Special Issue Article

new media & society
2021, Vol. 23(2) 322–343

DOI: 10.1177/1461444820929576
journals.sagepub.com/home/nms
SAGE

Visions of unification and integration: Building brains and communities in the European Human Brain Project

Tara Mahfoud
King's College London, UK

Abstract

The Human Brain Project (HBP) was launched in October 2013 by the European Commission to build an information and communication technology infrastructure that would support large-scale brain modelling and simulation. Less than a year after its launch, more than 800 neuroscientists signed a letter that claimed the HBP 'would fail to meet its goals'. Based on multi-sited ethnographic fieldwork conducted between February 2014 and January 2017 in France, Germany, the United Kingdom and the HBP headquarters in Switzerland, and over 40 interviews with scientists, engineers and project administrators, this article traces how competing visions over how brain models should be built became tied into debates over how scientific communities should be governed. Articulations of these different kinds of models and communities appealed to competing imaginaries of Europe itself – of Europe and European science as unified or pluralistic. This article argues that scientific models are sites of contestation over social and political futures. The tensions between visions of scientific unification and pluralism in the HBP mirrored the tensions between imaginaries of European political unification and pluralism.

Keywords

Controversy, Europe, imaginaries, information and communication technology, integration, neuroscience, unification, vision

Corresponding author:

Tara Mahfoud, Department of Global Health & Social Medicine, King's College London, London WC2B 4BG, UK.
Email: tara.mahfoud@kcl.ac.uk

Introduction

The darkness breaks with a flash of blue light. Little bits of white light cross the boundaries of the screen, coming together in the centre to form the Human Brain Project (HBP). Multi-coloured and multifaceted, the split down its middle separates the left hemisphere from the right, the warm orange and red from the cold blue and green. Music comes in; upbeat percussion imposes itself over a rolling list of airplane departures to Naples, Brussels, London and Stockholm. Then, a flurry of people moves about the airport. The drums stop as the pace slows down. We look up and over the snow-topped Swiss Alps, come back down to people walking through Geneva, Switzerland and then pause on a view of the shining sun in a clear blue sky. The video, uploaded by the communications team following the project's official launch, ends the way it started – with the HBP coming together out of the little bits that make it up.

This was the vision for the HBP. Launched in October 2013, the HBP had 500 million euros in funding over a 10-year period from the European Commission (EC), to be matched by funding from European national governments and research councils. The HBP brought together over 100 institutions and over 500 scientists across Europe to build an information and communication technology (ICT) infrastructure for neuroscience research. Launched with three main 'pillars' – 'Future Medicine', 'Future Neuroscience' and 'Future Computing' – and 13 'subprojects', the brain models built for 'Future Neuroscience' would help develop brain-inspired computers for 'Future Computing' and 'Future Medicine' would mine federated data from clinics across Europe for brain-based markers of brain-related diseases and disorders.

Following the announcement of the HBP's funding, its charismatic founder and leader Henry Markram explained his vision in an interview with *New Scientist*: 'We want to reach a unified understanding of the brain, and the simulation on a supercomputer is the tool . . . The model is our way of bringing everyone, and our understanding, together' (Griggs, 2013). The future of neuroscience was *in silico*, Markram would tell me repeatedly when I was based in his Geneva laboratory in 2015 – in brain simulation and its power to unify the fragmented experimental knowledge that has been and continues to be generated worldwide by thousands of neuroscience laboratories. Markram would say that instead of just investing in new research, which would lead to more fragmentation, it was more important to put all these data together into a single, unified model. It was through the process of building this model, he suggested, that gaps in data would become apparent, identifying 'strategic data' that would need to be collected by participating labs.

Markram's vision for the first 'big' neuroscience project of Europe was to unify the neuroscience community through the building of a singular unifying model of the human brain. But less than a year after its launch, in June 2014, more than 800 neuroscientists from across Europe and the United States signed a letter that questioned 'whether the goals and implementation of the HBP are adequate to form the nucleus of the collaborative effort in Europe that will further our understanding of the brain' (neurofuture.eu, 2014). Posted on a website titled 'neurofuture', aptly registered with the European Union's domain extension, the authors of the letter were explicitly putting forwards an alternative, pluralistic, vision to the unificatory 'Future Neuroscience' of the HBP. The signatories pledged not to apply for HBP funds or participate in any of its partnering projects should their concerns and recommendations not be addressed at the EC's biyearly review in 2015. The 'open letter', as it came to be called, launched a public debate within the neurosciences over how brain models should be built, and over how big science projects should be governed. The HBP, launched with the intention of unifying the neuroscience community of Europe, instead brought the cracks to the surface.

This article traces how competing visions over how brain models should be built became tied into debates over how scientific communities should be governed. At stake in the HBP controversy was not just a case of what kinds of brains were imagined in the building of these models, but also what kinds of communities were implicated in these modelling approaches. Furthermore, articulations of these different kinds of models and communities appealed to competing imaginaries of Europe itself – of Europe and European science as unified or pluralistic. In the HBP, as in other European science and technology projects, imaginaries of Europe become entangled with the visions and designs of technological systems and artefacts (Misa and Schot, 2005). Of course, there is no singular European monolith to speak of (De Genova, 2016), but through projects like the HBP, we can observe what imaginaries of Europe are being articulated, negotiated and embedded into the science and technology projects it funds. This article argues that scientific models are sites of contestation over social and political futures. The tensions between visions of scientific unification and pluralism in the HBP mirrored the tensions between imaginaries of European political unification and pluralism.

For those working across the boundaries between the neurosciences and informatics, the building of maps and models of human and animal brains is tied into visions of data unification, integration and standardisation. As I will show, for many scientists and engineers, the unity of data depends on the unification of the neurosciences – in other words, without the unification of what they call 'the neuroscience community', there cannot be the unified data sets needed to build standardised models of brains. For others, visions of unification are exactly that which stand in the way of 'the collaborative effort in Europe that will further our understanding of the brain' (neurofuture.eu, 2014). In these visions for the future of neuroscience in Europe, unification stands in contrast to pluralism; while the former assumes a singular whole, the latter calls for a multiple account of the ways data can come together. At stake in the HBP, it became clear, was a particular vision of how the brain can, or should, be studied and understood and of what techniques would make such a feat possible. In the process of building these unifying tools, whose data and methods would get integrated, whose would get left out and how would these choices be made?

Methods

This research is based on multi-sited ethnographic fieldwork I conducted between February 2014 and January 2017, following HBP scientists, engineers and administrators around European cities (including France, Germany, and the United Kingdom) for scientific coordination meetings, management meetings, academic workshops and conferences. I was also based in the HBP headquarters in Geneva, Switzerland, between February and August 2015 where I observed *in-vitro* and *in silico* neuroscience experiments, and attended meetings with several of the HBP's subprojects. In addition, I have conducted over 40 interviews with scientists, engineers and project administrators involved in the HBP. This article, in particular, draws on a thematic analysis of field notes, interviews, newspaper and magazine articles, and official EC documents during the first period of funding of the HBP (2013–2015) with a focus on concepts of unification and integration as they pertain to the neurosciences and to science and technology in Europe.

This research project was approved by the Research Ethics Office of King's College London in 2014, and was granted extensions in 2015 and 2016. Research participants gave verbal or written consent to having notes taken during participant observation in laboratories, meetings, public events and during interviews. Participants chose whether to be fully identified, partially identified or to remain un-named. The research on which this article is based has been shared with relevant research participants.

Visions and imaginaries of science and technology in Europe

The first time I met Markram was in June 2014 at the Institut Pasteur in Paris, where he was introduced by colleagues as the HBP's 'visionary leader'. Markram excitedly described his modelling framework with the help of an image-overloaded PowerPoint presentation – there were really no white spaces left on any of the many slides. He wanted to make an argument for why simulation was not just important, but also essential to the progress of the neurosciences. Brain simulation, Markram argued, was the solution to mapping variable and varying brains which would be impossible to map experimentally. He also presented simulation as a solution to the perceived data deluge of the neurosciences – neuroscience laboratories generate massive quantities of data and neuroscientists generally agree that solutions are needed to organise, standardise and share these databases (Brown, 2013; Strickland, 2014).

After showing the audience of HBP scientists a visualisation of a rat brain simulation with its flickering synapses and multi-coloured neurons, Markram said, 'I just want to point out that this is happening. Whether we do it or somebody else does it, this is happening. Merging ICT, neuroscience and medicine is happening. It's been happening. There will be *in silico* neuroscience medicine'. This was a phrase I continued to hear as I followed Markram and his team around European cities in 2014 and 2015.

Proclamations made by scientists and engineers about the inevitability of technoscientific futures have long been studied by Science and Technology Studies (STS) scholars (Selin, 2008; Tutton, 2011). There is, however, always an incredible amount of work needed to put in place the conditions to manifest future visions (Jasanoff and Kim, 2015). This is no different in the medical and biological sciences. 'In biomedical practices', argue Karen-Sue Taussig et al. (2013),

> [P]otentiality indexes a gap between what is and what might, could, or even should be. Such a gap opens up an imaginative space of magic and mystery in which future-building activities related to animating bodies and extending life in new ways loom large. (p. 5)

An attention to the potential (and risks) of the life sciences is, within this framework, an attention to change – how scientific concepts and objects shape one another in the spaces between that which could be but is not yet.

Other concepts have also been used to understand these in between spaces – visions (Hilgartner, 2015), imaginaries (Jasanoff and Kim, 2015), expectations (Borup et al., 2006; Brown and Michael, 2003), hope (Novas, 2006) and promise (Rajan, 2006; van Lente, 2000). Instead of assessing future expectations against 'actual' results of scientific projects, producing a rift between 'vision' and 'reality', many of these studies rightfully see scientific visions and imaginaries as generative and performative (Borup et al., 2006; Brown and Michael, 2003; Hedgecoe and Martin, 2003; van Lente, 2000). Grand visions serve not only as political, economic and rhetorical instruments that scientists use to get projects funded and gain public support, but also come to shape the development and socio-economic trajectories of emerging technologies.

Based on a close reading of HBP proposals and EC documents and reports, Francesco Panese argued that the HBP was funded because it effectively responded to political, economic and social issues which were on the agenda of European funding and political bodies – specifically in promising new technologies to treat brain-related diseases considered a matter of public health (Panese, 2015: 165–166). Indeed, hopeful expectations and promises are common characteristics of the contemporary neurosciences (Rose and Abi-Rached, 2013). The justifications for investing in the neurosciences are often framed in relation to the 'growing burden' of brain diseases and the hope that advances in these fields can provide a better understanding of what brains are and how they dys/function, which in turn can provide better treatments to those in need.

Panese further suggests that the HBP vision can be understood, following Sheila Jasanoff and Sang-Hyun Kim (2009), as a sociotechnical imaginary – 'collectively imagined forms of social life and social order reflected in the design and fulfilment of nation-specific scientific and/or technological projects' (p. 20). The definition has since been extended beyond the nation-state to include other forms of organisations such as corporations, and even more informal social movements (Jasanoff and Kim, 2015). Jasanoff (2015) maintains, however, that while sociotechnical visions can originate individually or collectively, they only 'rise to the status of an imaginary' when collectively held and institutionally stabilised (p. 4).

Five years into the HBP, the vision of brain simulation was replaced with another vision – that of building a data and computing infrastructure to support various modelling approaches rather than the singular unificatory model and corresponding infrastructure Henry Markram had put forward. How to make sense, then, of the HBP whose vision has been consistently negotiated and unsettled, institutionally stabilised and de-stabilised? Distinguishing between 'visions' and 'imaginaries', Stephen Hilgartner (2015) describes how competing visions 'reflect, resonate with, reinforce, and contradict extant sociotechnical imaginaries' (p. 35). Visions are, for Hilgartner, partially shared, not yet accepted by larger collectives such as nations, and not as stable or *longue durée* as imaginaries might be. While the HBP vision, as put forward by Markram and his colleagues, was institutionalised to the extent that it became one of the largest scientific projects funded by the European Union (EC, 2019), it was not completely shared by wider neuroscientific communities in Europe and even within the project itself.

In this article, I explore how scientific models become sites of contestation over social and political futures. Hilgartner argues, following Jasanoff (2015), that 'sociotechnical visions develop and are re-formed through a dynamic process in which their advocates encounter other actors with different goals, engage with extant institutional machinery, and interact with established collective aspirations and imaginations of the future' (p. 34). The HBP is an opportunity to analyse how techno-scientific visions draw on and interact with the longue durée European imaginaries of unification and pluralism. This is particularly pertinent at a time in Europe when these imaginaries are themselves being contested, in what seems to be a perpetual concern with European integration and disintegration. I show how these interactions come to shape how models of brains come to be built and what kinds of communities are imagined and brought together in the process. Visions of and for this large-scale scientific project became tied into different modelling approaches which in turn reflected the tensions between European imaginaries of unification and pluralism.

Many social scientists and humanities scholars have based their critiques on questioning the legitimacy of neuroscientific truth claims and the power these could have in transforming how we think of what it means to be human (Choudhury and Salby, 2016; Vidal, 2009). This critique, however, rests on the assumption that the neurosciences are a unified field of study. Joseph Dumit (2016) has recently noted that 'while the frame of neuroscience versus the humanities sets the stage [of contemporary critiques of the neurosciences], the real fights are revealed to be within neuroscience, and between neuro- and other sciences' (p. 224). Instead of a critique of what neuroscience findings could mean for how we think of 'the human', Dumit (2016) suggests that another 'critique of neuroscience . . . might be to question the apparently ubiquitous claims about the legitimacy of neuroscience (the Decade of the Brain, the HBP, and the BRAIN Initiative)' (p. 223). What this article shows is how the legitimacy of a big neuroscience project was both established and questioned, bringing to light the fractions and frictions within the neurosciences rather than treating the discipline as monolithic.

In fact, whether the HBP was a neuroscience or an ICT project was itself a subject of controversy (Frégnac and Laurent, 2014). Some have argued that the HBP may signal a shift of focus within the neurosciences away from the 'wet lab' and towards ICT, simulation and data science (Haueis and Slaby, 2016). This shift is linked to shifts in funding, whereby the neurosciences are increasingly funded through ICT budgets rather than pharmaceutical companies which have been abandoning unsuccessful drug discovery programmes for brain-related disorders (Aicardi et al., 2017; Dumit, 2016). Whether ICT budgets are or are not shaping the direction of neuroscience research, HBP researchers certainly exploited the increase in funding for ICT via the EC Flagships Initiatives to redirect it towards the neurosciences. Funding neuroscience through an ICT budget has consequently brought up questions about how (and whether) a renewed emphasis on computation might change neuroscientific practices.

The competing HBP models (or rather, modelling approaches) are simultaneously *models of* and *models for*[1] – they are models of different features and behaviours of animal and human brains, and also embody visions and conflicting futures of what neuroscience could and should be, of how the brain should be studied. Heather Paxson and Stefan Helmreich (2014) argue that models are 'not just . . . representatives, standards, or experimental objects, but also . . . moral exemplars – models that are not simply descriptive, but that might simultaneously be prescriptive' (p. 171). Paxson and Helmreich use this framework to argue that microbial models are not just descriptive, but also prescriptive of how concepts of 'life' and 'nature' may be rethought. I extend this to think of how models become prescriptive for certain visions of what European neuroscientific communities should be, what neuroscience is and ought to be – unified or pluralist. In doing so, I show how visions of scientific unification and pluralism become intertwined with imaginaries of political unification and pluralism whereby big science projects such as the HBP become a means of and for political unification in Europe (Galison and Stump, 1996; Krige, 2006; Ulnicane, 2020).

The argument is developed in three parts: Euro Visions, Neuro Visions and Imagined Communities. I first discuss the origins of the HBP vision in relation to EC science and innovation policies. I show how the boundary concepts of integration and unification were explicitly used by HBP scientists and administrators to link the project of data and model integration to the project of European integration. In the second part, I trace how debates over how to model brains became prescriptive for different visions of what the future of neuroscience should be in Europe. I show how the alternative visions of the HBP – as singular or pluralistic – reflected and interacted with imaginaries of Europe itself as unified or pluralistic. In doing so, I demonstrate how an attention to divisions and tensions within the neurosciences offers a different kind of critical engagement with the potential and promise of the increasing development and use of computational techniques in the life sciences. Finally, through an analysis of meetings between EC officials and HBP scientists and engineers, I show how by appealing to the European imaginary of 'unity in diversity', the HBP and its critics significantly shaped the direction of brain modelling, and the direction of science funding in Europe.

Euro visions

The HBP was one of two Flagship Initiatives funded in 2013. The Flagship Initiatives were launched as part of Europe 2020, the European Union's 10-year growth plan following the 2007 financial crisis. The 'European Economic Recovery Plan' reminded policymakers that in times of financial crisis, the trend in Europe has always been to cut funding to research and development (R&D) whereas other countries increase R&D expenditure, thereby laying 'the basis for their strong position in innovation' (EC, 2008: 15). Responding to the 2008 'European Economic Recovery Plan', another report by the Commission proposed a 'Strategy for research on future and emerging technologies in Europe' which foresaw

> . . . a FET [Future and Emerging Technologies] flagship initiative [that] could model and run large-scale simulations in order to understand the way nature processes information and to apply this knowledge to develop future biocomputers. Such a unique endeavour would attract the best computer scientists, biologists and physicists from Europe and beyond. (EC, 2009: 12)

Henry Markram's Blue Brain Project was already mentioned in this plan as 'the first comprehensive attempt to reverse-engineer the mammalian brain, in order to understand brain function and dysfunction with the aid of detailed simulations' (EC, 2009: 9). It is no coincidence that Markram himself was part of the EU Information Society Technologies Programme Advisory Group (ISTAG) which recommended the Blue Brain Project (BBP) as a successful example of an international Flagship Initiative in its report to the EC (Prem et al., 2010).

The imaginary of techno-scientific progress presented in these EC reports was that to lead in global innovation, Europe needed to invest more money into R&D at times of crisis; it needed to be risky. In the preface to the Europe 2020 strategy document, then-president of the EC José Manuel Barroso stated,

> The crisis is a wake-up call, the moment where we recognise that 'business as usual' would consign us to a gradual decline, to the second rank of the new global order. This is Europe's moment of truth. It is the time to be bold and ambitious . . . If we act together, then we can fight back and come out of the crisis stronger. (EC, 2010: 2–3)

Barroso's call to action imagined a Europe that would 'decline to the second rank of the new global order' if it continued to follow, not lead, innovation. Europe after the financial crisis would be 'bold and ambitious'. It is within this context that the Flagship Initiative was justified (Ulnicane, 2016). The aim of the Flagships was to

> become a new partnering model for long-term European collaborative research in the context of the European Research Area . . . by leading, inspiring and integrating efforts . . . turn scientific advances into concrete innovation opportunities, growth and jobs [and] contribute to addressing some of the major societal challenges Europe is facing. (EC, 2013)

The design of the flagships consisted of a 'core' which would lead the 'partnering projects' with a 'consistent vision' and a 'charismatic leader' across the 10-year timeframe. This unificatory imaginary of European science as having a singular, stable, consistent vision at its core was central to the conceptualisation of the HBP.

Visions become imaginable and plausible in their appeal to more stable sociotechnical imaginaries (Hilgartner, 2015). The HBP spoke to the aims of the EC's call by emphasising the societal challenges of mental health that investment into the neurosciences could provide (Panese, 2015). The HBP also, I suggest, used the boundary concept (Star, 1989; Star and Griesemer, 1989) of integration, and in doing so, exploited the concept's interpretive flexibility by linking its vision of data integration through brain modelling and simulation to the political imaginary of European integration through the Flagship Initiatives.

One of the EC-appointed reviewers of the HBP said the following of the HBP as a European project:

> What they're trying to do in the HBP is big science in a European way . . . which is of course very difficult . . . you have to have many countries involved and it has to be this grand scale . . . but it seemed clear that to have the HBP accepted, they had to have many countries represented and build an organisation for that . . . having a multinational project and also do it in this top-down way.

This comment suggests a tension that the HBP faced in appealing to the EC's singular, top-down, vision for the Flagships and the need to represent the diversity and plurality of neuroscientific efforts in Europe. This tension was also brought up by one of the HBP proposal's writers:

> If the commission had its way, the money would be divided equally between all the countries in the EU. And the richer countries, like Switzerland and Germany and the UK and France, would spend their own money to do more in the project . . . but this would go against the idea behind the Flagships which were to do a long term high risk project. It would turn into a long term, low risk politically palatable project.

The HBP, in articulating its vision, embodied multiple imaginaries of Europe by developing a 'core' with a 'consistent vision' and a 'charismatic leader', while also ensuring a broad representation of the member states. The shift in EU funding policy that the Flagships represented responded to concerns about the EU's global competitiveness with the United States and Japan by increasing funding for R&D during the economic crisis and encouraging a more centralised approach to scientific organisation. However, this was in tension with the EC's commitment to supporting EU integration and addressing the needs of all EU member states (Ulnicane, 2016).

In April 2013, just a few months after the announcement of the HBP on 28 January 2013, then-US President Barack Obama launched the BRAIN Initiative (Brain Research through Advancing Innovative Neurotechnologies). In a presidential address from the White House, Obama (2013) said,

> Ideas are what power our economy . . . today, scientists possess the capability to study individual neurons and figure out the main functions of certain areas of the brain . . . We can't afford to miss these opportunities while the rest of the world races ahead . . . I don't want the next job-creating discoveries to happen in China or India or Germany. I want them to happen right here, in the United States of America. And that's part of what this BRAIN Initiative is about.

Reiterating the American dream of foresight and innovation, Obama wanted to make sure that the next developments in neuroscience would take place in the United States, not Europe or elsewhere. Although the BRAIN Initiative was a fragmented initiative compared with the HBP – funding several small projects from many different federal funding bodies instead of one large one – presenting it as a unified 'Initiative' contributed to the public narrative of a 'brain race' between Europe and the United States (Modic and Feldman, 2017).

Other countries joined the 'race'. In 2014, the Australian Academy of Science launched AusBrain; the Japanese Ministry of Education, Science and Technology launched Brain Mapping by Integrated Neurotechnologies for Disease Studies (Brain/MINDS) and the Chinese Academy of Sciences launched the China Brain Project. In 2015, the Ministry of Education and Science of the Russian Federation put almost US$ 3 million into a human brain modelling project. For a little over a year, Europe was leading the way. But in that year, the Defence Advanced Research Projects Agency (DARPA), the National Science Foundation (NSF), the US Food and Drug Administration (FDA) and the Intelligence Advanced Research Projects Activity (IARPA) committed almost US$ 5 billion in funding to the BRAIN Initiative – far surpassing the HBP's 1 billion euros in committed funds.

The EC's vision for the flagships brought up quite a few European techno-scientific tropes – competition with the United States, and the role of science and technology in unifying Europe. Benedict Anderson (2006) has famously argued for the important role that information and communication technologies have played in constructing the nation-state as an 'imagined community'. Building on Anderson, Sheila Jasanoff (2005) has suggested that Europe be conceived of instead as a 'multiply imagined community' to reflect the tensions between unity and diversity endemic to the European project. For the EC, I was told by a senior administrator in the HBP that

> the scientific goal of [the HBP] is actually very much secondary . . . the flagships are in fact, if you will, just a policy tool for them and the scientific output is actually unimportant . . . I'd say the primary goal is the unification of the scientific effort across Europe or the educational value of generating the next generation of scientists skilled in a certain possibly promising area and so on, so it's an integrative effort that is aimed at increasing efficiency across scientific effort . . . their interest in simulation – they know that this is important. What you simulate, it could be the leg!

In less humorous words, the EC invested in the HBP because of the economic potential of biologically inspired computing, and to better integrate scientific efforts across Europe – and not to 'further our understanding of the human brain' as many HBP scientists had hoped.

Furthermore, Astrid Mager (2017) reminds us that the imaginary of European technology as a race with the United States is a common rhetoric found in EC policy. EC officials presented the desire to emulate US innovation success as a need to instate 'vision-driven' science through a commitment of funds to a singular scientific and technological goal – in this case, the simulation of the human brain. This singular unificatory vision for the Flagship Initiatives was reflected in Henry Markram's vision for the HBP – that building a single model would not just bring together fragmented neuroscience data, but would also bring together the fragmented neuroscience community of Europe. This unification vision, however, stands in contrast to the alternative vision for the future of neuroscience in Europe put forward by the writers of the 'open letter', as I discuss in the next section.

Neuro visions

The controversy around the HBP is often interpreted as being a resistance among neuroscientists over the encroachment of computational methods and tools and how these might change neuroscientific practices. Many neuroscientists who criticised the HBP have expressed concerns about the 'transformation of neuroscience into an engineering discipline' (Bruder, 2017: 119), and 'fear that machine learning and modelling techniques imported from foreign disciplines might eventually even disintegrate the field or threaten the financial support for "real" brain science' (Bruder, 2017: 118).

In this section, I add to these discussions by arguing that the debates within the neurosciences that led to the HBP controversy were debates over how much biological detail is necessary to include in computational models. In other words, the epistemological conflict that led to the 'open letter' was between computational neuroscientists themselves, and can inversely be understood as a resistance from the computational neuroscience community against the inclusion of 'too much biology' into large-scale brain models. In these debates over how to build brains, models became 'moral exemplars' (Paxson and Helmreich, 2014) – prescriptive for what to model and how to model it, prescriptive for standards of how to collect and annotate data and prescriptive for how scientific communities should be correspondingly brought together.

Model divisions

An electrophysiologist with years of celebrated laboratory work on the mechanisms of synaptic plasticity behind him, South African-Israeli Henry Markram joined the École Polytechnique Fédérale de Lausanne (EPFL) in 2002 to found and direct the Brain Mind Institute – the neuroscience division within the newly founded School of Life Sciences. In 2005, EPFL signed an agreement with IBM to acquire a BlueGene supercomputer. This launched the BBP – Markram's proposal to build a detailed simulation of a rat cortical column. Working with the assumption that the cortical column is the basic functional unit of the cerebral cortex – something that has since been heavily debated[2] – the BBP completed an 'initial model of the rat cortical column' in 2007, began testing their model against anatomical and physiological data in 2008, and in 2009, the BlueGene/L supercomputer was replaced by a BlueGene/P, which significantly increased the computing power available to the BBP team.

Markram became somewhat of a spokesman for *in silico* neuroscience, convinced that the project of building a unifying brain model could only happen if he reached out to a broader public. In 2009, he gave a TED talk – 'A Brain in a Supercomputer' – where he said 'it is not impossible to build the brain . . . we can do it within ten years' and with a smile, he continued, 'if we do succeed, we will send to TED in 10 years a hologram to talk to you'. Responses to these claims on the TED website ranged from 'brilliant' and 'very cool' to 'people don't want to just be a computational machine' and 'I really doubt he'll be back in ten years, given that his base theory is flawed'. Despite the criticism this talk continues to receive because of its bold claims, it served to inspire aspiring scientists. I would later find out that at least two people in Markram's lab applied for their positions at the BBP after watching that very video.

Later in 2009, IBM Chief Scientist Dharmendra Modha announced that he had simulated a cat-scale brain for which he and his team won the Gordon Bell Prize, awarded by the Association for Computing Machinery (ACM, n.d.) for 'innovation in applying high-performance computing to applications in science, engineering, and large-scale data analytics'. Markram sent a letter to IBM's Chief Technology Officer and forwarded it along to the press. 'I am absolutely shocked at this announcement', Markram said,

> [N]ot because it is any kind of technical feat, but because of the mass deception of the public . . . These are point neurons (missing 99.999% of the brain; no branches; no detailed ion channels; the simplest possible equation you can imagine to simulate a neuron, totally trivial synapses . . . (Adee, 2009)

Markram's comments were about the level of biological detail Modha's DARPA funded simulations missed. In contrast, Markram's approach was to add morphological and electrophysiological features to their neuron models. The story made headlines: 'Cat Fight

Brews Over Cat Brain' (Adee, 2009), 'DARPA's Simulated Cat Brain Project a 'Scam': Top Scientist' (Shachtman, 2009) and 'IBM cat brain simulation dismissed as 'hoax' by rival scientist' (Brodkin, 2009). As a biologist, Markram was very critical of modelling approaches that did away with anatomical complexity.

The Markram–Modha debate was emblematic of disagreements between computational neuroscientists. These disagreements were not over whether one should build large-scale brain models and simulations, but over what structural details can be excluded from neuron models without affecting the functional output. While there are numerous kinds of models that describe brain behaviour at different levels of detail, and any attempt to neatly classify them is bound to be simplistic, neuroscientists I spoke with during my fieldwork identified broadly two approaches: bottom-up and top-down.[3] Bottom-up models start at the level of the neuron, using anatomical and electrophysiological data to reconstruct neural networks. While more biologically realistic, including more detail means these models require more data, computing time and power. Top-down models, on the other hand, start at the level of the network, or population of neurons, using data from electroencephalography (EEG), magnetoencephalography (MEG), and optical imaging to test hypotheses from the behavioural sciences.

What kinds of data to collect and what kind of infrastructure to build was tied into the kind of modelling approach taken. Bottom-up models required modellers and experimentalists to work closely together and required neuroscientists to agree on data standards – but who would set these standards? Markram's proposal was that their models would dictate the standards needed to be followed – unifying neuroscience data through model-driven standards. When I asked a staff scientist at the BBP who gets to set the standard for what data to start with, he replied,

> It's not so much about setting the standards. It's more about legacy, in that Henry started acquiring data to reconstruct this part of the brain, using an experimental technique that he was familiar with. So as long as there are other labs that also use the same experimental technique then it is easy to integrate. If not then it is just harder.

Developing so-called 'bottom-up' models ironically required 'top-down' governance and a neuroscientific community unified around similar experimental techniques. The models that the BBP were building, then, dictated the data requirements – in terms of what data need to be collected, annotated, classified and shared. Collaborations between Markram's team and the labs that were supplying them with data for their models were not always easy. To build the anatomical models which were the basis for the simulations, they needed single-cell neuron models with the axon reconstructed in full with dendritic spines. Echoing the debate between Markram and Modha, the BBP collaborators did not always deem it necessary to model individual neurons at that particular level of detail. A member of Markram's supercomputing team, said,

> People model different things, and believe different things are important to model . . . that's how you get an uproar, when you tell people how they should be doing things when they've built a career on doing things another way.

The HBP ‘unified’ models embodied not only epistemological debates over what level of brain detail was essential for building functional brain models, but also embodied moral debates about how collaborations between modellers and experimental neuroscientists were to be organised in the project and what kinds of data were valued in such a model-driven approach. The recognition of scientific and model pluralism – that ‘people model different things, and believe different things are important to model’ was also such an epistemological and moral argument and was repeatedly highlighted among HBP critics – within and outside of the project. Different modelling approaches became prescriptive for different ways of organising scientific communities. Markram’s models were seen as unifying, but with him at the centre. This was not the way scientists in Europe wanted to work – they wanted pluralism and variance. The way HBP scientists proposed to ‘know the brain’ was not compatible with the way a large part of the neuroscientific community wanted to work together, socially and epistemologically (Panese, 2015: 191).

The open letter

The ‘Open message to the EC concerning the Human Brain Project’ was published on the purposely created ‘Neurofuture.eu’ website on 7 July 2014. The letter threatened to destabilise the entire project by calling for European neuroscientists to boycott it. ‘At stake’, the letter said, ‘is funding on the order of 50M€ per year [from the] European Commission for the “core project” and 50M€ in “partnering projects” provided largely by the European member states’ funding bodies’ (Enserink, 2014). Since the EC was only providing half the funding, the HBP partners needed to raise the rest of the funding from the partner member states. At stake, then, was the allocation of scarce research funds to a scientific project that, in the eyes of its critics, was epistemologically questionable and inadequately managed.

The controversy itself began after Stanislas Dehaene, a prominent French neuroscientist, and the ‘Cognitive Architectures’ subproject he was leading were removed from the HBP’s second funding application in 2014 by the HBP Board of Directors (which Henry Markram chaired). There are many rumours as to why the Board of Directors made this decision, but both Markram and Dehaene were not permitted to talk to journalists (and myself) about the reasons behind the disagreement due to the conditions of the ensuing mediation. After the disagreement failed to be resolved privately, many of the scientists who were excluded from the second round of funding in the HBP expressed their concerns through what came to be known as ‘the open letter’.

‘The open letter’ criticised the project’s goal of simulating a whole human brain in 10 years, which many deemed unrealistic, as well as Markram’s leadership of the project. The letter also indicated that there was a conflict of interest if Markram was the co-director of the simulation subproject, director of the management subproject which oversaw coordination and budget distribution, and was chair of the Board of Directors.

One of the authors of the letter, Zachary Mainen from the Champalimaud Centre for the Unknown in Lisbon, said the HBP ‘is not a democracy, it’s Henry’s game, and you can either be convinced by his arguments or else you can leave’ (Enserink, 2014). When Henry Markram first presented the HBP proposal at the Swiss Academy of Sciences (SCNAT) meeting on ‘Perspectives of High Power Computing in Neurosciences’ in 2012, his former BSc thesis supervisor, Rodney Douglas responded, ‘we need variance in neuroscience . . . we need as many different people expressing as many different ideas as possible' (Waldrop, 2012). How could other approaches fit into Markram's singular vision, many asked?

I mentioned Douglas's comment in an interview with one of the writers of the open letter, who responded that

> [p]eople were concerned Henry got to be the spokesman for European neuroscience . . . [the HBP] looks like the European neuroscience project, as if it represents European neuroscience, which in fact it doesn't do.

The concerns about a need for scientific pluralism were, in this response, linked to the European identity of the HBP and the conflicting pluralist and unificatory visions for European neuroscience. 'Neurofuture' imagined a different future for neuroscience in Europe than the 'Future Neuroscience' of the HBP. 'Neurofuture' presented itself as pluralistic, democratic, advocating multiple complementary approaches rather than a single risky vision. Close to 800 individuals have signed the letter since its publication, many of whom are leading scholars in both cognitive and computational neuroscience. While the majority are likely unaware of the disagreements between the HBP partners that led to it, and have signed it for a variety of reasons, the signatories vowed to boycott HBP funds and calls for proposals if their recommendations were not considered at the bi-annual EC review in January 2015.

In September 2014, Wolfgang Marquardt, Chairman of the Board of Directors of Forschungszentrum Jülich, was brought in to mediate the disagreement between Markram, the Board of Directors, and the other HBP partners. In January 2015, the Board of Directors received the first official recommendations from the mediation process, and the EC performed its first scheduled review of the HBP. Soon after, EPFL's Provost Philippe Gillet was asked to step in as head of the HBP management subproject and Markram was asked to step down from his role as chair of the Board of Directors and head of the management subproject.

The effects of these changes were palpable. After I had received approval from Markram about attending a meeting with the EC (which I describe in the following section), members of the administration told me that 'there was a new chief in town' – the CEO that had been appointed to manage the project in the wake of the controversy. All such approvals, now, needed to come from him instead. As these changes were taking effect, one of the scientists in Markram's team told me 'something dangerous is happening' – the discussions following the mediation, and the reintegration of the 'Cognitive Architectures' subproject led by Stanislas Dehaene upon the recommendation of the mediation committee meant that the HBP modelling infrastructure had to cater to the needs of multiple modelling approaches, shifting them away from Markram's original vision for the project of building a single unifying model.

Given the interconnectedness of models, data and infrastructure, the open letter and ensuing interventions had the effect of not only changing how the project was being managed, but also how brain models were taking shape, what kinds of data would then need to be collected and how the modelling and data-sharing infrastructure was to develop. By appealing to the European imaginary of 'unity in diversity', the HBP critics significantly shaped not only the direction of the project, but also the direction of modelling within the computational sciences in Europe. As Hilgartner (2015) argues, technoscientific visions often reflect and interact with extant imaginaries. In this case, the tensions and contestations between the alternative visions of unification and pluralism in the HBP mirrored the tension between imaginaries European unification and integration, more broadly. Indeed, scientists themselves exploited imaginaries of European integration and unification in their public statements and used these metaphors to claim the legitimacy of their approaches.

Imagined communities[4]

In May 2015, EC officials came to the HBP headquarters in Geneva to discuss how to move forward following the publication of the mediation and EC review reports. The officials opened the meeting by insisting that this was ‘a very friendly discussion, no politics’. But of course, the meeting was political. During the 2-day meeting, each of the platform developers gave a presentation. An issue that the EC officials kept coming back to was platform design and access. One of the EC officials said, ‘what I am missing is how to provide access to whom and under what conditions . . . I would like to see a collaborative model with other institutions . . . and define what the common good is for different people’.

The HBP was developing six platforms to support the modelling and simulation efforts. The platforms include (1) a neuroinformatics platform (to standardise data and to make them open access for researchers within and outside of the project), (2) a brain simulation platform (which makes available a suite of software tools for brain simulations at different levels of description), (3) a high-performance analytics and computing platform (which provides neuroscientists within and outside the project access to supercomputers to run their simulations on), (4) a medical informatics platform (which allows researchers to access genetic, imaging and other clinical data from hospital and research archives), (5) a neuromorphic computing platform (which develops and provides access to brain-inspired computing hardware) and (6) a neurorobotics platform (which allows researchers to connect their brain models to digital and analogue robotic bodies).

What used to be called the ‘Unified Portal’ – the digital point of access for the HBP platforms – was renamed the ‘Collaboratory’ in an attempt to please the EC officials who were trying to dampen the effects of the controversy and address the ‘open letter’ concerns about the need for a multiplicity of models and approaches. One of the EC officials asked, ‘The Collaboratory provides the interface but it does not provide who talks to whom . . . what are the conditions of access? The issue is, who contacts whom and makes sure other partners are part of the discussion?’ A member of the neuroinformatics team said they would need to have a working group that is consortium wide to address the issue of access. The EC official said, ‘yes, that’s what I wanted to hear’. He later insisted that the HBP needed to be a federated infrastructure, and that this was ‘different from the unified infrastructure’ Markram was suggesting. But, Markram insisted, there were too many partners in the consortium, and it would be difficult to reach a consensus on how to design the platforms and how to regulate access to them. While there were 'traditional ways of governing infrastructures in Europe, this was not a traditional project', Markram insisted. The EC official responded, 'as a consortium I expect there will be culture shock, I respect that, but as a consortium after some time I expect that you will converge. If this does not happen then we will have a major problem'.

The problem was how to build an infrastructure that serviced the plurality of modelling approaches – top-down, bottom-up and everything in between. In response to a question of how these modelling approaches would 'converge', or be integrated in the infrastructure, a senior member of one of the platforms said, 'this is a cultural thing in the community because each community thinks it is the center of the universe'. In other words, they were grappling with how to build an infrastructure without a centre. Building an infrastructure to support brain modelling and simulation required, according to these discussions, a centralised approach. What the EC was requiring, following the 'open letter' requests and mediation recommendations, was an infrastructure that would support a plurality of modelling approaches. This signalled a significant shift in its approach to the Flagship Initiatives – from a singular, unifying project, to a multiple, pluralistic one. How then, to deal with such a multiply imagined community (Jasanoff, 2005)?

Community has been a debated concept within the project from the start – with different understandings of what community might mean for the scientists, engineers, administrators and EC officials involved. What is at stake in these different articulations of community is, I have been arguing, how these are tied into scientists' struggles over what 'the future' of European neuroscience should be, and what shape brain models should take. I have also shown how the debates over how to build brains are inextricably tied into debates over how large-scale scientific projects should be governed and over what a European scientific community should be.

The singular brain modelling infrastructure Markram was building for the HBP was eventually abandoned with his removal from the management of the project because it required a form of community that was fundamentally different from the form of community the EC and the HBP critics demanded. The HBP's 'unificatory' conception of community was different from what the EC officials meant by community. The 'integrative' community was about federated infrastructure, platform access, consortia, working groups, collaboration and convergence. It subscribed more to the imaginary of Europe as 'unity in diversity' - "a deliberately ambiguous and ideologically loaded formula that can be interpreted either as a celbration of pluralism and local autonomy or as its antithesis: power to the center" (Shore, 2013, p. 54). It is important to note, in this respect, that while the HBP originated in Switzerland, in the periphery of Europe, the balance of power has now shifted to Germany and France and the coordination of the project and its infrastructure will now be based in Brussels, the 'core' of the EU.

Conclusion

What I have demonstrated in this article is the parallels between the unificatory visions of the HBP and EC through the Flagship Initiatives. I hope to have shown how the normative and epistemic negotiations that take place over what models to build allow for certain kinds of knowledge about brains and their workings to be possible. At stake in these encounters is a unitary or multiple future for the neurosciences – a singular Future

Neuroscience or many neurofutures? Following the EC led review of the project in 2015, as well as a change in leadership, the HBP has abandoned its focus on a single unifying model and is now instead building an infrastructure to cater to the diverse and multiplying brain modelling use cases. What this brings into question is unification as a project within the neurosciences.

Peter Galison (2016) argued that ‘we are seeing a topological shift in the intellectual and cultural structure of physics, one that takes a pyramid into a ring: facing outwards everywhere but without a single, acknowledged centre’ (p. 29). Galison argues that unity of science movements have, since the 19th century, taken place alongside and have been intertwined with political movements – the unification of physiology with physics ‘for a unified German nation’ in the mid- to late 1800s, the links between international politics and scientific unification leading up to the Second World War, and the pyramidal vision of the unity of science through physics during the Cold War. Scientific visions of unification are, then, necessarily tied into political ambitions.

The unifying and integrating visions of science were put forward before the start of the HBP as attempts to mimic past perceived successes, such as CERN or the Human Genome Project. But the encounters within the HBP that I have described show us that unification is perhaps no longer a possibility or even a vision to strive for. And through these narratives, Europe itself is posited as a problem – the tension between unification and pluralism serving as both metaphor for and backdrop to contestations over how scientific communities should be bringing data together in European ‘big science’ projects.

Europe is seemingly always on the brink of disintegration, always at risk of falling apart. The President of the Commission stated in late 2016, following the United Kingdom’s vote to withdraw from the EU, that the EU is ‘in an existential crisis . . . never before have I seen so much fragmentation, and so little commonality in our Union . . . we need a vision for the long term . . .we can be united even though we are diverse’ (Juncker, 2016). That is the very dialectic of unificatory and pluralistic visions – without the integral risk of things falling apart, there is no reason to come together. For the HBP and the EU itself, there is an inherent tension in the desire for unity, for things to come together and the desire – or fear – of things dispersing and multiplying. This is the very problem scientists, engineers, administrators and EC officials are grappling with – how to create disruptive, scientific revolutions while maintaining the pluralism demanded by the same ‘neuroscience community’ they seek to unify.

If Europe multiply imagines and builds its community through its science and technology projects, as Sheila Jasanoff suggests in response to Benedict Anderson (2006), then it is also through its science and technology projects – such as the HBP – that the EC faces its existential conundrum: How to unify while retaining diversity? And what kind of a community should Europe, and European neuroscience, be – unified or pluralistic? Within these spaces, maybe there is an opportunity to experiment with how the neurosciences can productively engage with multiple models of multiple brains and their multiple bodies and worlds. Instead of collapsing into the centre of the HBP, as we saw in the introduction, what would happen if the little bits of white light moved around, collided, merging and dividing? What could this multiple vision of brains modelling look like?

Author's note

Tara Mahfoud is now affiliated with University of Essex, UK.

Acknowledgements

The author would like to thank Christine Aicardi, Saheli Datta Burton, Youjung Shin, and Inga Ulnicane for their comments to earlier drafts of this article. Thanks are also due to Carlo Caduff, Joe Dumit, Guntars Ermansons, Philipp Haueis, Sabina Leonelli, Sam McLean, Johanna Pokorny, Tobias Rees, Nikolas Rose, and Abin Thomas for conversations that helped develop many of the ideas in this article. Parts of this work were presented at the 2016 and 2018 American Anthropological Association meetings – thanks to Yuliya Grinberg for organising the panels on 'Data Friction' and 'Searching for Community in Digital Data Discourse', and to Dawn Nafus and Tom Boellstorff for their comments. The final revisions for this article were completed while the author was a Visiting Research Fellow in the Program on Science, Technology and Society at Harvard University, where the author also presented a version of this article. Thanks to all the fellows for their feedback and suggestions and, in particular, to Sheila Jasanoff and Kasper Schiolin. The author is also grateful to the editors Astrid Mager and Christian Katzenbach for their patience, and two anonymous reviewers for their generous engagement and thoughtful, constructive suggestions for revision.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship and/or publication of this article: This work was funded in part by the King's College London Annual Fund Studentship Award, and the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 720270. The information and views set out in this article are those of the author and do not necessarily reflect the official opinion of the European Union or the Human Brain Project. Neither the European Union institutions and bodies nor any person acting on their behalf may be held responsible for the use which may be made of the information contained therein.

ORCID iD

Tara Mahfoud https://orcid.org/0000-0002-8270-9202

Notes

1. For a more detailed analysis of the representational and prescriptive dimensions of models in science, see Mahfoud, McLean and Rose (2017), Ankeny (2000), Cartwright (1997), Keller (2000) and Langlitz (2017).
2. See Haueis (2016) for a history of the cortical column since the 1950s, and Horton and Adams (2005) who argue that the cortical column has no distinguishable or specific function.
3. See Chris Eliasmith and Trujillo (2014), Maria Serban (2017) and Tom Stafford (2009) for more detailed analyses of different modelling approaches in the neurosciences.
4. The reporting on the European Commission representatives' statements is based on notes taken during the meeting, and were not transcribed from audio recordings. Therefore, these statements reflect the author's understanding of what was said at the meeting.

References

ACM (n.d.) About ACM Gordon Bell prize. Available at: http://awards.acm.org/bell (accessed 24 September 2017).

Adee S (2009) Cat fight brews over cat brain. Available at: http://spectrum.ieee.org/tech-talk/semiconductors/devices/blue-brain-project-leader-angry-about-cat-brain (accessed 4 January 2017).

Aicardi C, Datta S, Mahfoud T, et al. (2017) *Dual use in neuroscience and neurotechnology*. Scoping Report, 1, April. London: Foresight Lab, King's College London.

Anderson B (2006) *Imagined Communities: Reflections on the Origin and Spread of Nationalism*. London; New York: Verso.

Ankeny RA (2000) Fashioning descriptive models in biology: of worms and wiring diagrams. *Philosophy of Science* 67(September): S260–S272. Available at: https://doi.org/10.1086/392824

Borup M, Brown N, Konrad K, et al. (2006) The sociology of expectations in science and technology. *Technology Analysis & Strategic Management* 18(3–4): 285–298.

Brodkin J (2009) IBM cat brain simulation dismissed as 'hoax' by rival scientist. Available at: https://www.networkworld.com/article/2237806/data-center/ibm-cat-brain-simulation-dismissed-as–hoax–by-rival-scientist.html (accessed 24 September 2017).

Brown A (2013) The BRAIN initiative: surviving the data deluge. Available at: https://www.kavlifoundation.org/science-spotlights/brain-initiative-surviving-data-deluge (accessed 31 January 2020).

Brown N and Michael M (2003) A sociology of expectations: retrospecting prospects and prospecting retrospects. *Technology Analysis & Strategic Management* 15(1): 3–18.

Bruder J (2017) Infrastructural intelligence: contemporary entanglements between neuroscience and AI. In: Mahfoud T, McLean S and Rose N (eds) *Vital Models: The Making and Use of Models in the Brain Sciences*. Progress in Brain Research, vol. 233. Elsevier, pp. 101–128. Available at: http://www.sciencedirect.com/science/article/pii/S0079612317300547

Cartwright N (1997) Models: the blueprints for laws. *Philosophy of Science* 64(December): S292–S303. Available at: https://doi.org/10.1086/392608

Choudhury S and Salby J (2016) *Critical Neuroscience: A Handbook of the Social and Cultural Contexts of Neuroscience*. Chichester: John Wiley & Sons.

De Genova N (2016) The 'European' question: migration, race, and post-coloniality in 'Europe'. In: Amelina A, Horvath K, and Meeus B (eds) *An Anthology of Migration and Social Transformation: European Perspectives* (IMISCOE Research Series). Cham: Springer International Publishing, pp. 343–356.

Dumit J (2016) The fragile unity of neuroscience. In: De Vos J and Pluth E (eds) *Neuroscience and Critique: Exploring the Limits of the Neurological Turn*. New York: Routledge, pp. 223–229.

Eliasmith C and Trujillo O (2014) The use and abuse of large-scale brain models. *Current Opinion in Neurobiology* 25(April): 1–6. Available at: https://doi.org/10.1016/j.conb.2013.09.009

Enserink M (2014) European neuroscientists revolt against the E.U'.s human brain project. *Science/AAAS*. Available at: https://www.sciencemag.org/news/2014/07/updated-european-neuroscientists-revolt-against-eus-human-brain-project#

European Commission (2008) A European economic recovery plan, 26 November, Brussels. Available at: http://ec.europa.eu/economy_finance/publications/pages/publication13504_en.pdf (accessed 4 January 2017).

European Commission (2009) Moving the ICT frontiers: a strategy for research on future and emerging technologies in Europe, 20 April, Brussels. Available at: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52009DC0184

European Commission (2010) Europe 2020: a European strategy for smart, sustainable and inclusive growth. Available at: http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20

BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf (accessed 4 January 2017).
European Commission (2013) FET flagships. Available at: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/fet-flagships (accessed 10 February 2020).
European Commission (2019) Human Brain Project (HBP) flagship. Available at: https://ec.europa.eu/digital-single-market/en/human-brain-project (accessed 10 February 2020).
Frégnac Y and Laurent G (2014) Neuroscience: where is the brain in the human brain project? *Nature News* 513(7516): 27.
Galison P (2016) Meanings of scientific unity: the law, the orchestra, the pyramid, quilt, and ring. In: Kamminga H and Somsen G (eds) *Pursuing the Unity of Science: Ideology and Scientific Practice from the Great War to the Cold War*. Burlington, VT: Ashgate Publishing, pp. 12–29.
Galison P and Stump DJ (1996) *The Disunity of Science: Boundaries, Contexts, and Power*. Stanford, CA: Stanford University Press.
Griggs J (2013) One minute with Henry Markram: why we're building a €1 billion model of a human brain. *New Scientist*, 6 February. Available at: http://www.newscientist.com/article/mg21729036.800-why-were-building-a-1-billion-model-of-a-human-brain.html#.VO5GJcYfP-C (accessed 25 February 2015).
Haueis P (2016) The life of the cortical column: opening the domain of functional architecture of the cortex (1955–1981). *History and Philosophy of the Life Sciences* 38(3): 2.
Haueis P and Slaby J (2016) Brain in the shell: assessing the stakes and the transformative potential of the human brain project. In: De Vos J and Pluth E (eds) *Neuroscience and Critique: Exploring the Limits of the Neurological Turn*. New York: Routledge, pp. 117–140.
Hedgecoe A and Martin P (2003) The drugs don't work: expectations and the shaping of pharmacogenetics. *Social Studies of Science* 33(3): 327–364.
Hilgartner S (2015) Capturing the imaginary : vanguards, visions and the synthetic biology revolution Stephen Hilgartner. In: Hilgartner S, Miller C and Hagendijk R (eds) *Science and Democracy*. London: Routledge, pp. 33–55. Available at: https://www.taylorfrancis.com/ (accessed 20 August 2019).
Horton JC and Adams DL (2005) The cortical column: a structure without a function. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 360(1456): 837–862.
Jasanoff S (2005) *Designs on Nature: Science and Democracy in Europe and the United States*. Princeton, NJ; Oxford: Princeton University Press.
Jasanoff S (2015) Future imperfect: science, technology and the imaginations of modernity. In: Jasanoff S and Kim S-H (eds) *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*. Chicago, IL; London: University of California Press, pp. 1–33.
Jasanoff S and Kim S-H (2009) Containing the atom: sociotechnical imaginaries and nuclear power in the United States and South Korea. *Minerva* 47(2): 119–146.
Jasanoff S and Kim S-H (eds) (2015) *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*. Chicago, IL; London: University of Chicago Press. Available at: http://www.press.uchicago.edu/ucp/books/book/chicago/D/bo20836025.html (accessed 24 September 2017).
Juncker JC (2016) State of the Union Address 2016: Towards a better Europe - a Europe that protects, empowers and defends, 14 September, Strasbourg. Available at: https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_16_3043
Keller EF (2000) Models of and models for: theory and practice in contemporary biology. *Philosophy of Science* 67(Suppl.). Proceedings of the 1998 Biennial Meetings of the Philosophy of Science Association. Part II: Symposia Papers (September), pp. S72–S86.

Krige J (2006) *American Hegemony and the Postwar Reconstruction of Science in Europe*. Cambridge, MA; London: MIT Press. Available at: https://mitpress.mit.edu/books/american-hegemony-and-postwar-reconstruction-science-europe (accessed 18 March 2019).

Langlitz N (2017) Opaque models: using drugs and dreams to explore the neurobiological basis of mental phenomena. In: Mahfoud T, McLean S and Rose N (eds) *Vital Models: The Making and Use of Models in the Brain Sciences*. Progress in Brain Research, vol. 233. Elsevier, pp. 53–72. Available at: https://doi.org/10.1016/bs.pbr.2017.03.002

Mager A (2017) Search engine imaginary: visions and values in the co-production of search technology and Europe. *Social Studies of Science* 47(2): 240–262.

Mahfoud T, McLean S and Rose N (eds) (2017) *Vital Models: The Making and Use of Models in the Brain Sciences*. Progress in Brain Research, vol. 233. Elsevier, pp. xi–xx. Available at: https://doi.org/10.1016/S0079-6123(17)30098-5

Misa TJ and Schot J (2005) Inventing Europe: technology and the hidden integration of Europe. *History and Technology* 21(1): 1–19.

Modic D and Feldman MP (2017) Mapping the human brain: comparing the US and EU grand challenges. *Science and Public Policy* 44(3): 440–449.

neurofuture.eu (2014) Open message to the European Commission concerning the Human Brain Project. Available at: https://www.neurofuture.eu/ (accessed 1 February 2020).

Novas C (2006) The political economy of hope: patients' organizations, science and biovalue. *Biosocieties* 1(3): 289–305.

Obama B (2013) Remarks by the President on the BRAIN initiative and American Innovation. Available at: https://obamawhitehouse.archives.gov/the-press-office/2013/04/02/remarks-president-brain-initiative-and-american-innovation (accessed 4 January 2017).

Panese F (2015) Cerveau et imaginaire sociotechnique: le Human Brain Project entre science et politique. In: Audetat M (ed.) *Sciences Et Technologies Émergentes. Pourquoi Tant De Promesses?* Paris: Les Éditions Hermann, pp. 165–193.

Paxson H and Helmreich S (2014) The perils and promises of microbial abundance: novel natures and model ecosystems, from artisanal cheese to alien seas. *Social Studies of Science* 44(2): 165–193.

Prem E, Lasser S and Zergoi T (2010) *FET Flagships Recommendations for Implementation Summary Report*. Vienna: eutema Technology Management GmbH (eutema), Austrian Research Promotion Agency (FFG) in cooperation with the American Association for the Advancement of Science (AAAS). Available at: https://op.europa.eu/en/publication-detail/-/publication/508c87f5-5893-4711-b7d2-eb07539d79b7 (accessed 11 January 2017).

Rajan KS (2006). *Biocapital: The Constitution of Postgenomic Life*. Durham, NC: Duke University Press.

Rose N and Abi-Rached J (2013) *Neuro: The New Brain Sciences and the Management of the Mind*. Princeton, NJ; Oxford: Princeton University Press.

Selin C (2008) The sociology of the future: tracing stories of technology and time. *Sociology Compass* 2(6): 1878–1895.

Serban M (2017) Learning from large-scale neural simulations. In: Mahfoud T, McLean S and Rose N (eds) *Vital Models: The Making and Use of Models in the Brain Sciences*. Progress in Brain Research, vol. 233. Elsevier, pp. 129–148. Available at: https://doi.org/10.1016/bs.pbr.2017.05.004

Shachtman N (2009) Darpa's simulated cat brain project a 'Scam': top scientist. *WIRED*, 23 November. Available at: https://www.wired.com/2009/11/darpas-simulated-cat-brain-project-a-scam-top-neuroscientist/ (accessed 24 September 2017).

Shore C (2013) *Building Europe : The Cultural Politics of European Integration*. London: Routledge. Available at: https://www.taylorfrancis.com/books/9781315008462 (accessed 11 February 2020).

Stafford T (2009) What use are computational models of cognitive processes? In: Mayor J, Ruh N and Plunkett K (eds) *Connectionist Models of Behaviour and Cognition II: Proceedings of the 11th Neural Computation and Psychology Workshop*. World Scientific Publishing, pp. 265–274. Available at: http://tomstafford.staff.shef.ac.uk/docs/stafford09_ncpw.pdf

Star SL (1989) Chapter 2: the structure of ill-structured solutions: boundary objects and heterogeneous distributed problem solving. In: Gasser L and Huhns MN (eds) *Distributed Artificial Intelligence*. San Francisco, CA: Morgan Kaufmann, pp. 37–54. Available at: http://www.sciencedirect.com/science/article/pii/B978155860092850006X

Star SL and Griesemer JR (1989) Institutional ecology, 'Translations' and boundary objects: amateurs and professionals in Berkeley's Museum of vertebrate zoology, 1907-39. *Social Studies of Science* 19(3): 387–420.

Strickland E (2014) Can computing keep up with the neuroscience data deluge? Available at: https://spectrum.ieee.org/tech-talk/biomedical/imaging/can-computing-keep-up-with-the-neuroscience-data-deluge (accessed 31 January 2020).

Taussig K-S, Hoeyer K and Helmreich S (2013) The anthropology of potentiality in biomedicine: an introduction to supplement 7. *Current Anthropology* 54(S7): S3–S14.

Tutton R (2011) Promising pessimism: reading the futures to be avoided in biotech. *Social Studies of Science* 41(3): 411–429.

Ulnicane I (2016) Research and innovation as sources of renewed growth? EU policy responses to the crisis. *Journal of European Integration* 38(3): 327–341.

Ulnicane I (2020) Ever-changing Big Science and Research Infrastructures: Evolving EU policy. In: Cramer KC and Hallonsten O (eds) *Big Science and Research Infrastructures in Europe*. Edward Elgar Publishing.

Van Lente H (2000) Forceful futures: from promise to requirement. In: Brown N, Rappert B and Webster A (eds) *Contested Futures. A Sociology of Prospective Techno-Science*. Aldershot: Ashgate, pp. 43–64.

Vidal F (2009) Brainhood, anthropological figure of modernity. *History of the Human Sciences* 22(1): 5–36.

Waldrop MM (2012) Computer modelling: brain in a box. *Nature* 482(7386): 456–458.

Author biography

Tara Mahfoud is a lecturer in the Department of Sociology at the University of Essex, and was previously a Research Associate at the Department of Global Health and Social Medicine, King's College London.