.1 Negotiating significance and relevance through human health related outcomes

6.4.1.1 "It's not something we really talk about …"

When MSB researchers perform their projects for other MSB researcher peers, the potential human health-related outcomes of their projects (such as those we see dominate organisational activities in Chapter 5) are not something that are explicitly negotiated into presence. Whilst discussing this with Deepti, she explained: "it's just not something we really talk about because we know what we're doing". It was these words that ran through my mind as when I reflected on Marek's first presentation, then once again as I sat in the Garcia Lab a few months later again listening to Rachel present Project D42 to her peers.

Every fortnight, the Garcia Lab meet in a first-floor conference room to discuss progress on their projects. This forum is one of the key times the Lab comes together as a community. It provides an opportunity for team members to ask for advice, share frustrations, catch up on what their colleagues are doing, or practice a presentation amongst peers. That week, Rachel was using the opportunity to present the end-to-end argumentation she was planning for her thesis. In a 35 minute, 29 slide presentation, she outlined the patterning systems she had designed, and detailed her transgenic experimental systems, the experiments she had run, and the results she had generated all in microscopic detail. About ten minutes from the end of what was a very dense, technical presentation, a slide appeared on screen giving me cause to pause my notetaking. “Applications” it read simply. I was curious what this might mean in this context. As it turned out, it related to the experimental use of her cell systems to “control stem cell fate decisions” and to test if it could “break symmetry” in mouse embryoid bodies and rudimentary nephrons. It was not a discussion of any potential future human-health related applications or outcomes. As Rachel would tell me afterwards, this presentation was “not the place” for her to be ‘speculating’ for it was a presentation about “facts and science”.

6.4.1.2 “ ...because we know what we’re doing”

Yet, in these specialist community performances, the absence of any explicit references to human health related applications do not equate to a presence of *explicit* absence. Unlike the experimental performances we encountered in Section 4.4.4, notions of human health are not entirely ‘othered’ from the localised, specialist community enactments. Projects must demonstrate their worth and importance, even to localised communities. In line with the promissory rhetoric of the organising unit performances, potential human health-related outcomes continue to be one of the key ways in which research significance is accomplished. These connections to potential human health-related outcomes are entangled by merit of the function they perform; however, they typically remain ‘manifest’ in their absence (Law, 2004a). The significance and importance of Rachel’s work is instead inferred through a negotiation between what was explicitly brought to presence as content in the presentation, and what was simultaneously negotiated as context. In terms of the latter, there were some things that Rachel did not need to explain in her performance of Project D42 precisely because she knew her community already knew them. This information included how the research might relate to potential human health-related outcomes and what ‘potential’ such futuristic outcomes might have for the field of regenerative medicine.

Indeed, over my experience with Project D42, I too had assimilated quite a bit of knowledge that also allowed me to understand some of the inferences. I knew that "symmetry-breaking" was a vital process in developmental biology. Many organs in the human body have asymmetric features, yet much of *ex vivo* tissue engineering cannot reliably mimic that asymmetry. Being able to 'break symmetry' reliably would be a valuable step forward in being able to generate realistic tissues and organs. Similarly, I also knew that 'controlling stem cell fate decisions' using other cells could be a promising step forward for a new generation of sophisticated stem cell engineering techniques. To Rachel, this was "basic information" that anyone in the field already knew, it did not need verbalising. However, as she had talked through her 'Applications' portion of the talk, she made sure she created enough connections in what she *did* include in the content of the presentation, for the potential human health-related outcomes she left out to remain manifest in their absence through the pre-existing specialist knowledges of her colleagues.

6.4.1.3 Negotiating significance within a distributed specialist community

The line between what is explicitly performed as presentation content and what remains manifest in its absence as context varies dependent upon the overlap in pre-existing shared knowledges across the community membership. Not all engagement occurs through such well-characterised and familiar communities as a tight-knit team like the Garcia Lab. When engaging with wider scientific audiences, even those with a high degree of familiarity with the subject matter, it is not possible, nor desirable to wholly rely on assumed pre-existing knowledges and inference to argue for the significance of the work. This is especially the case when submitting research for publication.

For scientific claims to be validated as scientific knowledge, they must be evaluated through collective engagement with peers in the wider scientific community and ratified by subsequent use. The legitimacy of the research is judged on the accuracy of its claims (Dahlstrom, 2014). The first step in this process is to submit an original research article reporting (and arguing for) the findings to their peers. Such performances must not only report on the findings, but also negotiate the works' significance and validity to other scientists in the field (Myers, 1990, Clarke, 1998, ACS guidelines, 2022, Nature, 2021).

To ensure the significance of project work is rendered sufficiently explicit, the line between what is negotiated into explicit content and what can be left manifest in its absence as context differs. It does not necessarily equate to an increase in explicit

appearances of human health-related outcomes, but it does involve making sure the steps to connect to such outcomes are explicit. For example, in the first original article to be published from Project D42, Rachel and her colleagues assembled an argument that foregrounded the contextualising connections around breaking symmetry and controlling stem cell fate decisions far more explicitly than Rachel had done so in her presentation. She and her co-authors had explicitly drawn attention to the biomedically relevant territories of opportunity (developmental biology and regenerative medicine). They had also explicitly pointed to examples of physiological human structures that relied on their asymmetry to function properly (the 'kidney', the 'eye optic nerve'). Whilst explicit references to potential human health-related outcomes such as increased realism of tissue and organ engineering were absent, the steps to infer the potential human health-related outcomes were laid out with a clarity that reduced the burden on big leaps of inference. According to Rachel, it is a balance of negotiating significance without overstating any claims that are not empirically founded. Here, human health-related outcomes negotiate significance through an interplay of manifest absence and suggestion.

6.4.1.4 Implicating humans

Three types of potential human appearances are entangled in the assembly of this negotiation between content and context. Firstly, imaginations of human health related translational outcomes. We find these negotiated into manifest absence (or context) in the inferences of regenerative medicine or more realistic organoids. There is (once again) no reference to potential human users or consumers as part of these implied imaginations, potential human outcomes emerge entirely through the lens of technical trajectories. Secondly, we see an increased enactment of endogenous human physiology through which to argue the significance of the functions and pathways being targeted. For example, the desire to 'recapitulate' the higher order of asymmetric human organs such as kidneys. Thirdly, we also find appeals to human physiology as a knowledge object (more notably in Marek's presentation than Rachel's).

6.4.1.5 Spatiotemporal distributions of human entanglements and enactments

As to be expected amongst a heterogeneous set of community configurations (even within just the specialist communities), there does emerge some variation in the way that the negotiation between content and context is performed. For example, occasionally, potential human health-related outcomes are more explicitly brought to presence than in Rachel's publication. In one example from Project D44, Addison

and peers make the case for reporting some challenges they experienced with their replica chromosomes by explicating just how important replica chromosomes were for human health. They explicitly brought to presence multiple potential human health-related outcomes to make the importance of replica chromosomes sufficiently salient to justify the troubleshooting activities upon which they were reporting. At the other end of the spectrum, there are some performances that rarely entangle potential human related outcomes at all, even by inference. These emphasise other ways of negotiating their significance, such as through performing as 'foundational' or 'infrastructural technologies', thereby only indirectly enabling potential human health related outcomes.

However, these variations aside, across the potential specialist community performances of the four projects, there emerge four clear patterns in the distribution of human appearances. Firstly, whether explicitly negotiated into content, or inferred and manifest in their absence, human health-related outcomes (especially potential translational applications) emerge as located at the end of a linear programme of work. Here, project performances revert to underlying notions of clock-time (Adam, 1990) that sees potential human health related outcomes emerge as 'present futures'. These are held distinct and distanced from real-time MSB research practices. For example, in the opening vignette, Marek describes his work on Turing patterns to his colleagues as the "first step" in demonstrating natural processes (which in turn implicates improved knowledge of mammalian biology, and eventual human biology but much further down a trajectory of work). Elsewhere, Rachel argues that her system "puts us one step closer toward engineering *bona fide* synthetic organisers" (which in turn implicates improvements in stem cell engineering as also being further down a trajectory). Elsewhere other participants make similar links to 'step-based' approaches of linearity towards "eventual" human health-related outcomes "in the future". Much of the discourse with which project participants situate their work in relation to potential human-health related outcomes enacts distant and distinct, separable futures.

Secondly, there are temporal and spatial conventions in where in the discursive enactment itself the potential human appearances emerge (whether implicitly or explicitly). For example, during project presentations, human outcomes are typically gestured towards during the opening statements and the *closing* arguments. They are rarely brought into the discussion during the technical elaboration of the project details. Similarly, in written performances such as posters and journal submissions, human appearances are similarly implicated during the Introduction and Discussion sections, rarely in the specific detail of methods and empirical results. Indeed, it is

extremely rare to find any human entanglement with potential human health related outcomes during the methods, results, or the main body of specialist discourse. Instead, this is the preserve of forensic rhetoric (Fahnestock, 1986), or as Maxwell explains it 'what can be proven'. These conventions and expectations are typically set by the communities themselves. For example, the ACS Synthetic Biology journal - a publication where several project participants publish their original research articles - provide the following instruction to its contributors:

> "[A] referenced introduction should expand on the background of the work […] The purpose and significance of the research should be clearly stated and placed in the context of earlier work in the area. […] [The Results and Discussion section is to] interpret the results and relate them to existing knowledge in the field".

Project performances both adhere to, and in doing so, enact and perpetuate these conventions of the community, or as Livingstone (2007) suggests the 'location' of 'locution' (2007:75).

Thirdly, the further away the research is from the contextualising structures through which it emerged, the more human appearances emerge as a way to sort and order the discursive enactments. For example, across scientific publications and repositories of information, discursive enactments such as reports and publications have 'keywords' or 'metadata' assigned to them to enable a first glance orientation to the content and its overall 'findability'. When discursive enactments lose the context of their performance (for example, publication in a specific and targeted journal), instead being subject to storing in wider repositories of research (such as grouped into the PubMed database on which all project participants rely upon for sourcing literature), the more human health-related outcomes become a relevant practical ontology through which to sort and order the work. For example, as Rachel's SB-specific publication is moved out of the context of its wider publication issue and into PubMed, a more broadly scientific repository, the more it becomes classified by keyword metadata relating to potential human performances as: "body patterning", "humans", "organoids", "tissue engineering / methods", and more. These are all aspects of her work that are typically left to inference in more localised communities. Yet as her project enactments become shared in wider scientific repositories, these keywords are also ancillary to the negotiation of the facts or the evidence through 'forensic' discourse.

The final way that human appearances are distributed is through the sociomaterial performances that constitute the project performances. Several practitioners talked to me of their processes, especially in terms of publication. Maxwell for example only

draws on human-health related outcomes during the “interpretation stage” of preparing manuscripts or presentations. He tells me it is only during the work to situate his “objective results” in the “bigger picture” that he introduces human-health related outcomes as part of the process. He attempts to keep the “objective results” and the “interpretation” stages separate. Similarly, one disgruntled practitioner laments how they feel like they are never going to finish a manuscript they had been working on, precisely because they focus on the minutiae of the technical details for so long that they lose sight of the reasons for reporting it in the first place. Elsewhere, Rachel dismisses the importance of the human-health related outcomes as something that can follow on after she’s prepared the argument for the technical work. There emerges a practical separation in the way that manuscripts can be prepared. Additionally, there also emerges a separation in the community enactment of the project performances too. Human appearances receive a different level of scrutiny during peer review than the technical detail of the methods and results. Recall from Chapter 2 that Kastenhofer (2013) argues “true quality control is only applied to the methods and results section of the papers” (2013:21). As Rachel dismisses any equivalence of the future human health related outcomes of her project, she relegates it to a matter of opinion, or speculation.

There are many other examples of similar separation occurring in other practices through which community engagement occurs; for example, during specialist community conferences, in which human-related topics can be entangled as part of the conference agenda. Conferences play a pivotal role in the production and circulation of knowledge, and in establishing academic and professional disciplines/ They enable members of community to meet, collaborate and discuss their work, and are often symbolic of the ‘ties’ that bind the community (Stephens and Dimond, 2016). Deepti tells me of a SB conference relating to medicine she attended that had a “really good” panel session to close the conference with a handful of philosophy and ethics scholars debating “ethical consequences of synthetic biology and the human involvement”. Deepti had stayed to listen and had found it fascinating. However, it was the last session of the two-day conference, and not everyone stays on. Whilst social scientific entanglement (including relating to human-specific topics) exists, many practitioners themselves negotiated it into absence as they curate their own experience of the conference. Indeed, in my own experience attending one of the largest SB conferences in the UK most of the social scientific topics (all but two debates) were held apart in separate events, run by separate organising bodies, running in parallel to the main conference, or after the main conference had finished. Such engagement was negotiated into the periphery through agendas and institutional arrangements, for most of the sessions forcing participants into the

scientific programme, or the social scientific programme. Once again potential human appearances – might be entangled – but they are not always performed to presence for many practitioners who pursue their own interests at such community events.

Human health related outcomes are not the only human appearances to enact human appearances at the periphery of project performances; brought into negotiations of what is rendered content and what is rendered context. The way that project performances in specialist communities enact their biological materials and experimental systems also entangle potential human appearances in this constant negotiation contingent upon the community materialities and practices through which they are performed.

6.4.2 Negotiating biological materials through the narrative of science

6.4.2.1 Navigating communities with biological materials

When it comes to the biological and experimental materials of research, project performances in specialist communities typically provide a highly technical account of the experimental work that is either ongoing or has been completed. Posters, publications, and presentations are dominated by the technical account and focus on the biological mechanisms, methodological decisions, contexts of production, experimental results, and targeted experimental claims. Myers (1990) argues these are the hallmarks of a “narrative of science” (1990:141-192). As discursive performances enact their own realities (Fairclough, 1992) these performances of biological materials do not ‘represent’ or reflect laboratory performance, they are formed through their own discursive and sociomaterial practices (Law, 2004a).

In highly localised performances of community enactments, biological materials can often be performed in similar ways to those we might encounter in the laboratory. Watching Rachel’s technical account of her PhD project work, I had observed that her slides - and the corresponding narrative - never once referred to her human-derived kidney cell line (a HEK-293 derivative called ‘HEK293-TREx’) as anything related to their human entanglements. Routinely Rachel referred to her cell line technologies in terms of the function they performed in the experiment, such as “Wnt producers”, “integrin-expressing cells”, and more. When they weren’t enacting their functional performance, they were performed to presence through their production-related terms as “clones”, “transgenes”, and similar. In fact, much of her performance of the biological materials was broadly comparable to her corresponding discursive

performances during the experimental work. She performed her ‘patterning systems’ in line with the functionality they performed, rather than in relation to their composition. When she talked about them in relation to them as a cell line, or a collective part of the experimental system she referred to them as “293s” or “TRex-es”, rather than “HEK” cells (the fact they were human-derived was “just not relevant”). There was no entanglement of potential human enactments of the cells. I had observed comparable behaviour in many other presentations too, for example, Marek’s presentation to the Institute’s Parent Organisation. Whilst he had used HEK293 labelling on his presentation, at no point did he draw attention to this, or talk about his cells as human-derived. Discussion remained at the molecular level. Both Marek and Rachel perform their projects in relation to the pre-existing knowledges they know their communities have.

However, not many specialist communities share such a tight overlap in knowledges, experience, and familiarity with the laboratory performances of each other’s projects. What comes to count as “not relevant” in performances through one community can be performed to presence as relevant in another community. As Jensen (2010) and Gad et al (2015) remind us, materialities are situated in practice and configured accordingly. Across the community performances, biological materials vary in their discursive enactments. In doing so, they implicate more, or fewer, performances of potential human appearances.

6.4.2.2 Implicated humans

During community performances of the project biological materials, there emerge the same three ways in which potential human appearances are entangled we encountered in Chapter 4. The first of relates to their provenance. Provenance enacts the lineage from the original organism to the experimental sample or specimen. In doing so, it entangles the ‘original’ humans from whom the material was derived. In the case of cell-line technologies, these might include the donors (such as the 35-year-old fibrosarcoma patient). In the case of genes, it might refer to the “source” individual whose genome or tissues might have been sequenced and submitted to databases. To refer to HEK cells as “human-derived” necessarily implicates the anonymous human donor (and corresponding embryonic material) from whose specimen the cell line was originally derived. The second way that biological materials can potentially enact human appearances is through phylogenetic designation. Whilst provenance traces the origins of a biological specimen to its specific source, phylogeny instead emphasises its lineage through the broader evolutionary record. A phylogenetic designation of biological materials

as ‘human’ brackets together genetic similarities and differences across organisms, species, and populations designating biological materials and organisms to particular taxonomic categories (Bowker and Star, 1999). This can broadly be considered a species designation of the biological materials. Any cell line, gene, protein, or more designated as ‘human’, performs it into being *as* human material. Thirdly, biological materials can potentially entangle human appearances through physiology. Physiology relates to the typical structure and function of living things. There are certain structures and functions - typically exhibited by endogenous human materials - that can be considered ‘physiologically human’. If project biomaterials are found to sufficiently correlate with such structures and functions, they can be considered ‘physiologically human’.

6.4.2.3 Integrating projects into communities

The extent to which these potential human appearances form part of the project performance depends on three main factors contingent on the communities themselves. Firstly, the theoretical perspectives (knowledges, priorities, theorisations) that different community memberships hold; secondly, the format and conventions of the community; and thirdly, the argument that needs to be made as part of the performance to the community.

Firstly, the different theoretical perspectives and priorities of different communities engender different enactments of the biological materials. For example, during Rachel’s performance to her peers, she refers to the specific components of her experimental systems in terms of the experimental *function* within her experiments. Her patterning systems comprised of components such as “feeder cells” or “Wnt producers”. These performances foreground the functionality that has been engineered. However, as these components are performed through different types of communities, they are reconfigured in line with the priorities, perspectives, and materialities of alternative communities. For example, when engaging with the developmental biology community Rachel’s feeder cells are performed as “signalling centres” or “cellular organisers”; so-called by merit of the signals that such centres emit to trigger a range of morphological effects in the wider body (a key focus for developmental biologists) or the “highly localised cell groups” that come together to ‘organise’ these signals in the body. This has meaning to the community.

Meanwhile, when engaging with the stem cell community, Rachel’s feeder cells are performed to presence as “prototypical stem cell niches”; once again by merit of the effects the signals could have on stem cell differentiation specifically (the key focus

of stem cell scientists). Correspondingly, the different materialisations enact a different proximity to the endogenous behaviours they seek to mimic. For example, when patterning systems emerge as “feeder cells” and “Wnt producers” their functionality is not performed in ways that entangle endogenous behaviours of human physiology. Meanwhile performances of the patterning systems as “signalling centres”, “organisers” and “prototypical stem cell niches” emphasise a wider context of what goes on naturally in the human body. During these performances, the patterning systems emphasise their capacity to perform as a synthetic version of an endogenous systems of interest. In this way, performance of patterning systems as “signalling centres”, “cellular organisers”, or “prototypical stem cell niches” enact a closer integration with the endogenous human physiology they seek to recapitulate, performing as analogues. “Prototypical stem cell niches” foreground a wider set of ‘extroverted’ relations connecting them to human physiology more so than the small lifeworldly relations foregrounded through performances of project outputs as “feeder cells”.

Secondly, as well as performing in line with different community perspectives, both the biological materials (technical objects) and outputs (techno-epistemic objects) are also performed through the practices and conventions of the wider communities. For example, many journal guidelines request that biological materials and experimental systems are clearly articulated and align to a set of community standards and conventions. The biological material performances we encounter in experimental laboratory performances (and some of the more localised specialist performances such as project presentations to Lab teams) lack meaning outside the materialities of their enactment. They are too ‘locally contingent’ to negotiate relevance to wider communities. During community performances nomenclature is used to introduce and perform biological materials that means something to wider communities. Here, “TRex cells” and “293s” become instantiated as “human embryonic kidney 293 cells stably expressing TetR”. “HT1080s” become “human HT1080 fibrosarcoma cells”. According to Maxwell, this is just good practice. “It’s about accuracy” he explained, it was important to know that someone can recreate your findings accurately with the information you provide them, so you stipulate full nomenclature. In performing projects through the wider scientific community responsible for validating and legitimising the project findings, the ‘narrative of science’ (Myers, 1990) must be meaningful to the community standards and conventions. It must provide sufficient contextualising information through which to evaluate the findings. Across the projects, the phylogenetic of their biological materials are explicitly listed out. In the case of Rachel’s project, whilst her team presentation referred to her feeder cells as “TRExs” or “293s”, they are explicated in

full at least once in community performances (both journals and presentations), before then being performed in shorthand as “HEK cells” (in line with journal convention).

Thirdly, participants need to not only provide a technical account of their research that makes sense to the communities through which they are performed, they also need to perform their biological materials in a way that helps demonstrate validity and legitimacy amongst peers. Recall from Chapter 4, in Section 4.5.3, Addison explained her requirement to calibrate her replica chromosomes to be sufficiently similar to human chromosomes found in nature to represent what was “representative of what was really happening”. It was the wider specialist community she felt would identify if her system was not fit for purpose: “[…] If I go to a conference and I say ‘oh, I found out that my [replica chromosomes] in this cell line, this does that’, people can then argue ‘but how is this system … close enough’ … representative to what is really happening?’” Here, we return to the enactments of biological materials as analogous to physiological or endogenous counterparts. For example, as Project D42’s patterning systems performed as “signalling centres” or “prototypical stem cell niches” perform work to demonstrate their features are analogous to endogenous behaviour. Elsewhere, performances of Project D44 draw explicit comparisons of replica chromosomes with human chromosomes during statements of significance. For example, “we thus conclude that the replica chromosome contains a functional kinetochore resembling that of endogenous chromosomes”, which then “may be used in future studies” to tell us more about “natural human chromosomes”. This research relies on the biological outputs emphasising their similarity to “natural human” physiological processes to generate their significance.

6.4.2.4 Holding humans at a distance

Once again, the integration of biological materials with the materialities and practical ontologies of wider community performances tend only to emerge in specific parts of project enactments. These correlate with many of the same peripheral places we encountered with the connections to human health related outcomes. For example, comparisons to human physiology that situate biological materials in relation to the ‘natural’ world typically emerge in places where argumentation of significance emerges. In journal articles, these include the Introduction and Discussion sections, the Abstract and Next Steps sections of poster submissions, and the beginning and end of presentations. Developmental origins, as entangled in formal naming conventions of biological materials and initial elaborations, tend to emerge in initial

usage (before abbreviations or acronyms can be used as ongoing signifiers), and are elaborated further in the Abbreviations section at the end of papers. Throughout most materials and methods, abbreviations and acronyms are prevalent, not the full names that encompass developmental origins. Similarly, when it comes to presentations, developmental origins emerge as are more prevalent in the slides, rather than any accompanying narrative. They emerge as metadata; data about the content, but not of sufficient important to form part of the content itself. Similarly, even as human appearances do become implicated, there still emerges a separation invoked through their performance. For example, comparisons to endogenous human physiology only ever "resemble" the natural or endogenous behaviours or structures, the synthetic systems remain ontologically distinct - they are not assimilated *as* physiological, or "natural" themselves. Biological materials that make manifest their human biological connections typically do so away from the forensic discourse that negotiates the "facts and the evidence". As we shall see, this is not the case for non-specialist performances.

However, before moving on to unpacking the non-specialist human entanglements and enactments, I wish briefly alight on the appearance of human-enacted practitioner performances through community performances.

6.4.3 Navigating communities with practitioner enactments

6.4.3.1 Locating practitioner human enactments

There are two points to make here that emerge as pertinent by merit of their inextricability from other human appearances. Firstly, there is limited performance of practitioner performances - either human or non-human adapted - to emerge during the *content* of the specialist community enactments. Perhaps the most noticeable way that practitioners become part of the 'narrative of science' is through 'authorial stances' (Hyland, 2005). These are the appearances that indicate the authors' presence in the project enactment (for example, "we set out to provide a novel synthetic biology proof-of-concept application"). In most of the publications in which project research is published, the journals encourage authors to write in the first person (singular or plural). Correspondingly, it is not unusual to see authorial stances throughout journal articles, and first-hand accounts reported through presentations commonly use the first person to explain the scientific work that is underway. For example, Marek's presentation to the Institute Parent Organisation was performed entirely in the first person.

These authorial performances typically perform work as a narrative device. As Morgan and Wise assert (2017), the narrative makes no sense if the practitioners themselves are written or performed out. However, there does emerge a shift between active and passive voices that can be found across the range of community performances. The active authorial voice is involved in much of the Introduction, Discussion, and Conclusions of project performances. Some authorial stances are explanatory in nature. For example, the declarations such as “in this work, we have constructed a new replica chromosome”, or “we designed and generated […]”, and many more. However, most emerge in conjunction with interpretive statements. They mediate the relationship with the claims being made. For example, across the journal publications, posters, and even accompanying presentation narratives, there emerge practitioner interpretations such as “we propose […]”, “we suggest that […]”, and “we cannot exclude the possibility that […]”. As Maxwell notes, these performances correspond to the “interpretation” parts of the performance, where human enactments of practitioners belong, (as opposed “the facts”). Indeed, the authorial voice also all but disappears during the “technical” discussion. Instead, passive statements dominant: “two arrays were combined together”; “these clones were processed”; “images were taken”; “experiments and results were replicated at least four times”, and many more. The practitioner roles in these activities are all but elided. Community enactments continue to entrench normative associations with where human enactments do and do not belong.

Secondly, most human appearances to appear during community performances emerge not through the content, but in the broader sociomaterial performances of taking the project to the communities. It is not through the content of the narrative itself that we encounter most of the human practitioner enactments, it is through the sociomaterial performances of attending the conference, submitting the publication, or presenting the work that human enactments are to be found. In a heterogeneous field of expertise such as MSB, Rachel draws attention to the importance of what she considers “psychological manoeuvring”: presenting work at conferences is not just to provide a technical account of the work ongoing, it is to build relationships, get your work - and thus yourself - noticed, and to become known in that community. This chimes with observations from Stephens and Dimond (2016). This is seen as the particularly “human” part of their work, socialising the projects and “selling” it to the wider communities. Indeed, the first conference I attended was a large SB-wide UK event where both Addison and Marek were in attendance, displaying posters for Projects D44 and D41 respectively. As I watched them engage with passers-by, they ushered people to look at their posters and engage with their ideas and their enthusiasm for their work was palpable. At one point I went to talk to Addison about

her poster and after a few minutes she (kindly) suggested she should get back to engaging “with some scientists” to see who else she could find with overlapping interests. It was clear that the conference was the place for human enactments of practitioners, rather than the human enactments of her subject matter.

6.5. Contextualising projects for non-specialist communities

So far, we have seen that human appearances perform vital work to integrate project performances with specialist communities through practical ontologies. This is also the case for non-specialist community performances, but the extent to which human appearances are rendered explicitly into presence as part of those performances is significantly different.

6.5.1 Accommodating non-specialist communities through notions of health

As already noted during the early comparison of Marek’s presentation, when MSB researchers perform their projects for communities comprised of predominantly non-specialist audiences, we see a significant difference in the way that potential human entanglements are performed. In my continued discussions with Deepti, she explains that foregrounding the potential human outcomes happens more when “talking to someone that’s not really involved in our subject”; it helps to make the research more accessible to those who might not immediately understand or relate to the topic. In Chapter 2 we heard from Fahnestock (1986) and Myers (1990) about ‘accommodations’ that are made to non-specialist texts when making scientific research accessible for wider audiences. They both outline a variety of changes in the way that scientific research is prepared for an audience that comprises non-specialists in the subject[49]. These include rhetorical changes that can occur to titles, imagery, introductory statements, as well as a variety of syntactical and structural changes (Myers, 1990). They also include a shift in the type of statements being made (celebratory and value statements, rather than those arguing for the evidence of facts) (Fahnestock, 1986).

However, perhaps the most notable accommodation in relation to how non-specialist performances entangle the human is that they “get[s] to the point quickly” (Myers,

[49] Whilst both Myers (1990) and Fahnestock (1986) focus on written texts rather than other discursive enactments, many of these accommodations can also be found across the other forms of presentation in my four case studies, including presentations that accompany slides, as well as more visual written texts such as posters.

1990:171) and in doing so ‘leap to results’ (Fahnestock, 1986). Any detailed discussion of data, technical manipulation, and signals are elided in favour of the effects that are produced and their potential outcomes, effects, and applications. Myers (1990) terms this shift away from the methods and data to a focus on the effects and outcomes being described a “narrative of nature” (1990:141), no longer focusing on the technical manipulation and instead focusing on the results that are observed and how they relate to nature. Meanwhile, Fahnestock (1986) reminds us there are two ‘appeals’ through which a shift to celebratory discourse take place. First an appeal to novelty (or wonder), and the second an appeal to application. Whilst Marek’s second presentation in Section 6.2 demonstrates appeals to wonder (through the different sensory stimuli and novelty of techniques), it is the appeal to application that brings most of the human appearances to presence.

For an example of this increase in human enactment, we return to Project D42 and yet another of its performances as part of a broader ‘mini-review’ authored by Madelaine and Rachel about ongoing work into engineering patterns into tissues and cells. This review was specifically written for a non-specialist audience. It was published in a dedicated review journal that explicitly sought commentary on latest developments written for journal membership who were “not expert in the area”. Accordingly, the journal advised against the use of ‘jargon’ and urged authors to find alternative ways to make their information accessible, rendering the importance of the research situated in ‘broader contexts’.

Right from the outset, Madelaine and Rachel emphasise the potential effects and outcomes of the wider body of research. They draw attention to the potential human health-related applications and improvements in knowledge that emerge as a consequence of pursuing such research. They demonstrate how engineering tissues can lead to potential human application “either as engineered close copies of natural tissues or brand new ‘designer tissues’”. They proceed to explain that such tissues could be “intended, for example, to function in extracorporeal life-support machines, or to be a custom component to repair an atypically formed body […].” The authors also do not rely on the journal readership being able to infer exactly how the research projects described lead to such applications. Rather than relying on readership recognition of the importance of ‘breaking symmetry’, such as they do in specialist communities, the authors render these connections into explicit content. For example, in the case of the work relating to Project D42 (and a handful of other studies), the authors explicitly step through the importance of breaking symmetry. Firstly, by articulating “we find that the key to producing better large-scale anatomy lies in breaking the symmetry”, before then explaining how such ‘better large-scale

anatomy' contributes towards engineering "more anatomically correct shapes". These, they then link to the goal to turn "simple renal organoids into useful kidneys, with a view to eventual transplantation". In stepping through this process explicitly, the authors illustrate how engineered tissues can enable such applications by anchoring the work in the "normal" or "natural" processes they are trying to emulate.

Claims that link to potential human health and outcomes in this way are known as 'high level' claims (Myers, 1990). Rather than inferring significance through inference from the incremental 'stepping stones' of biological knowledge (the low-level claims) (Myers, 1990:67), the higher level claims directly signify the importance of the work to those lacking pre-existing specialist knowledge to make the connections themselves. Across the non-specialist performances of projects, such higher-level claims of application are rife. We encounter similar patterns in a review article detailing work on replica chromosomes. Tomas and colleagues proceed to explicate no less than nine human-health related applications where replica chromosomes might contribute, and how they might solve existing challenges. Meanwhile, in an array of interviews and newsletters, when asked about the future for her research, Madelaine hopes her research will "contribute to a future in which new organs can be made 'to order' from stem cells". Elsewhere, Tomas explains his fascination with chromosomes and contextualises this with high level claims for how "understanding them might help save lives".

6.5.2 Explicating humans

Across these high-level claims, four types of human appearances are explicitly negotiated into presence. Firstly, there emerge imaginations of a range of human health related applications. Examples include "new organs" being made to order from stem cells; replica chromosomes acting as screening tools for drugs that might help tackle cancer; a "custom component" tissue for an atypically formed body. These imaginations foreground the possible technical outputs of the research trajectories, identifiable as 'human' appearances by merit of their intended use. Secondly, there emerge imaginations of better characterised human physiology. For example, references to tissue engineering improving the "basic understanding of development", or human chromosomes being used to help study "mutant genes in human cells". These appearances position knowledge of the human body as a techno-epistemic object of investigation. A better understanding of which can help contribute to improved human health outcomes. Thirdly, there emerges an increased number of comparisons to endogenous human physiology and behaviour in relation to MSB research outcomes and effects. Non-specialist community performances

repeatedly encompass comparisons to endogenous or “natural” human processes to demonstrate what functions and features the MSB research projects are seeking to mimic. For example, in Madelaine and Rachel’s review of engineering tissues, the authors frequently anchor the outcomes and effects they hope to engineer in descriptions of the “natural” physiology of organs (such as the kidney) that they are trying to recapitulate.

Finally, there emerges a human enactment that we rarely encounter in non-specialist audiences; that of real-time human health challenges being foregrounded. Madelaine and Rachel draw our attention to this in their assertion that projects involved with engineering tissues can provide custom components to “repair an atypically formed body […]”. Tomas provides us with another example when he opened a presentation to a community comprising an array of non-specialist members by situating Project D44 in relation to the mechanisms of cancer. Opening his presentation with a slide of a cancer cell he outlined the importance of focusing on the epigenetics of chromosome segregation to better understand the mechanisms of cancer. Positioning mitotic segregation as “a diver of cancer genome evolution and tumour progression”, he positioned his replica chromosomes as a way to gain a more comprehensive understanding of disease pathologies. Through examples of this foregrounding of health challenges in the present, we also encounter for the first-time humans not just implicated as ‘users’ or ‘consumers’ of the technology, situated in the future at the end of a potential trajectory of translation. Instead, we encounter them foregrounded as ‘patients’ or humans with fallible bodies and health challenges in the present; “patients in need of a transplant”, those with “atypically formed” organ development, “patients with [monogenic diseases]”, and more.

6.5.3 Integrating humans

Project engagement with non-specialist communities vary in the purpose and nature of their performances, yet they share some strong similarities in the way these potential human appearances are assembled into presence. Firstly, they *are* explicitly assembled into presence as opposed to remaining implicated or manifest in their absence. All four human appearances are routinely performed to presence during the discursive enactments of each of the projects. Secondly, whilst the human appearances continue to emerge in the same parts of discursive enactments - such as the Introduction, Discussion, and Next Steps of both written texts and presentations, these parts of the discursive enactment comprise a much larger proportion of the project enactment. ‘Leaping to the results’ changes the composition of many of the non-specialist performances to emphasise the areas that situate

project work “in the bigger picture”. In doing so, non-specialist performances routinely debate project research in terms of the applications and outcomes it can produce. Indeed, recall Marek’s two performances; his performance to the predominantly non-specialist audience included a much higher proportion of the discussion focused on the ‘effects’, or potential human health-related outcomes, whilst his performance to the predominantly specialist audience included a much higher proportion of the discussion focused on the methodologies, and data. This is especially the case during an array of performances that do not so rigidly adhere to structural conventions such as interviews, blog posts, and podcast episodes. The effects and outcomes can emerge in many parts of those project enactments.

Thirdly, through an emphasis on these potential effects and outcomes, the different human appearances also tend to be elaborated in more detail. In Chapter 5, we encountered the benefits of loose guiding visions, allowing for ‘interpretative flexibility’ (Eames et al, 2006) amongst potential collaborators and investors. Meanwhile, in non-specialist communities, providing illustrations of potential products - or being specific about the types of diseases or pathophysiology that can be helped through MSB initiatives - helps non-specialist communities better relate to and evaluate the project and its findings. For example, Tomas and his colleagues provide much more detail on the way replica chromosomes can be used in project performances designed for non-specialists than the way they do for specialists. In their specialist community performances, replica chromosomes can be useful for “as screening tools” or “diagnostic tools”. Meanwhile, in non-specialist community performances, these opportunities are further elaborated:

> “Replica chromosomes may also be used as a pre-screen tool to study dosage effects of different anti-cancer drugs on oncogenic alleles of certain genes […] certain mutations [of those genes] lead to lung cancer.”

More elaboration negotiates more contextualising information into presence through which project information can be evaluated and understood (Bazerman, 2000).

Fourthly – and perhaps most notably for this study – there emerges a change to the spatial and temporal dimensions the projects enact through assembling these human appearances into presence. Whilst potential health applications and improved knowledge of human physiology are still positioned as future outcomes of potential trajectories, the effects they seek to recapitulate are first anchored “in nature” in the present. They are rooted in similarities between the outcomes and effects they are trying to accomplish and those that emerge in human physiology. MSB research objects seek to “mimic” natural asymmetry of organ development, or “replicate”

endogenous human chromosome behaviour. In enacting this ‘narrative of nature’ at the level of phenotypic results, there emerges a collapsed distance between the scientific research objects and the natural objects. The trajectories of work are also situated in response to an articulation of health challenges as a “medical need” in the present. As such challenges and corresponding “patients in need” are negotiated into the present, health challenges (such as ‘monogenic diseases’) are no longer the remit of ‘out there’, distant, and part of the distinct ‘present futures’ (Adam and Groves, 2007) that might eventually be addressed at the end of a trajectory of translational application. Instead, health challenges emerge in the present, through foregrounding of patients (“patients with monogenic diseases”), or real-time societal challenges with particular diseases (“cancer in humans”). They emerge as a “medical need” in the present to which MSB responds, also in the present.

This anchoring in present-day endogenous human physiology, as well as present-day medical need, collapses both the distinctions and distance between the MSB research and its outputs, and human appearances. Indeed, across the non-specialist audiences, the four different types of human appearances are negotiated into presence in conjunction with each other to materialise a narrative of ‘supply and demand’. Indeed, as Myers (1990) reminds us, skipping signs and proceeding to focus on the effects (and ultimately applications) can change the entire structure of the argument (1990:171). Human disease pathologies, chronic human diseases, or atypically formed bodies are assembled as the “medical need” or demand. Meanwhile, potential human health related applications (such as ‘designer tissues’) that seek to mimic endogenous human physiology (or complement it in some way) are positioned as a way to improve those human health prospects. Simultaneously, projects are also performed as aiming to better understand human physiology and disease pathologies (and in doing so “understanding them might help save lives”).

In doing so, MSB ‘unfolds a response’ to a medical need during its performance of projects to non-specialist communities. This changes the way that the futures with which applications and outcomes are associated are performed. Specialist community performances assemble human appearances associated with futures that are distant, distributed across a range of spatialities, held distinct from the project performances. However, non-specialist community performances assemble futures that are being made in the present, responding to a real-time medical need, and ‘unfolding’ a response in the present (Adam and Groves, 2007) that correlates tightly to endogenous human physiology. In this way, human appearances are integrated into the heart of project performance, enacting ‘performative time’ over clock time.

6.5.4 Accommodating a narrative of nature through biological materials

6.5.4.1 Different biological enactments

The leap to results and increased emphasis on outcomes and applications does not just change the way that projects enact their potential outcomes and applications, it also changes the way in which experimental systems and the biological materials of research are performed.

There are three main ways that a focus on outcomes and effects increase human enactments of biological materials. Firstly, there is an increased reliance on analogy and comparison. We have seen some examples of this in the preceding section. Analogy is a common technique practitioners use to accommodate non-specialist audiences. They provide a way to accommodate the complex biological processes and systems through comparison to a process with which the community audience is familiar. There are many examples of this across all four projects. Some relate to everyday items which non-specialists are likely to be familiar. For example, likening cellular patterns to a “chessboard/polka dots” (Rachel), or likening them to “animal stripes or spots” (Marek), or using visual metaphors during visual presentations such as disentangling string to describe the process of mitotic segregation (Tomas).

However, other analogies and comparisons specifically foreground comparisons with human biology to render biological materials and their mechanisms legible to a wider community of non-specialists. For example, in another review article encompassing discussion of the Garcia Lab projects, Madelaine sought to explain the concept of predictability and its role in pattern formation through elaboration of how it can be witnessed in the human body:

> “In pattern formation, an initially uniform field of cells acquired non-random inhomogeneity, predictable either in detail (e.g. the pattern of bones in the hand) or predictable in statistical character even though not in detail (e.g. the pattern of a fingerprint, which is unique to individuals even in identical twins)”.

In another example, Maxwell first introduced his project to me (as a non-specialist audience of one) through a series of comparisons and analogies he thought I might find helpful. “My particular project is looking at a specific type of cell behaviour, which is based on adhesion” he had opened, before proceeding to explain adhesion as a process of scattering and aggregating cells. He outlined his project as designing a cellular system that controls the scattering and aggregating using a light stimulus to produce “a sort of lifecycle where cells are scattering and then cells are coming back

together". Here, Maxwell had paused, seemingly trying to find a way to connect his description of abstract biological processes to a more accessible explanation. He alighted on an analogy in nature: "Coming from a different perspective, say bacterial cells, they have something called quorum sensing. Which is where they sense their size, they sense the size of a colony, so something like say 10,000 bacterial cells come together and then the minute you have a certain number of cells, you realise 'oops we are too many', and scatter. So this actually happens in nature".

Picking up steam, he alighted upon a more pertinent example, this time relating it to human disease pathologies. "So, tumour cells for example, yes, so one of the reasons tumour cells, you know massive tumours are bad for you is because once you have massive tumours, the chances are that some of these cells will break off and metastasise." In this way, he had not only anchored his biological mechanisms of interest and techno-epistemic objects of research in mechanisms and processes that happen "in nature" – and more specifically in *my* human body – but he had also conveyed its potential significance through implicating its connections to better understanding cancer pathologies. "And this is an interesting phenomenon" he had continued, "so my project hopefully, if I can understand how this happens and potentially control it, then I can - I don't know - there are *unlimited* possibilities". In this brief introduction, Maxwell had accommodated the biological materials, mechanisms, and behaviours of Project D43, firstly by relating it to behaviours and phenotypic effects (rather than molecular pathways, genetics, and cascades), and secondly by relating it to what happens in human bodies in nature to provide a contextualising set of information through which I could not only understand the project, but also evaluate its significance.

A second way that the focus on outcomes and effects increase human enactments is not to draw comparisons or use analogies but is through designation of biological materials as human themselves. It is through the designation of genes, proteins, and cellular systems as "human" that we encounter the collapse of the distinction between what are research objects of experimentation and what can be considered their natural counterparts. Across an array of non-specialist project performances from blog posts to guest talks, there are multiple accommodations to biological materials to perform them as "human cells", "a population of human cells", and more. In one example, Madelaine summarises the work on Project D41 as "using human kidney cells to make animal coat-like patterns". Elsewhere in Project D43, rather than expressing a system "in human embryonic kidney cells (HEK-293T)" the experimental work is described as performing work in "a culture of human cells". Meanwhile, other materials such as proteins and genes are performed as "human

genes", or "human proteins", rather than specifying the exact gene in question. The distinction between the biotechnical object, and the endogenous human biology they stand in for is collapsed. The human is no longer merely *implicated* through the 'representational scope' of the biological materials, nor comparable to effects in endogenous human bodies, nor is it even entangled in the broader epistemic domains and trajectories through notions of human health and application. Instead, the human is foregrounded as part of the experimental system itself.

Indeed, at one point I challenged one participant about her performance of her cells as "human cells" as she produced a poster designed for a mixed audience. Previously she had been clear to assert she did not consider her human-derived cell line technologies as 'human'. Yet in preparing her poster, she had shrugged off the incompatibilities of the cells as not being human; "well, they *are* human" she had asserted, frowning, seemingly perplexed by the question.

6.5.4.2 Explicating humans

What these human enactments share is a 'settled ubiquity' with which they can be considered 'human'. These performances remove any modalities or qualifications relating to the 'humanness' of the cells that we find during specialist discourse or interrogating practitioners for their views on the cells (such as "human-derived" or "not *human* human"). Instead of the three distinct ways in which biological materials can enact the human (through provenance, phylogenetic designation, or physiological form and function) – through which 'humanness' can be negotiated and clarified - there emerges just one generalised way the human appears. It emerges as a 'generalised human biological subject'. Here, I draw inspiration from Landecker's (2007) term "generalized human or cellular subject" (Landecker, 2007:165). Landecker introduces this notion in the context of HeLa cells where they seem to have such "settled ubiquity" that they were taken for granted as standing in for a "generalised human or cellular subject" (207:165)[50]. I adapt this term to encompass more than just cell culture, but any tissues, organs, or biological bodies more broadly, that emerge as 'settled', uncontested, and without the need to justify of foreground in what way they might come to be considered human (through provenance, phylogeny, or physiology, or all three).

[50] Here, Landecker (2007) specifically references scientific publication; this is - as Landecker acknowledges - a special case for Henrietta Lacks' cells. For the HEK293 and HT1080 derivatives of this study, this generalisation tends to emerge instead during non-specialist publications.

6.5.4.3 Integrating humans

Once again, these differing human enactments share some core patterns in the way they appear. Firstly, the human enactments of biological materials are almost continuously integrated through non-specialist performances. Through the emphasis on outcomes and effects, human appearances to emerge through comparison and analogy emerge in the parts of project performances associated with effects and outcomes. These may typically include the Introduction, Discussion, and Next Steps sections of presentations, posters, and articles; or indeed at any point during less convention-led formats such as blog posts, podcast episodes, and interviews. However, as already outlined in the preceding section, this type of content enjoys a much higher proportion of the non-specialist performances. Meanwhile, any discussion focused on the experimental systems themselves also enact human appearances, whether through designation as "human cells" or attribution of human-like motivations and character traits such as heroism or helpfulness. Between the process of comparison and analogy, as well as designation as human or attribution of human traits during any elaboration of methodologies and experimental systems themselves, there emerges a sustained integration of human appearances into the performance of biological materials. Such tighter and sustained integration brings human appearances into the 'here and now' of project performance. Any distinctions between human cells "in nature" and the biological research objects as "not what *I'd* call human" are summarily collapsed into a single generalised human enactment.

This shift to a narrative of nature not only collapses any distance between the "natural" and what the experimental systems enact, it also increases the ambiguity with which certain claims and statements are made. Recall Ankeny and Leonelli's (2011) discussion of the representational target of biological materials and how they can stand in for a broader representational scope. Human-derived cell line technologies can be assumed to stand in for endogenous human cells. However, whilst such representational extrapolation often underpins the experimental context, collapsing "human-derived cell lines" into "human cells" introduces ambiguity into how far along MSB research trajectories might be. As Rachel explains, you perform these experiments in the cell line technologies and only *then* might you proceed to more clinically suitable cellular systems. That distinction matters. When assembled into absence with unfolding futures and a narrative of supply and demand, ambiguity of the biological materials involved can encourage an imminence to any potential human-specific outcomes.

6.5.5 Performing human-adapted practitioners to presence

6.5.5.1 "Inserting and orienting oneself inside a phenomenon"

During non-specialist performances, practitioners often perform themselves as an inextricable part of the account, especially during audio and visual project performances such as presentations, videos, and podcasts. Practitioners routinely perform themselves to presence as biologically human to bring their account of project work to life. Indeed, as Myers and Dumit (2011) note, scientific storytelling is "a process of inserting and orienting one-self inside a phenomenon" (2011:243). There are occasions when such insertion occurs during specialist performances (for example to create rapport with audience members). For example, in his performance of Project D41, regardless of the type of community through which he is performing, Marek had taken to wearing a striped shirt to his presentations on Turing patterns (that can generate patterns of stripes or spots in cells). At points they quip that their choice of attire "isn't a coincidence", reinforcing the subject matter through inserting themselves into the performance. However, typically such insertions are more prevalent in non-specialist accounts to render project details accessible for communities who lack pre-existing contextualising information to relate to the information themselves.

Madelaine is particularly strong in her use of physicality to help non-specialist communities relate to some of the more complex biological topics. For example, during one meeting comprising a mix of both specialists and non-specialists, she had been introducing her present portfolio of projects in relation to a former project upon which they were built. This project involved programming certain cells to die. At this juncture, Madelaine held up her hand. Waggling her fingers, she tells the audience that cell death is what happens when the space between the fingers is created. Pointing to the space between her own fingers, she explained that the webbing that grows between our fingers during embryonic development is killed off through cell death, a process known as apoptosis. She dropped her hand and carried on summarising the outcomes of the project.

With this simple and fleeting bodily gesture, Madelaine had performed four types of work. Firstly, she had inserted herself into the discursive performance as an exemplar of human physiology, using bodily gestures and her own physicality (Myers and Dumit, 2011) to render concrete the human connection of the work. This type of humanising action was something not performed in solely specialist places of scientific practice. Secondly, she had 'accommodated' a potentially complex

biological idea in a way that not only made it accessible to a non-specialist audience, but in a way that also related it to each audience member. Thirdly, and relatedly, in doing so she also inserted the audience members into the performance of the project as exemplars of human biology. I was not the only audience member who fleetingly contemplated their own fingers and toes during Madelaine's explanation (Maxwell had later laughed when I told him and explained he had done the same thing). Finally, she shifted her project account from narrative of scientific work to an account of natural processes. Madelaine had used her own physicality as an example of what happens in nature.

6.5.5.2 Narratives about science

Yet inserting oneself into the project phenomenon through discursive enactment is not the only way practitioners are performed as 'human' during non-specialist performances. As identified in Section 2.4, there is a third type of narrative to emerge, that of the narratives *about* science (Davies et al, 2019). Here, practitioners sit at the centre of stories as the protagonists of their own experiences and the accompanying narrative shifts from accounts of explanation to accounts of *expression* (Davies et al, 2019). The accounts are infused with anecdotes and stories that make for a more engaging experience (Dahlstrom, 2014).

We see this happen in non-specialist performances across some of the four case study projects. During interviews with Principal Investigators about their experiences working on the projects (Tomas and Madelaine) as well as with some of the lead project researchers (such as Addison and Marek) there emerge accounts *about* the science, not just about what it can tell us. In addition, through new media formats such as podcasts and materials produced to tell stories to non-specialist audiences in innovative new ways (such as a short comic strip cartoon explaining about replica chromosomes), we encounter narratives *about* science that also enact the case study projects. It is through these that we encounter many more human practitioner enactments. For a first example, we turn to a podcast with Tomas talking about Project D44 and his own experiences with making replica chromosomes.

"Discover the stories behind the science" reads the strap line of the scientifically focused podcast featuring an hour-long discussion with Tomas. Sometime in 2020, Tomas had featured on this podcast talking about replica chromosomes, their long history, and Project D44 in its current incarnation. The podcast itself self-identifies as a scientific podcast although Tomas considers his work with these types of forums as 'public engagement'; he is engaging a community who have little pre-existing

knowledge of replica chromosomes, albeit scientifically literate. Accordingly, Tomas oscillates from embarking upon detailed technical descriptions to accommodating non-specialist audiences. However, the genre of project performance is undeniably epideictic or celebratory (Fahnestock, 1986); at its heart this is the origin story of replica chromosomes, and the variety of practitioners and contributors who came together to make them possible.

The first replica chromosomes emerged in the face of limited tools and technologies available to observe chromatin and the kinetochore of chromosomes. Rather than continuing to face with such challenges and limited technologies, Tomas and his colleagues set out to build a replica human chromosome which they could then use to study chromosome behaviours, rather than relying on techniques to interrogate endogenous ones. Over the rest of the episode, there unfolds a gradual 'enlightenment' (Wise, 2017) that led to modern day replica chromosomes and Project D44 in its present-day incarnation. Tomas takes control of the unfolding story through pivots and tangents ("it's a long story") and what unfolded over the space of 60 minutes was a journey into Tomas' experience from early challenges, to designing the replica chromosomes, to building them and working with them in the present day.

Throughout the story, there also remained some explanation of biological components and how the replica chromosomes work - some in highly technical detail befitting a scientific audience. One anecdote stood out for its performance of human enactments. Tomas was recounting his thwarted attempts to secure some samples from human scleroderma patients that might contain some rare antibodies that he needed: "you send one last letter" he explained "and finally [the doctor] replies! It turns out that she's really special. […] Because her husband is a scientist, she takes every one of the samples of her patients and saves them […] so she had 60,000 patient sera in these -80 freezers and she knew what was in there […] and these antibodies are *rare* […] so she said, 'oh I have some of these antibodies, I can give you some". Tomas explained how he could essentially 'shop' for the sera he needed and in doing so came to tell the tale of "one of the best sera" they ever secured: a woman whose sera was eventually used to clone to two of the major proteins involved in the kinetochore. Tomas recalls, "she suffered greatly with scleroderma. She had very hard veins" he tells us, "it was very difficult to be bled, it was difficult and painful to be bled. So she was a real hero. […] that patient […] made a *huge* contribution".

With this account, Tomas celebrated how the one patient's contribution changed the research landscape enabling him and his colleagues to accomplish replica chromosomes in human before even in yeast. It was a compelling story, and a tribute to the woman whose biological materials had made Project D44 (and its precursors) possible. This part of the story was a personification of the research, focusing on the relationships between his rheumatologist colleague, the sclera donor, and he and his team, increasing the empathy and ability to relate to the research (Dahlstrom, 2014). Indeed, Joubert et al (2019) argue that creating emotional connections between scientists and the nonspecialist communities and audiences is a key part of the science communication endeavour moving forward.

Here, Tomas performed himself through a handful of human enactments: not only as the protagonist in the story through his creativity and curiosity, but also through his role in its re-telling, through the passion and emotion (including his reverence of the courage of his donor) which he provides the account. Both are performances that embrace positively valued human traits. As Olson (2009) might characterise it, the hour-long account is a combination of facts wrapped in emotions. However, what is also of note is how the focus on this small band of protagonists also foregrounds the human enactments associated with the human biological materials. Tomas foregrounds the role of the donor of the human sclera for the "*huge* contribution" she made. Providing a protagonist led personification of science in this way entangles the contributions made from an array of human actors.

Indeed, it is not just the human actors who are performed into presence through human appearances, but also the non-human actors as well. Occasionally, the biological materials themselves are performed to presence as protagonists in their own story, personified and attributed 'human' characteristics. In a short second example, we turn to a short comic strip story that is written about the replica chromosomes and the work they perform. Here, we encounter Davies et al's (2019) suggestion that 'fiction' can also be used to effectively communicate projects to non-specialist communities. In this short comic, replica chromosomes become the "legendary heroes" of their own story. Mimicking the folk tales that follow a hero through a series of challenges (Dahlstrom, 2014), we follow the replica chromosomes as they are made by Tomas and his team. We see the challenges it takes to make the replicas, and how they can be identified. We switch to follow them in the cells and the work they can perform and how they are tools for "combatting cancer". The replica chromosomes are performed as being eager to help, selfless, and heroic. Humanised through metaphor and personification, they enact valued human-like characteristics and become the protagonists of their own stories.

6.5.5.3 Integrating humans

Across the performance of practitioners, human enactments are performed to presence as an ongoing part of the project materialities, central to the scientific endeavours. Within the content of the story being told, practitioner human enactments are foregrounded as central to the research endeavour and performed to presence across the different stages of research, not just the design stages, or the 'interpretation' stages[51]. In the retelling of the story, they do not just appear in a set number of places (such as introductory sections or concluding sections); story telling structures are quite different (Dahlstrom, 2014) and follow a gradual 'enlightening' (Wise, 2017) which sees them performed to presence for the duration. Meanwhile, when it comes to the discursive enactments *of* the content, practitioner human enactments occur to make multiple sets of information more relatable, not only biological materials, but also project goals, and outcomes and effects, they are to be found inserted across all aspects of the story. At all stages of both content and discursive enactment practitioner performances can be found, brought to presence and integrated into the story telling. In this way the practitioners themselves are performed as "inspiring communicators", performing the 'human aspects' of the MSB research.

At the same time, within both the content being told *and* the discursive performance of the projects, the practitioners in their human performance are also performed as inextricable from their relations with other project materialities. In the case of the story about science, Tomas' account foregrounds the relationships he has not only with his other practitioners, but also the materials with which he works, and the donor of his biological materials. Meanwhile, during the discursive enactment Madelaine renders herself inextricable from the patterning systems and mechanisms of cell death they seek to control. For the duration of the project enactment, practitioners are not only foregrounded, but they are also foregrounded as inextricable from their relations with other project materialities.

These narratives about science negotiate human enactments of practitioners into presence as protagonist roles, and in doing so science becomes a very human endeavour in both accounts of past activities and ongoing activities in the present.

[51] Although it should be noted that some residual separation still exists in some discursive enactments. For example, the strapline of the podcast refers to discovering the stories "*behind* the science".

6.6 Assembling relations, complexity, and places

Throughout this thesis, Karin Knorr-Cetina (1999) and Doreen Massey (1994) have provided us two ways to think about project materialities in terms of their set of relations to each other. On one hand, Knorr-Cetina (1999) provides us the idea of small, localised, and closely related set of materialities enacted in practice. She refers to these as “small lifeworlds” (Knorr-Cetina, 1999:217). We have already seen how these emerge during experimentally focused performances of the Laboratory. This is a useful heuristic to think about the immediacy or proximity of the relations between materialities that are foregrounded. Meanwhile, at the other end of the spectrum, Doreen Massey (1994) talks of ‘extroverted relations’ as a way to consider - in her case - places, but any cluster of materialities, meanings, and practices and more distributed relations between the materialities. Massey (1994) draws on this notion of ‘extroverted relations’ to demonstrate how specific performances of places can entangle imaginations from the future, or representations of objects from the past, or connections on the other side of the world into their performance, assembling them within the enactment of particular place. Taking this as a heuristic for project enactments, performances of projects that foreground their connections with imaginations of human applications in the future, representations of donor contributions from decades ago, and other project enactments in the present can be considered ‘extroverted’ in their arrangement. It is through these two conceptualisations of materialities and their relations that I wish to use to draw the differing community performances together.

During specialist performances such as a Lab Team meeting, projects are performed at one end of the spectrum in tight, small lifeworlds on a comparable scale to experimental work itself. However, as projects are performed through distributed communities – for example the wider scientific community to ensure project research is validated – the practical ontologies through which they are performed differ. More distributed relations are emphasised. Contextualising information is foregrounded, projects enact practical ontologies through the standards and conventions of wider scientific communities, they adhere to the requirements of journal editorial guidelines that require significance be made clear. Practitioners even attend conferences around the world to showcase their projects and perform them as part of specific communities, whether synthetic biology, cell biology, developmental biology, or others.

As part of performing as a member of specialist and wider scientific communities, human appearances emerge through work to accomplish significance and

integration through the conventions and ontologies of the community. Additionally, as the overlap in specialist knowledges also decreases, the entanglement with more generally accessible knowledges increases. At some point, the decrease in contextualising specialist knowledges renders a community predominantly non-specialist. It is through these communities that as well as human enactments and appearances to provide significance and integration, they also emerge to provide an accessible foundation through which to evaluate, understand, and relate to the project performance. The extroverted relations are far-ranging and entangle and bring to presence multiple human appearances in doing so.

During the small-lifeworld arrangements that focus on excluding human appearances into context, or – as they expand – negotiating them into presence in the peripheral or ancillary parts of project performances, human appearances are discursively and sociomaterially negotiated into set designated places. Whether they are ‘out there’ in the natural realm, or ‘in the future’ as part of human applications, or ‘in here’ in designated sections of the performance such as Introductions and Conclusions, in the “interpretation” not the “facts and evidence”. There is a ‘time and place’ for the human entanglement and enactment. This performance is in line with the romantic conception of complexity where everything has its place (Law, 2004b).

Meanwhile, non-specialist performances perform a different type of material arrangement and thus enact differently configured places. The extroverted relations are discursively performed in a more inclusive way. The extroverted relations (Massey, 1994) are ‘condensed’ into an ‘in here’ (Law, 2004a) in a way that collapses the distinctions of an ‘in here’ and an ‘out there’. As Law (2004b) would argue, it performs a ‘baroque’ notion of complexity, where everything is present if you look hard enough. During non-specialist community performances, participants ‘looked hard enough’ and foregrounded the extroverted relations as part of the project performance. In doing so, the distinctions between health applications and futures are collapsed through the supply and demand narrative, and the real-time “medical need” that emerges brings human appearances into the supply chain as a driver, not an ‘end result’. The same can be said with distinctions between research objects and natural objects – they are all but collapsed, research objects performed through their natural effects and outcomes, or even designated as “human cells” (typically the preserve of the ‘natural realm’). Even practitioner performances become integrated into not only the discursive enactments of the project performances, but the project content itself. Protagonists sit at the heart of scientific endeavours.

In this way, through the discursive performances of spatiotemporal exclusion, specialist community performances enact romantic complexities, pushing the extroverted connections to the periphery of their performance, into ‘placed’ connections, and places they ‘belong’. Meanwhile, through the discursive performances emphasising connections and similarities over differences, non-specialist community performances enact a baroque approach to the complex set of relations they entangle. They bring them in to the here and now; expanding the project performance to encompass much more than the small lifeworlds of the specialist performances.

6.7 Conclusion

In this final empirical chapter, I have produced an account of not only what human entanglements and enactments emerge, but – like the chapters preceding this one – how they emerge, the circumstances under which they emerge, and the work they do through their performance. In doing so, I characterise the places of specialist communities as generating places of peripheral and manifestly absent human contexts. In contrast, I characterise the places of non-specialist communities as generating places of integrated human inclusion. This account has completed the process of building the empirical evidence that we use in the next chapter to draw together all the themes and answer the research questions. In addition, it has afforded the opportunity to pay a little closer attention to the performances of material arrangements and dive into theorising their performances more fully in terms of their ‘small lifeworldly’ arrangements (Knorr-Cetina, 1999) or their ‘extroverted relations’ (Massey, 1999).

Armed with the insights from this chapter, and all the preceding chapters before, all that is left to do is to start drawing all this evidence together.

Chapter 7: Synthesis and discussion

7.1 Introduction

At the start of this thesis, I set out to understand the ways in which the human appears in the context of real-time MSB research practices. In doing so, my goal was to generate a better understanding of what types of human appearances emerge; how, when, and where they emerged, and what work they might perform as part of the MSB research materialities. In turn, this goal came with two objectives. Firstly, to contribute evidence and socially robust knowledge generation to an area that is empirically underserved. Secondly, to generate insight that might be useful in guiding how to engage with MSB researchers on topics relating to the human moving forward.

In this final chapter, I return to these two objectives. Firstly, in Section 7.3, I draw the accounts from the empirically led chapters together, link them with the theoretical foundations outlined in Chapter 2, and produce a response to the overarching research question and sub-research questions I posited in Section 1.4. In this way, I hope to satisfy the first thesis objective, contributing evidence and knowledge to an underserved area. Specifically, I start by recapping the research questions and introducing the ways in which it is possible to answer them. I then distil the accounts from the empirical chapters to produce an overarching response to the questions. I conclude this section by stepping back to consolidate what we have learned about the human in mammalian synthetic biology.

Secondly, in Sections 7.4 and 7.5, I pivot attention to how we might be able to make use of what we have learned and make some suggestions for STS engagement with MSB research moving forward. Specifically, I advocate for future STS research into MSB research (specifically in relation human entanglements and enactments) to develop methods of interaction that are more ‘place-centric’, acknowledging and incorporating the importance of place. I first summarise the existing methods of STS interaction with MSB. I then identify how they already engage with concepts of place, before drawing on the findings of this thesis to offer some suggestions for rethinking STS interaction with MSB. Specifically, I offer a discussion on using the concept of ‘topical contextures’ encountered in Chapter 2 as a potential method of intervention

in STS-MSB interactions. Finally, in section 7.5 I offer a final reflection before concluding the thesis.

7.2 Approaches to addressing research questions

In Section 1.4, I outlined one overarching research question and four sub-research questions this thesis set out to address.

> RQ: How does the human appear in the context of real-time mammalian synthetic biology (MSB) research practices?
>
> > S-RQ1: What types of human appearances are there (if any)?
> >
> > S-RQ2: What are the circumstances of human appearances: how, when, and where do they emerge?
> >
> > S-RQ3: What work do human appearances perform in practice?
> >
> > S-RQ4: What can we learn from the answers we find?

There are two ways to respond to these. Firstly, there are answers that respond to the questions in a literal sense. These provide targeted accounts that answer the questions with the specific details encountered by studying situated materialities and practices in the four case studies. Secondly, there are answers that respond in a more generalisable way (notwithstanding the objections to generalisability I outlined in Section 3.2.2). These distil broader patterns from the similarities and differences emergent in the empirical detail in a way that connects the preceding empirical data to the themes of materiality and practice, function, and place in the Theoretical foundations chapter (Chapter 2). This lends a significance to the results that has broader currency outside of the four case study projects.

In the case of the first approach, each of the preceding empirical chapters stand as a literal response to the overarching research question. In each chapter, I have produced an account of how potential human appearances are entangled and enacted in a specific place through which real-time MSB research occurs. I have presented the empirical evidence to speak to each of the sub-research questions. I identified the different types of human appearances (corresponding to S-RQ1). I used thick description (Schwandt, 2001) to elucidate the circumstances of how, when and where they emerge, paying close attention to the mechanisms through which they do (corresponding to S-RQ2). I unpacked the work that each of the

human appearances performs in practice (S-RQ3). Throughout each chapter I also reflect on the key patterns we find for what we can learn from the preceding answers about the performance of human appearances in real-time MSB research (S-RQ4).

However, it is the second approach to addressing the research questions that generates a more significant and useful response with which to move forward. This is the subject of the following section.

7.3 Placing the human in mammalian synthetic biology

7.3.1 Answering the questions

As we have already seen from the empirical chapters, human appearances are inextricably connected with the circumstances of their performance and the function they perform. Instead of artificially disentangling these relations to step through each question in turn, I instead generate the answers to these questions in an account that addresses them in the context of their connections.

7.3.2 Characterising human entanglements and enactment

Across the empirical data, there are an array of different ways that potential human appearances emerge. In the preceding chapters we have encountered and characterised multiple types. There have been imaginations of potential human-health related outcomes (such as imaginations of future gene therapies, or better understanding of human physiological processes). There emerged a variety of biological enactments (human provenance, phylogenetic performances of biological materials as 'human', enactments of human physiology, and a generalised human biological subject). In some places we have also encountered stories about the human donors of biological materials, or real-time human patients and health challenges. There have also been 'very human' traits (such as curiosity, creativity, and less valued 'subjectivities' such as human error, or bias). Amongst this diversity, however, there are some broad principles about human appearances we can make.

Firstly, in line with the permissive approach I adopted for what comes to count as a 'human appearance' (see Section 1.3.), human appearances can – and do - take a range of forms. Firstly, potential human appearances emerge as both 'direct' or 'indirect' appearances. A 'direct' form emphasises the human as a direct focus of the performance. For example, the explicit discussion of past human donors of human biological materials we encountered in Tomas' podcast (see Section 6.5.5), or a

biological material designated as ‘human’ when accommodating projects in narratives of nature (see Section 6.5.4). Meanwhile, an ‘indirect’ form might comprise an imagination of a future gene therapy for monogenic disease (see Section 5.4.1), where the humans are an indirect focus of the performance, and the ‘human’ emerges more as a characterisation by merit of indirectly ‘relating’ to the human.

Secondly, human appearances emerge in three types of material form. In the first instances, they can emerge as imaginations of humans, such as imaginations of human-health related outcomes. There emerges no physical corresponding reality being ‘reported on’ (Law, 2005). We see this, for example, in the promises of human-health related outcomes encountered in Section 5.3.1 when negotiating the organisational lives of projects. Human appearances can also emerge as representations, where performances seek to ‘report on’ a reality that may be enacted elsewhere (Law, 2004a:42), such as Tomas’ discursive representation of his sclera donor (Section 6.5.5). In addition, human appearances can also emerge as physical presences, such as the enactment of humans as biologically human in Madelaine’s performance of inserting her own biology into the story telling (Section 6.5.5.). Whilst the performances are different, all three forms are *materialised* in the present through the practical achievement of imaginations, representations, and physical matter being performed as material act in the present (Woolgar and Lezaun, 2013; Law, 2004a).

However, whilst on the surface these multiple forms of human appearances bely a great diversity of human entanglement, there are many other potential human entanglements and enactments in the wider UK MSB context that do *not* emerge during real-time practice. Indeed, during my engagement with participants there were multiple occasions when they might suggest ‘taking a break’ from their work or going for a walk. It was through these ‘distantiated’[52] performances – including some parts of the semi-structured interviews which followed actors into topics that departed from their own research - that other human appearances relating to the ethical contexts of MSB tended to emerge. Deepti, Zofia, Tomas and more all discussed science fiction references such as Gattaca and Never Let Me Go. Meanwhile, several participants debated the case of He Jiankui and his CRISPR editing work, or Josiah Zayner and his biohacking approaches. Almost without fail these appearances emerged as cautionary tales to perform boundary work (Gieryn, 1983) to put distance between those projects and their own, usually accompanied with assertions of ‘absurdity’

[52] A term I borrow from Michael et al (2005) who describe a ‘distantiated bureaucrat’ (2005:380) as someone capable of reflecting on their work ‘from a distance’.

(Tomas) or claims that “my project is nothing like that” (Maxwell). As Zofia explained during a discussion about a range of science fiction, these types of ethical contexts and ‘futuristic’ imaginations just had “absolutely nothing” to do with any of the work that she was involved in with Project D41. However, during performances of the real-time MSB research practices themselves, these potential ethical debates and cautionary tales were nowhere to be found.

Instead, the human appearances that do emerge represent a subset of potential human entanglements and enactments. Specifically, they comprise a typically biomedically focused and research orientated set of possibilities. This subset is predicated on – and shaped by – the fact that *what* human appearances emerge is contingent on the materialities and practices through which it is performed (Gad et al, 2015). Instead, what is and is not performed into presence is already implicated and thus constrained by specific materialities and practices through which it emerges.

7.3.3 The contingencies of human appearance

This narrow and biomedically focused subset of human appearances is therefore predicated on two key circumstances of appearance. The first is that human enactments are inextricable from the practices through which they emerge. As evidenced across the empirical chapters from the first trip to the Meier Lab (Section 4.3) to the last discussion of Tomas’ podcast episode (Section 6.5), human enactments do not just ‘appear’ from a “a position in the metaphysical clouds” (Jensen and Marita, 2015:82). They are performed into being through practices in action and constantly negotiated and renegotiated into being as a practical achievement (Woolgar and Lezaun, 2013).

The second is that appearances are inextricable from the other materialities with which they are performed. For example, molecularised and biomedicalised visions of human health are more likely to emerge through biomedically focused institutional arrangements and molecular biology techniques. In this way, it stands to reason the converse is true. Imaginations of science fiction, ethical contexts, and science fiction have less overt connection to either the practices or the materialities being performed if there are negligible other related materialities or practices through which they can be ‘practically achieved’. They become unlikely subjects for practical achievement. Indeed, typically, the range of human appearances in real-time MSB research are found grouped into three main clusters – or contexts - of project enacted materialities. These include those relating to project goals and outcomes, those that form part of the performance of biological materials, and practitioner

performances that explicitly foreground ‘human’ traits. As Barad (2003) observes, these constrain *potential* human entanglements before enactment through practice is achieved.

7.3.4 Performing functions and doing work

Building out the argument for inextricability with materialities and practices, whether a human appearance is negotiated into presence (and when and where) is also contingent on the function they can perform. Across the different places of research, we encounter a wealth of evidence to suggest that human enactments that can perform a useful function as part of the immediate research materialities are more likely to be foregrounded; those that are not, are elided. For example, we have seen how imaginations of human health-related outcomes are routinely negotiated into presence as ‘guiding visions’ in the promissory rhetoric of organising units to mobilise funds (see Section 5.4.2).

However, we also see how performing those useful functions performs a wide range of additional work in the present, often beyond the function for which it was selected. For example, we have seen how human appearances enacted in guiding visions to negotiate alignment between research activities and societal priorities also provide direction to the research projects, generate a ‘sense’ of momentum across the field more broadly, and inform institutional arrangements across the Institute and the Laboratories.

Meanwhile, in Chapter 6, we find countless examples for how different human appearances are configured across narratives of science, narratives of nature, and narratives *about* science to negotiate significance and relevance across a diverse range of communities. For example, we see how practitioner performances enact their own body as biologically human helps accommodate complex topics for non-specialist communities (see Section 6.5.4).

Even in places where human appearances are rare, the human enactments we do encounter emerge due to the useful function they perform. For example, in experimental laboratories the fleeting comparisons of experimental systems with human physiology serves a useful purpose to ensure experimental systems are still capable of contributing towards their human health-related aims. Elsewhere, practitioner enactments of curiosity and creativity emerge during the design phases and troubleshooting where innovation, ingenuity, and novel ways of engaging with design or thorny problems serve a utility.

Typically, there are two types of work that the human appearances perform. Firstly, they perform collaborational work to bring different people or materialities together. Examples include human health-related imaginations being used to align societal priorities and experimental priorities (Fujimura, 1986); or constructing a narrative *about* science using the human stories of donors, practitioners, and potential patients to generate interest amongst the membership of a community. Secondly, they perform epistemic work to help make sense of materialities or performances. Examples of this include performing biological systems through human metaphors and traits to render unpredictable behaviour more legible; or using potential human health-related outcomes to contextualise the significance of research amongst communities who lack pre-existing knowledge of the topic. In line with the subset of humans that appear, it is rare to find human appearances performing any overt ethical work through their appearances in real-time research.

In performing useful functions such as collaborational and epistemic work, human appearances also perform 'performative' work in the present. One of the most prevalent is their role in configuring the spatial, temporal, and social expectations of the places through which they emerge. We return to this in Section 7.3.7. But first, we turn to how places configure the human appearances.

7.3.5 Human appearances enacted in places

Perhaps one of the most prevalent actor-led categories in the empirical data is the way in which human appearances are tightly linked with notions of place. Human appearances routinely emerge through spatially, temporally, and socially ordered performances of place. Each empirical chapter has stepped through the ways in which human appearances are sorted in relation to space, time, or 'social order' (Agnew, 2011) during their performance. As outlined in Section 2.4.11, places are powerful. In performing the sorting and ordering work outlined above, places enact normative assumptions and expectations of what materialities and associations belong where (Cresswell, 1996).

Indeed, nearly every participant routinely performs human entanglements into presence or absence in line with some form of place-related normative association or expectation. Indeed, place is one of the easiest ways of including and excluding materialities (Cresswell, 1996). For example, there is almost a conspiratorial conviviality about "dialling up" such medical links in places of organisation, and Deepti amongst others are quick to point me in the direction of non-specialist

communities as being “where the human comes up”. Conversely, the laboratory is a place where the human – in nearly all its forms – does not belong. There are ‘right’ and ‘wrong’ places for human entanglement and enactment. This creates opportunities for transgression (Bowker and Star, 1999). For example, Maxwell appears horrified at the prospect of entangling imaginations of human health and outcomes whilst they performed work at the bench (“my whole science training is wasted”), invoking notions of ‘matter out of place’ (Douglas, 1966).

Massey (1994) and Law (2004a) amongst other both remind us that realities grow out of ‘right’ and ‘wrong’ patterns. Places as a process wield performative power; the ‘rootedness’ and notions of what does and does not belong helps shape future sorting and ordering practices. In effect the expectations extend or deny chances to other materialities and meanings (Cresswell, 2014) through the very processes that give rise to them. Across the empirical chapters my research shows that ‘rootedness’ or ‘sense’ of place repeatedly sort, order, and constrain the potential human appearances that do or do not belong there.

7.3.6 Tensions across human appearances

Place is powerful. In wielding this power, it can create tensions with other factors that affect potential human entanglements and enactments. For example, if potential human appearances perform a useful function, they still do not guarantee an enactment into presence if the potential appearances do not ‘belong’ there. We encounter this tension at several junctures in the empirical accounts. For example, in Section 4.6.6. we encountered such a tension when participants renegotiate their relationship with biological materials through drawing on conceptual behaviours of human traits to render unpredictable biological performances ‘legible’ (Szymanski, 2018). Human likes, dislikes, attitudes, and emotions all have value in helping the researchers navigating their experimental systems (Waytz, 2010). However, multiple participants including Maxwell, Rachel, and Zofia, asserted vociferously on multiple other occasions that affective feelings and subjective experiences have no place in the laboratory. Similarly, in Section 4.6.6., we see how imaginations of human health-related outcomes that *could* be used to motivate researchers are actively elided from places of experimental work to avoid also foregrounding less ‘desirable’ human performances such as researcher ‘subjectivities’ that categorically ‘do not belong’ in the laboratory.

This latter example demonstrates another inextricability of enacted materialities. Building out the central tenet of inextricability of human appearances from other

materialities, we can also extend a special case to the other potential human appearances that are entangled in the same research materialities. Across the empirical chapters, we have seen how inextricability of human appearances from each other can cause tensions. In the above example, it is the inextricability of the imaginations of human health-related outcomes from the researchers' own human enactments of 'bias' or negatively valued subjectivities that sits behind the refusal of many practitioners to consider the "bigger picture" of their work whilst they are conducting experiments, regardless how motivating it might be. To bring one type of human appearance into presence can sometimes entangle another that is incompatible.

As well as creating some tensions, place also offers a way to manage other tensions, especially those born of the multiplicity arising from differently enacted material performances. Indeed, separating potentially non-coherent enactments by place is one of the most common ways that ontological differences can be handled. Across the empirical findings we have experienced two common ways that place is used to handle these tensions. The first is through spatial or temporal distribution of potentially competing materialities (Mol, 2002). We routinely see this when incompatible materialities are othered into alternative places of belonging. For example, throughout Chapter 4 especially we witness multiple acts of othering that not only other potential human appearances from the laboratory but also associated them with alternative places of belonging. In most instances, this appeal to romantic complexity where everything has its place sidesteps the potential tensions that arise from the multiplicity arising from the performative idiom.

The second way place is used to manage tensions is through performing social ordering in line with the normative hierarchies in places. For example, in Section 5.5.4 we encounter the way that hierarchies operate not only along the spatial and temporal dimensions, but also in the social dimension of place. What human appearance is prioritised over another is sorted and ordered based on a social hierarchy. This 'social' placement enables one potential enactment of a human appearance (such as human biological materials) to 'submit' (and thus elide into absence) to a more desirable human enactment (such as tokens of human utility).

In this way, places as a process (Massey, 1999) intervene in disputes and tensions.

7.3.7 Places enacted in human appearances

Human appearances are not just constituted *by* place; however, they are also constitutive *of* place. In the preceding chapters we have compiled a wealth of evidence that human enactments contribute to the spatial, temporal, and social footprint through which places are performed.

Across the empirical chapters, we have seen that each enactment of human appearances that gather in the 'locales' of real-time MSB practices also affect the way that the 'site' it comprises is performed (Knorr-Cetina, 1999; Agnew, 2011). Indeed, the contrast between the performances documented in Chapter 4 and those in Chapter 5 provide a great point of comparison to demonstrate how significant this effect can be. In Chapter 4, we encountered significant othering of potential human appearances to alternative places of belonging. The laboratory 'site' that is enacted into being as part of this process of othering is characterised by its performance of regional space, linear time, and romantic notions of complexity where 'everything has its place' (Law, 2004a; Kwa, 2002). In Chapter 5, we encountered a different configuration. Here we observed future human-health outcomes assembled into presence and prioritised over other potential human appearances that emphasise their associations with past or the present. Yet the way these human appearances are performed enact 'dilated' (Meckin, 2016), or performative time. The organising unit 'sites' that are enacted as part of these processes continue to enact regional space and romantic notions of complexity but combine this with performative time. This sees the organising units characterised by their 'unfolding' into space and time in the present, generating a sense of orientation and momentum.

Indeed, as already detailed across all three empirical chapters, the different practical achievements and practical ontologies that are performed in each of the four different places of research generate four distinctly characterised places of real-time MSB research. Recapping from the characterisations outlined in Chapters 4, 5, and 6, these are: experimental laboratories emerging as a place of human absence; organising units emerging as a place of human orientation; specialist communities emerging as places of human context and peripheral presence; and non-specialist communities as places of human inclusion. Whilst experimental laboratories and specialist communities predominantly perform as strongholds of human estrangement, organising units and specialist communities emerge as strongholds of human engagement.

Each of these different places also enacts different spatiotemporal configurations in relation to human appearances[53]. Experimental laboratories enact regional space, linear, clock time, and a complexity best clarified as romantic. Organising units enact regional space (and corresponding fire space when subordinated human appearances are rendered entirely absent) as well as a romantic complexity, but instead enact a performative notion of time. This sees dilated temporalities, and an 'unfolding' approach towards human orientation in both time and space. Meanwhile, specialist communities assemble very similar human appearances to experimental laboratories. The main point of difference is that instead of othering human appearances into explicit absence in the way that occurs in the laboratory, human appearances are typically only negotiated into manifest absence and occasional peripheral presence in these community performances. This sees them performed slightly differently to the laboratory, but nonetheless, the differences are insufficiently significant to change the regional space, linear clock time, and romantic complexity it shares with the laboratory. Finally, non-specialist communities perform in complete contrast to all three. They enact a space that is predominantly similar to networked space, performative approaches to time, and a complexity that has much more in line with the 'everything being present' baroque characterisation (Kwa, 2002).

7.3.8 Non-coherence of human performances across place

> "If we attend to practice, we tend to discover multiplicity. But here is another important point. We discover multiplicity, but not pluralism […] it implies that the different realities overlap and interfere with one another" (Law, 2004a:61)

In Section 3.6.2 during the discussion of putting the narrative to work, I identified that the places of project performance were not mutually exclusive. I gave the example of the laboratory. In Chapter 4, the materialities, practices, and meanings entangled with the laboratory are configured into experimental systems and small lifeworlds through which experimental laboratories emerge. In Chapter 5, the materialities, practices, and meanings of the laboratory are configured differently to become places of organisation, emphasising their 'extroverted' relations (Massey, 1994). I also add into the fray a third performance of the laboratory as a specialist community enacting a different set of 'extroverted' relations.

[53] It should be remembered that space and time can be isotropic (Law and Mol, 2001), the assertions here specifically relate to the space and time as performed through enactments of human appearances.

As such, in attending to practice in the performative idiom, multiple 'realities' emerge through the different configurations of materialities, practices, and meanings that are clustered together. These are not entirely mutually exclusive, but instead, overlap and overlay each other with their different configurations. Importantly, they often emerge as *noncoherent* performances. Imaginations or recollections about entanglement with human appearances in one configuration or place that are made whilst removed from that place and dwelling in another do not always correspond to what might (or did) happen in practice. Indeed, I have also resoundingly encountered this through the conversations during *ad hoc* coffee meetings, and even 'distantiated' semi-structured interviews.

Here, I wish to introduce a short, new empirical account to illustrate this point. Firstly, during an interview with Addison where we had been discussing her replica chromosomes and how she considered their similarity to natural human chromosomes. During the interview, Addison had explained to me that when she "zoomed in" to the molecular detail of the replica chromosomes and went right to the molecular detail, the processes she encountered were equivalent to natural human chromosomes. She would be working with human equivalence. From our comfortable room a couple of floors above her laboratory with a coffee in hand, I thought nothing more of this assertion. However, much later on in the Tissue Culture (TC) room, I encountered a quite different enactment. Whilst Addison was clearing up after a routine passaging of cells, I was peering down the microscope at the cells containing the replica chromosomes. "It's like the forest and the tree" Addison offered, coming over to join me, "the more you zoom in there is no forest, it's just components". The replica chromosomes were still as structurally and functionally indiscernible from endogenous human chromosomes as they were when we were in the 'distantiated' interview. However, she did not consider them equivalent to human chromosomes at that point, because she didn't consider the human at all. They were just "DNA arrays" and "chromatin fibres". Rather than yielding the human equivalence, 'zooming in' when enacted in practice *in situ* just yielded yet more human insignificance.

This example stands representative of a range of similar non-coherent imaginations of experiences I observed during my fieldwork. It appears it is no more possible to traverse from one performance of place (the distantiated interview) to another (the experimental laboratory) through an assumption of coherent material performances as it is possible to gain the same view entangled at the periphery of practices as one might from being at the centre of them (Haraway, 1988; Star, 1991; Massey, 1994). This small example provides yet more evidence that accounting for the situated

perspectives and subjectivities must be accounted for *in situ* as part of the performance of place.

7.3.9 What can we learn by knowing these answers?

These findings generate four key take-home messages in relation to the human appearances in the context of MSB research I wish to take forward in the remainder of this chapter.

7.3.9.1 Human appearances are significant

One key learning to take from this study is that human appearances are of key significance to the performances of real-time MSB research practice, just as much as they are in the performance of wider social institutions, such as governance and regulation[54], albeit differently so. The imaginations may not be as utopian or dystopian as those encountered in Section 1.1, and many of the other human appearances relating to biological materials and practitioner performances may be encountered in the mundanities of research. However, through each human appearance as part of the real-time research materialities they perform significant work in the present in constituting real-time MSB research practices, institutional arrangements, *and* the places of real-time MSB research practices. Even in their absence, human appearances perform work, contributing to what is made present and correspondingly the normative expectations of places of research.

7.3.9.2 Human appearances are performances

The second key learning is that human appearances in MSB research are enacted in practice, something Wynter (2007) advocates as 'human as praxis'. We have witnessed first-hand that cell line technologies that come to count as human biological materials in a presentation to non-specialist communities do not count as human cells in places of experimental work. Similarly, practitioners adapted to themselves as human (Knorr-Cetina, 1999) in the creative elements of MSB design do not enact these human traits when running PCRs in the laboratory. Knowing this is useful. As Barad (2003) notes, the process of constituting the human is "not a fixed or pregiven notion", but neither is it "a free-floating ideality" (2003:823). Humans are performed in practice, but those practices themselves are already

[54] For examples of how the human emerges as significant during regulation and governance more broadly, see Brown (2003), Haddow et al (2010), and Hinterberger (2017; 2020), as well as Phillips (2015) for how it interfaces with political dimensions more broadly.

constrained by the material configurations in which they operate. To work with the topic of the human as practical achievements (Woolgar and Lezaun, 201) is to render them inextricable from the wider materialities and relations through which those practical achievements are accomplished.

7.3.9.3 Place is significant

The third key learning is that place is inextricable from the performance of human appearances in real-time MSB research. Human appearances are spatially, temporally, and socially ordered by notions of place through all kinds of discursive practices (both physical and linguistic). In turn, places are shaped by the human appearances that are performed through them. Humans and places are mutually co-constitutive and to engage with human appearances without acknowledging and accommodating the role of place in their practical achievement is to lose a significant part of the wider materialities and relations through which they are performed.

7.3.9.4 Places are specific

To understand human appearances and engage with them, one has to engage within materialities enacted in practices, *as part* of the places themselves. There are various times throughout my fieldwork that insights I had generated through 'distantiated' interview, or episodes of reflection over coffee or lunch with participants, did not bear out when I encountered them again performed in action. The example offered in Section 7.3.8 above with Addison's imaginations of how she recalled she made sense of her replica chromosome and how it was enacted in practice provides a good illustration of the non-coherence of these places. It is not possible to reliably engage with the nuance of potential human appearances within practices at a distance from their means of practical achievement.

These four key take-home messages underpin the central assertion of this thesis: human entanglements and enactments in the context of real-time MSB research are significant topics with which to engage; but to engage with them moving forward we need modes of interaction in STS research that recognise and accommodate the significance and specificity of place in their performance.

7.4 Re-enchanting place

As outlined in Section 2.4, STS has a long history of the analysis of the spatial and temporal situatedness of research. Section 2.4.3 goes on to discuss a recently renewed interest in the spatial and temporal dimensions of how fields of research (such as SB) are disciplined, choreographed, and placed. However, there still remains limited STS enquiry that explicitly foregrounds the third aspect of how 'places' are performed: the norms, conventions and sociomaterial associations that enact a 'sense' of place and contribute to constituting the sites and locales by shaping what does and doesn't belong there.

Given the empirical findings and the four key take home messages outlined above, I argue that a productive first step to rethinking STS interaction with MSB research (in relation to its human entanglements and enactments) is to re-enchant theorisations of place as performative *and* normative, and in doing so position place as a technology of intervention.

7.4.1 Existing STS interactions with SB: modes of engagement, roles, and spaces

This suggestion sits within a groundswell of broader STS work that emphasises the value of integrative engagement and collaboration between scientists and social scientists within real-time SB research. In the last decade (and more) in the UK SB community, there has been a strong interest in integrated and 'upstream' engagement and collaboration (Calvert and Martin, 2009). This interested emerged in response to criticisms of the early 'ethical, legal, and social implications' (ELSI) paradigm of social scientific engagement. There are many criticisms of the ELSI approach, two of which are that it takes place 'downstream' of the scientific practices and has an overly narrow focus on applications and outputs. An 'upstream' approach, however, instead focuses on a wider array of issues beyond those that just relate to potential products. It also offers opportunities to explore different types of engagement between STS and SB as the research unfolds. It expands beyond the observational wheelhouse of STS into more collaborative and interventionist initiatives. Indeed, collaboration between the disciplines has since been demonstrated to encourage responsible behaviour and reflection within real-time synthetic biology practices (Calvert, 2013; Delgado and Am, 2018).

Whilst Balmer et al (2015) talk of roles, integration into existing relations, and *spaces* for collaboration, I advocate that STS researchers could also adopt a 'place-centric' approach to designing interaction between the disciplines. This includes paying attention to the way that the concrete, material places (as opposed to abstract 'spaces') in which those collaborative activities take place play a role in the

engagement itself. As we have seen from preceding discussion, places are both normative and performative and their conventions and rules about what does and doesn't belong also shapes, sorts, and orders the practices that are performed through them.

7.4.2 Existing frameworks for interaction: 'place-aware'

Being aware of the importance of place in the engagement between STS and SB is not new *per se*. There has already been some acknowledgement and incorporation of *where* engagement occurs in attempts to develop productive relations between STS and SB. For example, designing for specific, targeted places of engagement. One notable example includes Rabinow and Bennett's (2012) work on Human Practices. Adopting a stance of collaboration and intervention, their aim was to design new interactions between disciplines (and sustain them) so both technical and social scientific disciplines could 'flourish' together. Here, Rabinow and Bennet talk about the importance of physical adjacency in designing social scientific enquiry to intervene in – and problematise – sets of experiments (2012:177).

Elsewhere, in the wake of Owen et al's (2012) formulation of Responsible Research and Innovation (RRI) approach, there emerged a slew of other initiatives to enact RRI agendas by bringing together STS and SB scholars in a way that took into consideration physical places of practice. These activities took different forms: including social scientists being invited into laboratories to increase awareness of social and ethical contexts, and activities to broaden innovation activities and create frameworks to guide such practices (Fisher and Rip, 2013:172). Fisher and Rip (2013) dwell on two examples of what they term 'soft intervention' methods that target specific and material places of scientific research.

Firstly, they introduce us to the Socio-Technical Integration Research (STIR) programme. This is a protocol-driven approach to voluntary self-checks that seek to unpack social and ethical values 'mid-stream'. STIR integrates responsible research and innovation principles by embedding a social scientific scholar to conduct a study identifying a framework of 'mid-stream modulation' that recognises and reflects on ethical and social dimensions of ongoing work (Fisher et al, 2006). The aspiration is that there emerges an increased reflexivity at key decision-making points within the specific places of science, such as laboratories, meetings, and more. In terms of its interventionist agenda, STIR attempts to steer deliberation and reflection through introducing a new practice to be performed within specific moments and places of science. This is one type of activity that can be considered 'place-aware'.

Another type of concrete activity enacting the RRI agenda (albeit before it was described as such) is put forward by Constructive Technology Assessment (CTA). From the late 1980s onwards Arie Rip and colleagues produced CTA as a method of engagement to 'open up the laboratory' and include more aspects and more actors into the process of technological development. Into the twenty first century the approach was adapted to accommodate the promises of new technologies (such as nano-technology) and their potential for dual use. In terms of its interventionist agenda, CTA is a 'soft' interventionist approach (Rip and Robinson, 2013:38) and 'inserts' a dedicated CTA actor (such as an STS scholar) to move from place to place across different places of work, taking into account what happens on the 'work floors' such as research laboratories, planning meetings, public debates, and more. It involves the use of collaborative workshops to anticipate scenarios and trajectories that 'could happen' and identify what is at stake. In this way it seeks to address "embedding in society, if only through anticipation" (Rip and Robinson, 2013:53). Such 'insertion' offers an integrative approach, but it is one that also emphasises action. The premise is that when the CTA analyst leaves, the traces of their presence and changes in visibility of certain topics that have emerged accordingly remain. The assumption is that relationships with the place of scientific activity are sufficiently reconfigured to leave behind positive change.

There are other initiatives attempting to enact RRI agendas such as Value Sensitive Design (VSD) and Toolbox Project (Fisher et al, 2015), amongst others. However, the examples outlined above stand representative of some of the more collaborative methods of integrating social scientific and technical enquiry.

Yet even though these methods acknowledge specific places of collaboration or intervention as part of their work, they still only tend to consider place either as a 'site' to perform intervention, or at best a 'locale' of gathered practices in which to intervene. Coupled with this, many interventionist STS strategies tend only to target changes in individuals' behaviours, practices, and processes, or at times changes at an institutional level (Fisher and Rip, 2013; Fischer et al, 2015). What is missing is a strategy to explicitly work with the places *themselves* and the role *they* play in shaping what does and doesn't 'belong' in them. Without paying attention to the role that the places themselves play, existing strategies only leverage a fraction of the capacity to intervene in any lasting capacity.

7.4.3 A new type of STS interaction with SB: working *with* place

The above frameworks and methods have been met with varying degrees of success (Fisher et al, 2015). Smith et al (2022) remind us that despite RRI garnering widespread support in the development of SB, there remain very real practical challenges to ensuring the changes and interventions become integrated as long-lasting RRI capabilities (Smith et al, 2022). Smith et al (2022) offer some suggestions for activities and interventions that could address this challenge. These include targeting specific practices such as tackling more thoughtful funding calls, creating time and space for reflections in research projects, encouraging mission orientated RRI activities, prioritising weak spots, amongst others.

Based on my empirical findings underscoring the importance of place, I propose adding an approach that prioritises a 'place-centric' view to addressing this challenge. Specifically, I propose adding working *with* places - as understood as sites, locales *and* social spaces - designing them in ways to encourage interaction and reflection in real-time MSB research. We have already witnessed how place wields significant normative and performative power in relation to MSB and its relationship with human appearances. I advocate targeting the places, intervening in what materialities (as enacted in practice) are gathered there, and experimenting with and agitating some of the sedimented norms and associations that make up such places.

Working *with* place in this way would allow us to experiment in two ways. Firstly, intervening in real-time places of MSB research in this way might encourage different types of engagement with potential human components. This will bring with it another opportunity to learn how alternative MSB real-time relationships with the human might be possible - if at all - and whether that would even be desirable[55]. Secondly, in the process it would also provide an opportunity to explore what else we can learn about MSB conventions, expectations, and the 'sense' of real-time MSB places by actively designing disruption into them. We have already seen in Section 3.4.3 how my own presence acted as matter out of place (Douglas, 1966) and sometimes sparked discussion and debate that would not otherwise have happened. Based on the strength of my empirical results, it feels a fertile avenue to explore what else might be learned by transgressing and disrupted expected norms of scientific places.

[55] It should be noted that this type of intervention is not instrumental in nature. It does not hope to bring about any predetermined normative outcome. Instead, it is merely exploratory; to agitate what currently exists to see if it could be otherwise.

7.5 Rethinking interaction

7.5.1 Complementary action

At this juncture, it is important to acknowledge that any suggestions I make here are complementary to other methods of interaction between MSB research and STS research. They do not seek to replace them. Different methods have different aims and accomplish different results. For example, I wholeheartedly advocate the use of liminal spaces – and their more entrenched counterparts 'transitory dwelling places' (Shortt, 2015) – as spaces for reflection (Matthews and Livingstone, 2017). Liminal spaces provide a productive route to engage scientists on topics that relate to MSB more broadly. Indeed, without them I would have limited knowledge of all the absent potential human appearances with which MSB does not engage (as outlined in Section 7.3.2). I have learned much from liminal spaces, and in return, I have seen the excitement from practitioners at being able to engage with topics they do not usually get to consider. Rachel especially bemoaned the challenge of finding appropriate places to talk about the socioethical dimensions of MSB more broadly. She would try to engage with colleagues at work, but they rebuffed her citing being 'at work'. She would then try to engage with the same colleagues at the pub, only to be shut down with cries of "that's work, we're at the pub, don't talk about work". Liminal space affords Rachel the opportunity to reflect on the human entanglements of her wider field.

The aim of the recommendations here is not to replace the existing way that liminal places (or spaces) are used, e.g. turned into opportunities for reflection. Instead, it is to add to that approach with a deeper integration of STS action and places of real-time MSB research. Specifically, potential interventions in the places of *real-time* MSB research that could disrupt existing relationships between MSB research, human appearances, and place, and potentially encourage new ones.

7.5.2 Operationalising empirical insights in relation to place

How can one start thinking about working with place in this way given all that we know so far from this thesis?

Throughout the empirical chapters, we have encountered many places of real-time MSB: these include the laboratory, the organising units, and the various places of communities. They also include discursive enactments such as journal articles and presentations. These places have appeared in this thesis as a central part of the

empirical findings for the role they play in shaping human appearances. Given that importance, they have also been used the organising concept for the narrative (as elaborated in Section 3.6). However, any place related insights have consistently been framed through their ability to inform the subject of this investigation: i.e. how the human appears in the context of MSB. The next step is to operationalise the empirical insights to instead inform what we can learn about place in the process.

Reframing the findings of this investigation in such a way helps us pivot from understanding place *for* its role in human appearances, to arguing for place as a new object of interest, and maybe a possible method of intervention to explore the relationship between MSB and human appearances further. To do this, we return to Michael Lynch's (1991) theory of topical contextures - as elaborated in Section 2.4.7. In the discussion that follows, I put both the theorisations of place from human geography, and the empirical findings from this thesis about the normative power of a 'sense' of place, into conversation with the concept of topical contextures.

Before we proceed to bringing them all together, a brief recap from our first encounter with topical contextures in Chapter 2 may be useful. Topical contextures offer a way to understand places of scientific activity as comprising a) a local constellation of technological complexes (the equipment, devices, and actions); and b) a corresponding 'spatial grammar' for each technological complex that gives rise to different ways of experiencing and ordering the physical and perceptual space, as permissively understood and complete with symbolic ideals, norms, and conventions (Lynch, 1991). To bring this concept to life and render it more concrete, over the next two paragraphs I step through a worked example of how we might understand an episode of real-time MSB research as a topical contexture.

Topical contextures are tied to episodes of practice (Lynch, 1991). Therefore, to illustrate this example, we shall briefly return to the laboratory. In Section 4.4.4, we heard about when I joined Rachel in the laboratory constructing plasmids. As recounted in that section, I had been following Rachel as she isolated DNA fragments, performed PCR, tested the results, and started to grow colonies. We were surrounded by laboratory equipment such as the PCR, centrifuge, an electrophoresis gel (pre-prepared and ready to use) and were mid-way through preparing DNA fragments for the plasmid. As we discussed her work, Rachel had waved her hand over the array of apparatus and 'in-progress' plasmid construction declaring she was "just making tools, not considering the human at all". Following a description of this episode, Chapter 4 went on to elucidate these practices through

the lens of the human appearances and how they were negotiated out of the laboratory and into alternative places (see Section 4.4.5).

However, using Lynch's (1991) topical contextures as an analytic, we can also view this episode through the lens of place rather than the lens of human appearances. Specifically, we can see it as an example of a topical contexture in action. In the Garcia Lab that day, the PCR machine, centrifuge, electrophoresis gel, vials of DNA fragments, the UV dye, reagents, pipettes, and everything else entangled in Rachel's experimental practice of DNA isolation can be understood as comprising the 'technological complex' – the devices, apparatus, the actions required (Lynch, 1991).

Yet these materialities and actions ('technological complexes') were also simultaneously physically ordered and experienced in a particular way. Drawing on spatial predicates (see Section 2.4.7), the physical space was ordered in a series of 'befores and afters', 'insides and outsides', and more. The centrifuge lay a little away from the PCR machine, past where Rachel was preparing her vials mid-way between the two. The electrophoresis gel plates that had been prepared at another workstation but had been set aside on another bench, spatially separate and temporarily discarded from the technological complex whilst they set, before being brought back into the complex after all the other steps of the procedure had been performed. During the procedure, the vials of DNA fragments moved variously from Rachel's hand, into the PCR machine, the centrifuge, to the stand designed to store them. They moved with Rachel as she moved between the apparatus conducting her experimental activities. This enactment of physical space was akin to a well-worn dance: from the PCR machine to the bench to pipette dye into the vials, to the centrifuge to spin the DNA fragments down ('just in case'), and eventually to the electrophoresis gel that had been brought back into play right at the end. This performance of the laboratory's physical space enacted not just a spatial ordering, but a temporal ordering. There was a routine procedure to the protocols with strict conventions of what went before, and what went after.

Yet the laboratory being choreographed and performed in this way also involved more than just physical space. Rachel's activities and the apparatus she used also enacted the laboratory's perceptual space (Lynch, 1991). Rachel engaged visually with her material components, making judgement calls by eye rather than relying on computer analysis. As a result, the entire experiment was condensed into a small corner of the laboratory, visually and phenomenologically accessible to her directly. Rachel's experimental systems were a small 'lifeworld' localised to the three benches, her manual labour, and her understanding of the biological materials

mediated through her own senses. In this short episode, the experiment was not connected to other experiments, computer databases, or a meaning beyond these three benches. Goals were tied to the technological complexes in question ("isolating DNA fragments") rather than untethered apprehensions of future human application. And the perceptual space was imbued with expectations and associations of how to experience the experimental activities in those spaces. For example, navigating the perceptual space of the technological complex included behaving in a way that was 'proper'. Tensions between having a "feeling" for what might work, and the strong expectations and norms of being "unbiased", "objective", and "logical" had to be navigated and balanced (see discussion in Section 4.6.5). At the same time, there was a strong sense of mundanity and routine: in procedures like this where such routinisation meant she didn't have to overly concentrate, I was told it was ok to have the radio on, relax, and chat whilst working.

The aim behind recasting this small empirical episode as a 'topical contexture' rather than in relation to its human appearances is to allow us to consider the notion of intervention in place more concretely. If we disrupt Rachel's technological complexes (apparatus, practices, devices and more) sufficiently, Lynch (1991) would have us also understand that the 'spatial grammar' of how she experiences the physical and perceptual space might also change. If so, then a new topical contexture might result and - in theory – this could encourage different behaviours, expectations, and ways of being.

7.5.3 Mobilising new topical contextures in real-time MSB research practices

Armed with this provocation, how might we go about designing interaction between STS and MSB to encourage new topical contextures? And what might we learn from it?

Below I offer three illustrative examples to bring to life what types of intervention *might* be possible. Each increases in the level of engagement, collaboration, and buy-in required from social scientists and synthetic biologists. Each also allow us to experiment with the spaces of interaction between STS and MSB in two ways. Firstly, to disrupt the existing topical contexture and ways of experiencing the physical and perceptual space. This allows us to render visible some of the differences between existing and alternative ways of being for debate and discussion. This opens doors to learn more about the conventions, practices, and places of science and question our own assumptions why we have the conventions we do about potential human appearances; as well as challenging our MSB

colleagues to do the same. Secondly, to disrupt existing places of scientific practice to generate new topical contextures tests the potential utility of this as a method to encourage the integration of RRI capabilities (such as reflection or anticipation) into the enactment of places.

7.5.3.1 A Lab meeting takeover

In Section 6.4.1, I provided an account of the fortnightly Garcia Lab meeting where members discuss progress of their projects. This is an important forum for the team and is one of the key times the Lab comes together as a specialist community and reinforce their membership to the laboratory as an organising unit. It provides an opportunity to discuss each other's work, practice presentations, or catch up on what their colleagues are doing. It is typically closed meeting, and a place of deep, specialist community knowledge.

The Garcia Lab meeting can also be considered its own topical contexture. The technological complexes (the devices, practices, and people gathered there) rarely change from one meeting to another. It typically occurs in the same meeting room every fortnight, with very similar attendees, a similar agenda, and a similar format. The walk from the Garcia Lab down the flights of stairs and along the same corridor is accompanied by the same scientific posters on the wall (at least for the duration of my fieldwork). It has a wealth of convention and routine associated with both the physical space and how that space is experienced.

When I attended the Garcia Lab meetings as part of my fieldwork, I was largely there to listen to updates, watch presentations and make my own observations, and my presence was largely unremarked upon. This was not the case, however, when I was called upon to deliver a presentation of my own project at the meeting. We have already seen in Chapter 6 that rarely do specialist communities enact human appearances explicitly. In Section 3.4.3, I discuss how I experienced being 'matter out of place' during that meeting (Douglas, 1966). After delivering my presentation, the conversation moved rapidly into a Question and Answer session about qualitative methods and subjectivity. It was a novel experience for everyone in the room and the discussion tone was engaged and animated. The inclusion of my qualitative research had disrupted the topical contexture and its entire experience that week, there was space for debate and reflection upon topics that didn't normally emerge.

This example demonstrates the opportunity of the Lab Meeting as a potentially productive place of intervention. One potential intervention would be to stage a (mutually consenting) Lab Team Meeting Takeover. This would necessarily involve changes being made to the technological complexes that enact its physical and perceptual space (Lynch, 1991). This might involve disrupting the Lab meeting (including the experience of the walk down the stairs and corridor to get there) in a way that insinuates alternative relationships of MSB with potential human enactments into the technological complexes to generate a new topical contexture. This might involve creative use of the walls lining the long corridor to access the meeting venue; perhaps a series of posters challenging the linear narrative of the translational model of human health. It could involve a presentation from a social science speaker in the field, and / or a collective discussion reflecting on the existing topical contexture of the Lab Meeting and what it engenders from the perspectives of both social scientists and synthetic biologists. For one Lab Meeting at least, the disruption to the existing technological complexes and spatial grammar would demonstrate alternative ways of being in the space, challenge assumptions for all those in attendance, and create new types of relationships to the Lab Meeting. Repeating the exercise semi-regularly would also then help to expand what might come to be expected – and considered 'proper' – at meetings such as this.

7.5.3.2 A Collaborative Event Ethnography at a scientific conference

A second example could involve changing the topical contexture of a synthetic biology conference. Conferences play a pivotal role in the production and circulation of knowledge and in shaping and establishing academic and professional disciplines (Gonzales-Santos and Dimond, 2015). They are a place for a community to meet, collaborate and discuss and present their work. They can simultaneously reflect and shape the nature of a field, and they are also symbolic of the ties that bind a community (Stephens and Dimond, 2016). Whilst there are differences in potential formats (for example: plenary, multi-track) they are also bound by many similar conventions. There is a relatively homogenised format to the physical space, the cadence of the agenda, the structure of talks and posters that are showcased, the peripheral activities of dinner and networking, and even the location of any social scientific participation (a point discussed in Section 6.1.4.5). Even the way the place is experienced - down to conference fatigue, juggling incoming emails, and jetlag (for some) - share some conventional qualities.

Faced with this configuration, one way to intervene in the technological complexes might be to curate a group of synthetic biologists and social scientists to conduct a

Collaborative Event Ethnography (CEE) at the conference (Brosius and Campbell, 2010). CEE is a method of ethnography that emerged as a solution to the challenge of capturing the range of activities that occur at large scale meetings, workshops, symposia, or conferences. Whilst typically such a method would involve a team of social scientists, by adapting it to also include synthetic biologists it offers an opportunity to intervene in the way that scientific conferences are experienced for both synthetic biologists *and* social scientists. Scientists could experience becoming ethnographers of their own field, and social scientists could benefit from conducting ethnography with diverse co-collaborators.

Using the methods of CEE, to make this work as an intervention in place, *new* technological complexes could be introduced. For example, a digital space for collective notetaking (thus allowing for real-time observations and subverting the way a plenary auditorium might be experienced) and creating new check-point meetings amongst the co-collaborators to debate interesting themes in more detail. Indeed, collectively navigating places of SB such as these together could offer new insights into topics that might not otherwise have been experienced (Delgado and Am, 2018) and change the perceptual space by encouraging the group to 'see with others' and experience the synthetic biology content together. For the duration of the conference, this could offer an alternative way to experience the conference, render visible conventions and behaviours of all those attending conferences and stimulate cross-disciplinary debate on conference content and use of space. Over time, repeated interventions into conferences in this way might start to encourage a more expansive notion of what conferencing could involve.

7.5.3.3 An STS-MSB paired residency

A third and final example involves a longer-term proposition to create a residency within a laboratory for a social sciences scholar to pair with a synthetic biologist to work on an MSB project for a short duration (perhaps three months). This is a more challenging proposition. The conventions of laboratory performances are well documented throughout Chapter 4. They do not require repeating here. There are also many institutional challenges and tensions of working across academic Schools and departments. There are challenges of assessment criteria and many other practical, real-world problems. It feels churlish to set these aside, but were it possible to address some of these, the benefits of a more sustained intervention into place and its norms and expectations could be substantial. Indeed, the discussions in this thesis about 'matter out of place', and my own presence encouraging a significant increase in participant engagement with the topic of the human in MSB, stand in

testament to the potential value of disrupting the multiple laboratory topical contextures through an STS residency within an MSB laboratory.

Perhaps one way to trial an intervention in the laboratory might be to devise a master's student or early PhD student-level shared project that is laboratory-based. Pairing a synthetic biologist and social scientist to work together on all aspects of the project would significantly disrupt the existing topical contextures and spatial grammar and create new ways of being in the laboratory.

Taking lessons from my own presence in the laboratory, the disruptions to the physical and perceptual space would likely be considerable. To start, undertaking paired work engenders a different use of both the physical and perceptual space. Experiments would need to be physically managed differently to accommodate division of labour and collaborating so physically closely. In addition, an STS scholar might disrupt the small-lifeworlds of the experimental laboratory (for example, Rachel's plasmid construction) by integrating different ways of making and making sense of the biological materials, drawing on ideas from beyond the laboratory. This would likely distort the perceptual space of the laboratory for both collaborators, bringing in ideas and concepts that exist beyond the laboratory and indeed beyond the scientific disciplines, expanding what is drawn upon to make sense of the experimental systems. For the duration of the residency, 'seeing with others' in this way could also render visible the co-collaborators' assumptions for debate and discussion. Indeed, perhaps repeating such initiatives, might even start to change assumptions of what is considered 'proper' research activity in the laboratories in question.

7.5.4. Considerations and next steps

In putting forward these illustrations, I hope to show that thinking in terms of 'topical contextures', and their technological complexes and spatial grammars, might be a productive way to think about place as a method of intervention in STS; providing us a mechanism to think about not only the site and locale but also the sense of a place. However, it is also necessary to caveat the potential of their use.

The first caveat relates to the 'physical' nature of these topical contextures. It should be noted that whilst these three illustrative examples are rooted in physical structures (a meeting room, the conference, and a laboratory), it should be possible to extend Lynch's (1991) concept of topical contextures to a discursive enactment,

such as a journal article. As discussed in Section 6.4, there are very specific conventions enacted by journal articles. These include strong conventions around the experience of physical and the types of content that are expected in each section. This engenders social conventions and norms of publishing writ large. It is therefore entirely possible to conceive of the article (or any other discursive medium) as a topical contexture. As Lynch (1991) reminds us, topical contextures are linked to materialities enacted in practice, and as discussed in Section 2.3.3, journal articles are a discursive enactment themselves. An article's 'technological complexes' might be considered its structure, its metadata, the content in each section. Meanwhile, the perceptual space such a complex enacts is navigated through a series of expectations about the meaning from each section, and what those sections are. To disrupt the topical contexture, it should be entirely possible to introduce additional sections, or disrupt that which appears in existing sections.

The second relates to the transience of these interventions. Lynch (1991), notes that topical contextures only exist as long as the practices through which they are performed persist. Indeed, the same stands for places they comprise. As Massey (1994; 1999) amongst others argue, places are in process, constantly being made and remade through their relations. Arguably, no performance or configuration of place is permanent. Instead, it undergoes constant, iterative assembly and disassembly. Cresswell (2014) summarises it succinctly when he asserts places are becoming and dissolving daily. As such, permanence and transience are unhelpful ways to think about the STS-MSB interactions I propose here. A useful way to think about the level of intervening in place is through a combination of repetition and duration. The more the topical contextures repeat, the more they might insinuate new norms and conventions into the settings where they are found.

The third and related consideration, is that if any intervention is left too long or repeated too often *in situ*, it brings with it the need to consider the downsides of repetition and duration. As we have seen in this study, repeated appearances can lead to ubiquity and routinisation. For example, there are occasions when potential human appearances become so routine, they become absent (Law, 2004a). Examples in the laboratory include the labelling of incubators as human, or the specific experimental conditions configured in line with human biological needs (such as incubation at 37 degrees). This is especially a common problem with infrastructural components (Bowker and Star, 1999). As such, there must also be a balance between two competing objectives when designing places for interaction. The first is that existing topical contextures should be disrupted enough to benefit from encouraging different experiences of being in the place of scientific activity,

demonstrating alternative ways of being, and potentially fostering the opportunity for new associations and conventions to form. The second is that there should be sufficient transience and 'dissolving' of topical contextures to prevent their own routinisation and a slip back into absence (Bowker and Star, 1999).

Finally, it should be noted that the examples here are illustrative only to render more concrete and practical how my empirical findings relating to place might be operationalised moving forward. Future interventions in place to create new topical contextures in the space of old ones (even if temporarily) will need thorough design and investigation to understand the best way to intervene in the technological complexes (apparatus, devices, practices) in ways that maximise the chance of disrupting the spatial grammars and thus creating a different experience of the physical and perceptual space (the 'sense' of place) from which we might be able to learn.

As such, the value of using topical contextures to intervene in place in this way is speculative. Whilst I strongly consider that re-enchanting place - especially in relation to its normative power - offers opportunities to adopt more 'place-centric' approaches to STS-MSB interaction, the interventions to disrupt topical contextures and thus potentially the norms and experiences of places of scientific activity are just one suggestion. It does, however, offer an intriguing prospect for further investigation.

7.6 Final reflections and concluding remarks

This has been an ambitious topic with which to grapple. In adopting a permissive approach to what counts as 'human appearances', I not only generated a wealth of data, but kept open a variety of directions in which I could have taken my analysis. Indeed, there were many interesting avenues I wish I had chance to explore further.

I would like to end somewhat fittingly by returning to the beginning and revisiting the first conversation I had with Marek in the airport departure lounge all those years ago (see Section 4.4.1). Marek and I had enjoyed a thoroughly interesting conversation, and I recall the first flush of excitement at getting to talk about my research. After Marek and I had parted ways to find our respective seats on the plane, I had scribbled notes on our conversation almost immediately. I had made a point of underscoring the fact he had suggested he and his research had "nothing to do with human applications". Yet it already struck me as curious; I had already been part of Institute meetings where I was *sure* I had heard Project D41 discussed in terms of its

human applications. In the margin of my notes, I had scribbled: “NTS [note to self] check what that’s about”. I parked the idea and returned to letting my imagination run away with me considering all the possibilities that I might encounter human appearances at the conference to which I was headed. I imagined the huge diversity of ways in which the human would appear and be theorised by MSB researchers, and possibly – with a bit of luck - how eventually all the data I would generate might enable me to make some big pronouncements on how MSB research entangled and enacted the human. I did not know it then, but perhaps the only sweeping pronouncement to be made about the human contexts of real-time MSB research is that there are no sweeping pronouncements to be made.

In fact, neither did I know in the airport departures lounge, nor on the plane as I scribbled my notes, that a germ of an idea had already taken hold: place is critical to how the human appeared. As the empirical evidence attests, over the weeks and months that followed, everywhere I turned there were place-related performances of human appearances, especially in relation to notions of ordering and belonging. It soon became impossible to contemplate potential human appearances without engaging with notions of place: to explore the human in the context of MSB real-time research is to explore its practical achievement as also enacted in place. And so, it is with the (almost too fitting) metaphor of an airport departure lounge that I conclude this thesis on a note of opportunity and anticipation: there are still so many places to explore.

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Appendix 1: A word on words

In Chapter 2, I outlined a variety of literature relating to how MSB research materialities and practices are performed with a view to better understanding the way that human appearances emerge and perform amongst them. In Section 2.5, I elaborated upon the importance of clear usage of words. Below articulates my usage of some of the more ambiguous terms.

Entanglement

In the context of this thesis, entanglement relates to the latent inter-relatedness of MSB research materialities. Concrete relations have not yet been forged through practice, hence latent, but there remains a connection by merit of other indirect arrangements that have assembled the materialities into each other's orbit. Callon (1999) uses the term entanglement, borrowing its usage from quantum physics. Indeed, turning to quantum physics provides a surprisingly accessible way of making sense of this latent relatedness. Quantum entanglement denotes that the state of any given particle belonging to a group of particles cannot be considered independent of that group, even if it is separated by significant distances. Einstein referred to this through the more enjoyable and descriptive phrase 'spooky action at a distance'. The premise of entanglement is that particles have somehow been arranged through indirect action that has resulted in their inextricability. Callon's (1999) use of the term denotes a set of overlapping, complex relations between the materialities of social life. It is a bundle of relations that are indirectly inter-related, until they are subject to dedicated action that either draws them into a concrete set of relations (something Callon (1999) terms 'framing'), or disperses them and breaks the association, something Callon (1999) refers to as 'disentanglement'. Here, I use the term entangled to denote the latent inter-relatedness of MSB research materialities (such as physical cell lines, or representations of biological donors) that have yet to be rendered concrete - or disentangled - through practice.

Enactment

I use the term enactment to define the process of rendering those relations concrete (or disentangling them) through practice. This definition draws on a combination of scholarship from Woolgar and Lezaun (2013) and Law (2004a). It asserts that enactment is the condensing of a thing or object into being through - and during - a specific set of practices. The term rose as a form of anti-essentialism to illustrate that

objects do not acquire meaning due to a pre-existing context, instead, they are 'brought into being' and realised (or materialised) during specific practical activities (Woolgar and Lezaun, 2013:323-324). There is no limit to the kinds of things or entities that can be enacted. It can include people, things, objects, concepts, theories. As such, a human-adapted practitioner performance can be enacted, as can an imagination of human application. Enactment is simply the rendering concrete of a thing or object in the here and now through practice. The rendering concrete does not equate to 'presence'. Enactment can negotiate things into presence, manifest absence, or absence (Law, 2004a:14). Additionally, what is 'enacted' (whether into presence or varying forms of absence) are only brought into being this way for as long as the practice lasts. For example, a fragment of a human gene only enacts "a human gene" for as long as the practices that enact it as such are in process. Once the practices that sustain the gene as "a human gene" have ended, so too does the enactment of the genetic fragment as such. It is this temporariness that Woolgar and Lezaun (2013) argue sees it differ from the term 'construction'. They suggest 'construction' confers durability that enactment does not have. Elsewhere, Law (2004a) asserts that enactment is a near synonym for performance (2004a:159), though some scholars eschew such a term due to its dramaturgical connotations. Although there are very nuanced differences in the terms enactment and performance, for the purposes of this thesis, I use the two interchangeably, with the definition of enactment outlined here in mind.

Human enactments, appearances, materialities, performances, and more

Taking the term 'enactment' to mean the process of condensing a thing or object into being through specific practical activities, a specifically designated *human* enactment can be considered one that has enacted the human (or human-related appearance) specifically into *presence*. Whilst not technically wholly synonymous, human enactment, human appearance, human materialities, and human performances, are sufficiently *practically* similar to be used interchangeably (Law, 2004a). Which one takes precedence will depend on the context of the discussion (for example whether talking about the *outcome* or resultant materialities that have been made manifest, or whether focusing on the *processes* of making them manifest or apparent. It will also depend on whether one might be more accessible or less confusing than the other. As outlined in Section 1.3, the term 'appearance' has connotations of apparition at odds with the specific and material process of performing human appearances as enacted in practice. However, its common usage suits the task of being a legible object of investigation to those less familiar with terminology of the performative idiom (such as enactment).

Potential human enactments, appearances, materialities, performances, and more

The terms '*potential* human- enactments, -appearances, -materialities, -performances', and more, are used for entangled materialities that *could* emerge as human appearances. Their potential as candidate human enactments tends to derive from being designated as such in other practices and performances that have been performed elsewhere. Although, it is not possible to indicate what emerges as 'human' based on a definition, there are some ways to indicate what could become, for example by looking at other performances elsewhere. As Mol (2002) reminds us, we do have other references through which to designate the potential of materialities to become something different:

> "A place where things are what they happen to have become but could have been different — not just because they have been different in the past, but also because in fact they *are* different right now, a little further along (in another site or situation)" (2002:114)

Only the enactment in the practice in question will arbitrate whether they actually *become* human appearances but until that point, they can be considered *potential* human appearances (whether they eventually become so or not). By extending that logic if they are *potential* human appearances, it is also possible to position them as still in the 'entanglement' phase. Although entanglements have yet to be practised in action, thus neither human nor not-human, for practical reasons Mol's argument for can be used as an indicator that something *could* become human when enacted (as above). As such potential human *enactments*, potential human *entanglements* or just human entanglements are occasionally used interchangeably. They all mean a component yet to be enacted in practice, but with the possibility of being enacted as human.

Together, a better understanding of these terms should help more clearly elucidate the relationships being elaborated in the empirical chapters that follow.

Appendix 2: Expanded case descriptions

Case 1: Project D41 - Programming RD patterns (or Turing patterns)

Project D41 is a project designed to engineer types of patterns into groups of cells and in doing so, prove a set of theoretical principles. In developmental biology there are three key stages to developing tissues and body parts, including our own. These three stages are: pattern formation amongst the cells (patterning); specialisation of cells into different cell types (differentiation); and development of cells into shapes (morphogenesis). Project D41 focuses on the first of these mechanisms, the way cells organise themselves to form groups and patterns. Cell patterning is the process by which order arises in groups of cells and is critical to mammalian development. It is responsible for several phenomena from driving skin pigmentation to forming digits to patterning the alveoli in the lungs. Without cell patterning many body parts would not be able to form. It is also the process that generates animal coat patterns such as the stripes of zebras or spots on a cheetah's coat.

The scientific community generally agrees that naturally occurring cellular patterning is likely achieved by a specific biological mechanism that activates and inhibits specific molecular interactions in a series of co-ordinated events. This mechanism is called the 'reaction-diffusion' or 'RD' system. The mathematician Alan Turing was the first to propose such a system and the patterns resulting from the RD system - such as zebra stripes and cheetah's spots - are referred to as 'Turing patterns'. Yet these principles had yet to be unequivocally proven in mammalian systems[56]. Project D41 uses synthetic biology tools and techniques to introduce new 'genetic devices' into host cells to attempt to trigger an RD system based on the principles that Turing identified with the hypothesis that it will mimic the natural RD systems found in nature. In doing so, it will validate the basic principles. Project D41 has been attempting the system in two different cell lines. One derived from human embryonic kidney cells called HEK293[57] (and its derivatives) and the second derived from canine kidney cells called MDCK[58]. The project has been an ongoing interest in the ML laboratory (a pseudonym) and several practitioners have been involved with the project.

[56] Correct at time of starting the investigation, subsequently partially proven.
[57] HEK stands for human embryonic kidney, whilst the 293 of HEK293 refers to the cell line being the 293rd experiment to create it.
[58] MDCK stands for Madin-Darby Canine Kidney Cells, after the two scientists who originally isolated the cells from a cocker spaniel in 1958.

Case 2: Project D42 - Programming multicellular organisation and communication

Like Project D41, the focus of Project D42 also relates to engineering particular types of patterns into groups of cells. Unlike Project D41, the aim is not to mimic the natural system that organises cells into patterns, but to synthetically engineer an entirely new way to drive cell patterning (*de novo*) as a proof of principle project. Specifically, Project D42 aims to exploit mammalian cells' natural ability to cluster and disperse to evaluate if these natural behaviours can be controlled through different mechanisms to execute 'on demand' patterning. To do this the project has created new 'genetic devices' comprising a combination of genes and proteins of interest that are 'stitched' together to produce new genetic circuits. Once transfected (transferred) into the host cell, these circuits elicit changes to the phenotypic responses of cells. This project contains two different devices to elicit differing responses in separate cell types. When the cells are co-cultured together and exposed to a particular trigger, the cells self-organise in line with their differently engineered behaviours to produce patterns such as grids or chessboard patterns. Project D42's second objective is to extend *de novo* patterning systems to test if they can control development of nearby stem cells. It does so by engineering a secondary function into cell patterning system. This sends a pattern of differentiation triggers to nearby stem cells, stimulating stem cell development in the shape of the imprinted pattern. To conduct this work, Project D42 uses a combination of human embryonic kidney cell line (HEK293) derivatives for the patterning system and mouse embryonic stem cells (mESC) to observe the effects of corresponding stem cell development.

Case 3: Project D43 - Engineering light-control into patterning

Project D43 also involves creating cellular patterning systems but deviates from those in Projects D41 and D42 by merit of its stimulus. Both Projects D41 and D42 control their patterning behaviour by introducing a particular molecule or drug to trigger behaviour. However, the focus of Project D43 is to understand if mammalian cellular patterning can be controlled using light. Light control is of particular interest to synthetic biologists. It confers some significant advantage over drug-induced behaviours, such as increased precision of targeting and improved expression of target genes. Control of activities including cell death has already been demonstrated in mammalian systems, but control of more sophisticated biological processes - such as those involved with cell clustering (adhesion) and dispersal (scattering) behaviour - have only been demonstrated in bacterial systems. Project

D43 is a ‘proof of concept’ project. It aims to use synthetic biology techniques and tools to demonstrate the possible scattering and dispersal of mammalian cells in response to specific wavelengths of light. It aims to create pattern formation through choreographing the scattering and clumping of cells with light as they grow and divide to mimic the life cycle of cells from single cell states to multi-cell states. To conduct this work, a variety of co-ordinated behaviours are engineered into cells first to create a light ‘trigger’ that then turns off production of adhesion molecules to allow cells to scatter into single cells. When the light trigger is stopped, the cells can grow in groups of cells again. Project D43 used derivatives of HEK23 cell lines for the first six months, before switching to MDCK cells.

Case 4: Project D44 - Creating replica chromosomes

Project D44 differs from the other projects because it does not aim to produce phenotypic cellular responses. Instead, it focuses on adding cell machinery within individual cells. Project D44 is part of a global community that focuses on constructing and characterising replica chromosomes. Project D44’s primary contribution to this stream of work is to build and evaluate a new generation of these chromosomes. Typically, a human cell contains 23 pairs of chromosomes, the additional chromosome is generated through complicated processes that ’seeds’ the new chromosome. Once transferred (transfected) into a host cell, the cells generate a temporary (and truncated) replica chromosome. These chromosomes can be manipulated and interrogated to investigate how chromosomes work. At the start of my engagement with Project D44, the team had been focused on iterating the development (and evaluation) of more sophisticated versions of the chromosome. After identifying some DNA oddities during chromosome generation (similar to naturally occurring mutational processes), focus was diverted to characterising and understanding these. To perform their work, Project D44 predominantly uses a specially modified version of the human derived HT1080 cell line originating from human connective tissues.

Type of experimental work

In terms of the type of work the cases pursue, all four projects involve making changes to the existing behaviour of mammalian cells to introduce novel behaviour. To do this, all four projects involve biological work *in vitro* (with components extracted from their natural biological context) rather than *in vivo* (within a living organism). This is typical of mammalian synthetic biology in present day research

programmes. It does, however, mean that the projects require specific types of mammalian cells to enable study outside of the body for prolonged periods. Cells routinely can be made amenable to experimental manipulation by undergoing transformations - or ‘culturing’ - that render them robust and self-perpetuating biotechnical objects (Landecker, 2007). Cells transformed in such ways are referred to as cell cultures. Cells can be temporarily cultured - for example from patients to perform diagnostic functions - or they can be cultured long term for the express purpose of conducting ongoing experiments. These latter cell cultures are known as ‘cell lines’ (Landecker, 2007). All four of my case study projects use long-term ‘immortalised’ cell lines in their work to act as the cellular site of experimentation.

Appendix 3: Sample 'Project Information Sheet'

Science, Technology & Innovation Studies
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Researcher
Sophie Stone
s1687032@sms.ed.ac.uk

Supervisors
Dr Jane Calvert:
Dr Erika Szymanski:

PhD Project:

"Towards an empirical account of the relationship between synthetic biology entities and concepts of the human"

Dear [*insert name of participant*],

You are receiving this project information sheet because you have been invited to participate in the above research project. The aim of this project information sheet is to introduce you to who I am and provide further information for you to understand the purpose of the research and what participating would mean. Please read the below carefully and do not hesitate to contact me should you require additional information.

About me:

My name is Sophie Stone and I am a PhD student in the Science and Technology Studies (STS) programme within the School of Social and Political Science at the University of Edinburgh. My two supervisors are Dr Jane Calvert and Dr Erika Szymanski from the Science, Technology and Innovation Studies Department.

Purpose of the research project:

The research aims to explore the social dimensions of mammalian synthetic biology. In particular, I am keen to understand how 'the human' may appear in the context of synthetic biology practices – if at all.

What participating will involve:

If you were to participate in this research, it would involve my presence at your place of work for half a day, approximately once a fortnight over the period of 6 to 9 months (to be organized and agreed in advance). It may also require access to some documents (with permission), and a follow up interview to clarify any aspects that may warrant further discussion.

Data and confidentiality:

With your permission, I will record interviews. The audio files will be transferred from the recording device to an encrypted computer at the first possible convenience and the original files deleted. In the case of any documents that become part of the research data, I will take copies and return the originals to the owner. All information you provide will be treated in accordance with the Data Protection Act (1998) and treated confidentially. Real names, anecdotes and information leading to identification will be removed. The research has been considered by the Ethics Committee of the School of Social and Political Science, University of Edinburgh.

Use of information:

Should you agree to participate, the information you would provide will be used to produce a PhD thesis that will be published and publicly available. Small excerpts from the data may be used – fully anonymised – within the project report to support key findings. These findings may also be used in other ways such as being included in presentations or academic papers where relevant.

Consent and further information:

Provided with this information sheet is an informed consent form. If you are happy to participate in this study, please read the form carefully, sign it and return to myself. Should you wish to discuss anything further to better understand the nature of the research of your potential involvement, please do not hesitate to contact me and I will be delighted to elaborate further.

Thank you for considering participating in this research.

Yours sincerely,

Sophie Stone

Appendix 4: Informed Consent Form

Science, Technology & Innovation Studies
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Researcher
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Supervisors
Dr Jane Calvert:
Dr Erika Szymanski:

PhD Project:

"Towards an empirical account of the relationship between synthetic biology entities and concepts of the human"

Participation:	**Yes**	**No**
I, the undersigned, have read the Participant Project Information Sheet for this research and understood the information contained within it.	☐	☐
I have been given the opportunity to ask questions regarding the study and understand that I can ask questions at any time during the research duration.	☐	☐
I understand that taking part in the research activities may include being audio-recorded, and I am willing for this to happen.	☐	☐
I have been given time to consider my participation and agree to take part voluntarily.	☐	☐
I understand that I can withdraw from the study at any time and I do not have to provide reasons for why I no longer want to take part.	☐	☐

Use of information provided:	Yes	No
I understand that my personal information will be anonymised - and remain anonymous - with every effort made by the Researcher to preserve confidentiality.	☐	☐
I understand that data will be collected and stored, safely and securely, in accordance with the Data Protection Act 1998.	☐	☐
I understand my words may be anonymously quoted in publications, reports, or other research outputs.	☐	☐
I understand that my signature will be kept on file securely to indicate consent and not used for any other purpose.	☐	☐

Participant Name	Signature	Date
_____	_____	_____

Researcher Name	Signature	Date
_____	_____	_____

Appendix 5: Interview Guide

Indicative guide for initial interviews with project leads

Early Focus Topics

Processes: Intentional design, creation; sorting/ordering; contextualisation
Products: Hybridity, natural, physiology, function, use, identity, origin, tools
Ideation: Role and type of 'human', expectations (current, future), absence/presence

Interview Questions

MQ = Main question; FQ = Potential follow up question / probes where appropriate

MQ1*:* Can you tell me about your current research?
- FQ: What first interested you in this project?
- FQ: What do you expect or hope from this project?
- FQ: Who is involved / has an interest in this project? What are their expectations?

MQ2*:* Can you tell me about the experimental systems you use?
- FQ: What biological material do you work with? In what capacity?
- FQ: What went into the decision behind it?
- FQ: What else have you worked with in the past? How does it / they compare?
- FQ: What are the techniques / instruments you use? How do you use them?
- FQ: How would you describe the products of the laboratory work? How do you make sense of / feel about them?
- FQ: What are the hoped-for uses of the products you're creating?

MQ3: How do you go about articulating and discussing your research?
- FQ: Who are the main audiences of your work?
- FQ: How do you communicate with them? What messages do you convey?
- FQ: Do you have any preferred ways of articulating your work?
- FQ: What is important to communicate?
- FQ: How much (if at all) do you discuss your work in terms of the human?
- FQ: Do you see any consequences from the way you communicate your work?

MQ4: What comes to mind when you think about the human in the context of your work?
- FQ: What comes to mind when if I ask you what the term 'human' means?
- FQ: How do people talk about the human in synthetic biology, if at all?
- FQ: Where / when / in relation to what, are you most likely to see these sorts of discussions?

MQ5: What do you think the future holds for your research?
- FQ: Are there any particular things you think scientists should be doing, thinking about or addressing that are not happening currently?

MQ6: Is there anything you wanted to discuss that we haven't talked about today that you think is important?
- FQ: Is there anyone you think I should be talking to next?