Knowledge and Normativity: A matrix of disciplines and practices

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Abstract

This chapter introduces the matrix approach as a method of studying the life sciences. It builds on insights from the philosophy and sociology of science over the past decades against which it is laid out. The contribution of this new approach is that it reconfigures the life sciences as multidisciplinary and multi-institutional societal projects. The case study of stem cell research shows that one cannot separate internal and external, that is epistemic, social, ethical, and political factors affecting the development of a life science. The matrix approach allows for the examination of this complex and dynamic web of interests and societal practices and highlights the important role of legal, normative, technical and political conditions and activities in making the science work in specific ways. Life sciences operate in a matrix of diverse societal intersections and spheres of dominance. The approach especially reframes the role and scope of the humanities and social sciences. It prepares the ground for a self-critical reflection in bioethics, social sciences, and philosophy. These disciplines do not just analyse stem cell research as an object, from a distance, they co-configure it and shape its contemporary gestalt and practices.

1) Introduction

The matrix approach is a new method for investigating the developing life sciences in the context of societal demands and practices. It configures the social practices and institutions that engage with the life sciences as constitutive factors and parts of said development. The matrix approach builds on theories in the philosophy, history and sociology of science, and aims to enhance critical self-reflexivity in the life sciences as well as in the social sciences and humanities. The case study is stem cell research, which was developed from the early 2000s and is entangled with more and more social and institutional contexts as well as academic arenas.

After some situating remarks, we begin to discuss the matrix approach by first distinguishing it from the conventional narrations of the breakthrough myth in science journals and institutions. We then discuss how the history of science has increasingly included socio-political and normative dimensions into its analyses of how science advances, changes, and the reasons for this – pointing out that the normative ethical dimension is still being under-represented in concrete science studies. We then question whether stem cell science can be understood as a unified field due to the obscure object that lends it its name, or due to the aim of advancing new clinical treatments that is supposedly shared by the partaking life science disciplines. The literature has shown it to be the case that, and why, these perspectives are falling short, and the matrix approach offers the alternative of a situated approach to life sciences in and as social practice. The chapter closes with a brief overview of the segments in the stem cell matrix which the individual book chapters bring out.

2) The Matrix Approach

Our method is based on problematization. Problematization means putting the issue in problem form and identifying it as a problem for politics (cf. Foucault, 1997, 114). It follows Paul Rabinow, who suggested not to take descriptions of a current 'situation as given' (cf. Rabinow, 2003, 15ff.), referring to Michel Foucault's suggestion to examine discourses using multiple methods and perspectives. Critical normative interactions with stem cell research, undertaken in philosophical epistemology and ethics as well as in empirical Science and Technology Studies (STS), ask and give accounts of both the problematizations that inform which 'facts' about a science are presumed as given and not spelled out or questioned, as well as focussing the analysis on the power relations in and around stem cell research.

Terminologically, we chose the matrix term not least as a nod to Thomas Kuhn's 'disciplinary matrix', defined in the postscript to *The Structure of Scientific Revolutions* as: 'the entire constellation of beliefs, values, techniques, and so on shared by the members of a given community' (Kuhn, 2012, 174). Like Kuhn, we explore the constitutional conditions for the development, contents, and constellations of science. But we move beyond looking at science as if it developed largely 'insulated' from society (Kuhn, 2012, 163). We widen the term to include analyses of the power relations, with the socio-economic, political, cultural, and epistemic dynamics and forces in stem cell research discourses and practices.

Political governance, funding policies, and organizations of research are comparatively transparent societal conditions shaping science. Furthermore, public funding arguably entails a responsibility put upon science with the aim of benefitting the public good (e.g. European Commission, 2009). The social, economic, and intellectual conditions of science are, we propose, not additions on top of the ‘real’ intra-scientific developments. They are an integral part of scientific development. In stem cell research this is particularly readily apparent, given the public debates about the ethical acceptability of hESC (human embryonic stem cell) research still in force in many countries, and the legal and regulatory limitations established to restrict conduct of stem cell clinical trials (Hauskeller, 2017).

Insights articulated in the philosophy and sociology of science followed and expanded on Kuhn, such as the Mode 2 concept by Helga Nowotny and colleagues. Mode 2 conceptualizes science as inextricably interwoven with past and current social practices as well as future plans and expectations, as a complex collaborative endeavour that generates knowledge in the context of application. ‘Science could no longer be demarcated from the “others” of society, culture and more arguably economy’ (Nowotny et al., 2001, 1). Including these dimensions in the study of a science better captures the dynamics we want to highlight, opening up reflective and constructive studies of life science developments. What is missing is a similar inclusivity and subjection of the social sciences and humanities to said analysis of, for example, stem cell research.

The common metaphor ‘field’ as used widely in the history and philosophy of science, suggests that a research area can be identified through reference to its object or method. The field metaphor suggests that a distinguishable science develops in a logic of its own, driven largely by immanent factors and with definable boundaries. Yet, the conduct of research is cross-sectional in and between the life sciences, humanities, and social sciences, not confining itself to integrate into a neat order.

Stem cell science represents itself as unified by the object from which it gets its name: stem cells. *Stem cells*, however, embody an obscure and transient empirical object. Plus, stem cell research has commonalities with many other life sciences in its methods and social embeddedness. Concerning its methods, stem cell research is not a distinct 'field' but a cross-section relating to various disciplines with shared routines and knowledge. Conflicting and mutually re-enforcing engagements between many pre-existing or accompanying developments in social and scientific practices and institutions are often not reflected in the narratives scientists and journals use to explain science. We problematize the marginalization of these influences in order to portray stem cell research as shaped in and by the socio-political and ethical conflicts in society.

The matrix does not require the notion of a field or similar metaphors. It emphasizes that disciplines, institutions, practices, and interests that contribute to the life sciences are shared across life science specialisms. For example, particular applications as well as moral norms and laws apply to genetics, reproductive medicine and stem cell research, which among one another exchange materials and build on one another's laboratory techniques and objects. The matrix is a discontinuous, multi-institutional and multi-disciplinary space of knowledges, interests, norms, and practices. Social, economic, and other conditions are not weighted as secondary to developments in the laboratory and clinic. They are inextricably part of the stem cell science and its objectives, as elements of its matrix. Ethics and philosophy, historical narratives and journalistic accounts, too, are constitutive and representative parts of stem cell science – they are not external to it.

A comprehensive whole of stem cell research cannot be captured because of these open boundaries and the many connections to other practices. The matrix approach opens up and includes interconnecting partial perspectives that can be held to account for their viewpoint and methods. They contribute situated knowledges (Haraway, 1988) to the stem cell discourse, for empirically informed and conceptually reflective ethics and philosophy of science.

The advantage of the matrix approach is that it can conceptualize the epistemic convergence and divergence that characterize recent life sciences (Andersen, 2016). It can recognize and attend to the tensions between plural norms and values in the moral, epistemological, and economic sense (cf. Rajan, 2006; Gottweis, Salter and Waldby, 2009). In the matrix we find multiple and changing loci of power and gravity. It is in flux, a multi-intersectional web of ways of knowing, doing, laboratory and governance technologies, and modes of evaluation.

The understanding of a problem affects and is affected by normative debates about different kinds of values enmeshed in it. If the object, in this case the stem cell, is itself overdetermined with conflicting value judgments and contentious in society, then commentary and judgement cannot style themselves as from the outside or the margins. Ethicists, too, often take positions implicitly, when and through choosing what they accept to be facts and decide to emphasize, thus privileging one perspective over others. Because the social science, humanities, and media debates also influence the perception and understanding of stem cell research in wider society and even to some extent in science itself, it matters that they are critically aware and reflective in their interactions and judgements. In the matrix, normativity and ethics enter at different points and in diverse ways that normative ethics especially must reflect, in view of its own role. An examination of the multiple factors shaping the development of stem cell research also has a heuristic function for ethics. Many ethical issues in the broadest sense fall into the chasm between different disciplines and tend to be overlooked by common bioethical approaches. Moral norms and values, often implicit in acts that seem not to discuss normativities beyond those directly at stake, reach further and actually build on a whole set of societal premises and conditions as well as material conditions for scientific practice. Complex implicit and explicit values that create conditions for laboratory research or legal discourse, for example, are mobilized and weighted. If certain forms of stem cell research cannot actually come into the clinic via the approved channels of scientific medicine because regulatory hurdles and conditions have aligned to form major obstacles, then research pathways dry up –, whilst the unproven use flourishes in private hospitals (Tanner et al., in this volume; Hauskeller, 2018).

Building on critiques of bioethics (Haimes, 2002; Hedgecoe, 2004; De Vries et al., 2007), the matrix approach provides a reflexive framework for responsible ethical and normative examinations of the life sciences. It can also encompass analyses of their roles in societal power and knowledge dynamics. To advance ethical reflection that can keep pace with the complexity of the tasks, the ethics within and relating to stem cell and adjacent research needs to be considered also in the context of the socioeconomic interests, political influences, value orders, and in the epistemological configurations organizing it.

In what follows we first discuss different ways of representing stem cell science in different disciplines and discourses and examine the implications of these representations for the ongoing critical discussions and ethical reflections. This section develops the matrix perspective by drawing out how it differs from existing approaches of making sense of stem cell research. In step two, we explain briefly how this perspective is illustrated across the book chapters, most of which report findings from analyses of specific practices in stem cell research, some from within, most from without the laboratory.

The chapters in this volume present different aspects within the matrix, some accepting or challenging directly the conventional definition of stem cell research as a field, others studying how the practices employed and produced in this research are adopted, reflected, and used by different professional or academic groups such as lawyers, theologians, patients, or economists. In the matrix of diverse, intersecting elements, biology and medicine are prominent, but they do not feature as the mutually interdependent but epistemically and socially independent producers of the gestalt and trajectory of the research and its uses. What we hope to show is that the conditions in and responses from different parts of society to that research have become constituent parts of its specific configurations and practices in different research projects, different laboratories and clinics, and in different countries. We believe that this characterizes the life sciences more generally, but argue for this perspective especially in relation to stem cell research.

3) Different Approaches to Conceptualizing the Life Sciences

In what follows we discuss why the matrix approach rejects forms of understanding and the presentation of stem cell research in idealized, simplistic ways, especially in what we call *origin narratives* – and how the approach builds on and integrates insights from historical accounts of how stem cell research came about, as well as philosophical and STS approaches.

3.1) 'Breakthrough' myths

A conventional narrative about stem cell research, widely found in articles, text books, and online (Vogel, 1999) goes something like this: stem cell research emerged as a distinct domain of bio- and medical science triggered by a scientific 'breakthrough'. Usually this past event is marked with reference to a pair of articles reporting the cultivation of human stem cell lines in the laboratory (Thomson et al., 1998; Shamblott et al., 1998). The new kind of cell lines, a contemporary research object in the laboratory derived from early embryos *in vitro* using refined cell culture techniques, attracted researchers in different existing specialisms, who began to work on such human cell lines. Diverse research agendas and specialisms regrouped and rearticulated their aims and methods increasingly using the new denominator stem cell research. Twenty years after the first cultivation of hESC lines, stem cell research is a fast-paced field with a large economic turnover and, in some countries, big private markets for stem cell treatments that do not conform to established standards of safety and efficacy (Petersen et al., 2017). Of the many cell therapies envisioned, only a few have been licensed, although numerous are at different stages of clinical trial (Trounson and DeWitt, 2016). A range of new techniques and biological insights into the properties of cells and tissues *in vitro* has been created, informing regenerative medicine but also reproductive and organ transplantation medicine (Hauskeller and Weber, 2011; Zenke, Marx-Stölting and Schickl, 2018).

Such a narrative selects, orders, and interprets one or several origin events to create a coherent birth story for a new endeavour in the sciences. It suggests progress, major successes owed to identifiable specific discoveries, and reaffirms the importance of that new ‘field’. It also firmly places the evolution of this ‘field’ as an inherent part of the dynamics within science – as a product of science.

Scientific practices and foci are in flux. Elements and techniques overlap and researchers transition from one into another (Powell et al., 2007). Objects and technologies as well as physical infrastructure and laboratory space are often shared. One research project can be framed as a contribution to several fields, for example, establishing markers for hematopoietic properties can be achieved through genomics, stem cell or cancer research. These metaphoric ‘fields’ are not separated by hedges nor is ownership registered. Between the zones of overlap, crossover and similar interests, there is also competition. A team may apply for research funding from different dedicated streams and results may be published in a range of specialist journals with different aspects of the method and findings highlighted. Specialisms emerge and regroup, coalescing around new concepts or practices. This fluidity allows the regular celebration of advances and ‘breakthroughs’, which in turn feeds the expectation that the life sciences are moving forward. Reasons to produce such rationales – apart from self-celebration and reaffirmation of status – are pragmatic, especially in light of the pressures to defend contested research in public and attract the required large amounts of public and private research sponsorship.

The breakthrough narrative is ideological more than explanatory. It creates the myth of both the extraordinary scientist and dramatic immanent change. The long term labour across many laboratories and teams upon which ‘breakthroughs’ rest, as well as the societal contexts that shape science in practice, are not taken into account. Kuhn (1962) and Foucault (1970) have, in different ways, analysed broader conceptual shifts in how science operates, such as paradigm changes, or the order of things it studies. Ludwik Fleck has illustrated how power and community relations among teams affect what counts as proper science (Fleck, 1935). In each of these classic works science is a social enterprise, in which individuals who apply unconventional perspectives with inconvenient implications, if accepted, tend to be ignored or marginalized rather than awarded laurels, at least for a while. The narration of origin events creating stem cell research in particular has been criticized in the history, and social studies, of science (Geesink, Prainsack and Franklin, 2008). The matrix approach builds on these critiques – moreover though, it problematizes the idea that science is driven, if not solely then mostly, by science *per se* (cf. Collins and Pinch, 1998). We develop these points in the next two sections.

3.2) Expanding multi-strand history narratives

History of science studies often situate the different disciplinary and knowledge elements of a contemporary 'field' and explore their genealogy. For example, an overview on the notion of *stem cell* in a science journal concludes,

> [in] summary, the early uses of the term stem cell were made in the late 19th century in the context of fundamental questions in embryology: the continuity of the germ-plasm and the origin of the blood system. The demonstration of the existence of hematopoietic stem cells … established these cells as the prototypical stem cells: cells capable of proliferating nearly indefinitely (self-renewal) and of giving rise to specialized cells (differentiation).
> (Ramalho-Santos and Willenbring, 2007, 37)

It highlights the point that stem cell research absorbs different strands of nineteenth and twentieth century biological and medical research, depending on whether the word, the concept, or the laboratory identification of such cells are foregrounded. There is not one grand discovery. The single breakthrough from 1998 appears as just one of many elements in a complex research landscape.

Taking into account histories not of a particular disease or cell type but multi-disciplinary genealogies contributing to stem cell research, the historical analyses show that no single definitive origin or founding event can be identified. Whereas the name and idea of a stem cell had been around since the late nineteenth century, the laboratory creation of the first embryonic stem cell lines, from mice, happened in 1981 and has been credited to two British teams (Evans and Kauffmann, 1981; Martin, 1981). In 2007, after hESC lines had been created, the prominent Nobel Committee recognized the importance of this earlier work with an award for Martin Evans (Nobel Committee, 2007). Although it undermines birth event myths, the common type of account that lists a chain of individual discoveries and discoverers usually pays insufficient attention to extra-scientific events and conditions that drive and shape science.

Broader analyses have been provided by historians of science and medicine on individual elements such as the histories of embryology, genetics and heredity, or cancer research. Research into first heredity, then conceptually narrowed down to genetics, now wider again in the concept of genomics in tandem with cell biology and embryology, are all very prominent in stem cell research and highlight the latter's close entwinement with the former. Further historical studies of basic and applied research draw out a web of contributing knowledge practices that cover both epistemological and political quests, for example in Helga Satzinger's analysis of the role of political ideologies, racism, and sexism in the status and promotion of different concepts informing genetics and hormone research (2014). Concerning stem cell research directly, Beatrix Rubin (2008) and Holger Maehle (2011) among others, examined it in relation to radiation and cancer research. Understanding the response of the human organism to radiation and its often deadly effects became politically imperative from the first half of the twentieth century onwards. Scientific experimentation, medical use, and especially the use of atomic bombs created an imperative to find ways of helping those affected or at risk. From the 1950s, medical research with cultures of stem cells from bone marrow and tumours began to find ways of offsetting radiation damage, incubating the development of radiotherapy combined with the reconstitution of their blood and immune systems for some cancers (Rubin, 2008; Maehle, 2011).

The matrix approach differs from history of science narratives in its emphasis on the mutual interdependence and influence of diverse and contradictory societal and scientific developments in addition to multi-strand and non-linear scientific and political events changing sciencescapes. Stem cell research as a 'field' was politically and socially promoted, albeit as a fusion of diverse disciplinary techniques and concepts around an object within the sciences. Its contemporary gestalt has been influenced by decisions and events since the late 2000s. Those include choices and directed collaborations across political, social and commercial sectors, in the hope that this focus and coalescence of biomedical sciences would deliver societal benefits, a viewpoint expressed for instance in UK policy papers in the early 2000s (Hauskeller, 2004). The 1998 'breakthrough' may represent both the technical fine-tuning of methods of cultivating and altering embryonic cells, as well as a convenient rhetorical vantage point to make a new 'field'. Terminologically, however, it seems that instead of disciplines (biology, medicine), institutions (clinic, laboratory), or techniques (radiation, transfusion and cell transplantation, developmental microbiology), the object was chosen as identifier: the (human embryonic) stem cell. The myth of the field formation around an object is established in the naming routines in medicine, e.g. cardiology, embryology or haematology, and has been adopted in the life sciences. Also in stem cell research, an object-based denominator has gained recognition and traction in academic and public discourses, so that historians, philosophers, and ethicists rarely critique the suggested unity of stem cell science.

3.3) Why 'stem cells' are not field-forming objects

What stem cells *are* is a controversial subject among philosophers and stem cell scientists alike. The special characteristics of a stem cell as commonly defined by scientists, are a high proliferation rate and the capacity to divide into both cells such as itself and more differentiated daughter cells. But whether such are the properties of special cells that are naturally and continually present, often dormant, in the organism – or whether they are states of cells that many cells can potentially enter into and leave again – is matter of a long-standing controversy. Put differently, stem cell capacities may be intrinsic features of identifiable cells or rather a transient feature of many cells, a way of being adopted in response to conditions in the cell environment. How stem cells are conceptualized has implications for the feasibility of advancing therapeutic strategies, as has recently been discussed by Lucy Laplane (2016) with the example of cancer stem cells. She demonstrates a spectrum of possible metaphysical background assumptions and the relevance of clarifying these assumptions for therapeutic application. For now, consensus and clarity about stem cell concepts are lacking not only on the ontological level. The empirical concepts implicitly or explicitly guiding practitioners' identification and characterization of stem cells are manifold and not unified in an overarching concept.

The huge variety of different stem cell types in different species, developmental stages, tissues and cell cultures, raises the issue of clear and unambiguous criteria for distinguishing stem cells from other cell types. So far, at least, specific features measurable in all but only stem cells have not been proved experimentally. Three attempts at identifying a common molecular signature of stem cells in the early 2000s failed (cf. Laplane, 2016, 115–20). This lack of a reliable characteristic of stem cells could have consequences for the unity of the 'field' of research: '[w]ithout a general "signature" of traits shared by stem cells across different environments, the field of stem cell biology seems fragmented, unified only by a common label for disparate objects of study' (Fagan, 2013, 7).

Melinda Fagan argues that shared among stem cell researchers are the basic experimental steps of extracting cells from an organismal source and determining their properties, but that knowledge about stem cells is always bound to specific experimental designs and refers not to any 'natural stem cell' but to artificial entities in specific laboratory contexts (Fagan, 2013, 68). This 'experimental relativity' (Fagan, in this volume) implies that extrapolation of experimental results is problematic and that the influence of the cell culture conditions on the measured features of cells is indeterminable: 'the investigation might be forcing the stem-cell phenotype on the population being studied' (Zipori, 2004, 876). Other epistemic problems arise from the stem cell concept itself and the basic structure of stem cell experiments such as the 'evidential gap between experimental data and hypotheses about stem cell capacities' (Fagan, in this volume).

Far from providing an empirical and unambiguous basis for the formation of a new research field, thus far 'stem cell' is a messy concept referring to not-well-defined objects with fuzzy boundaries. That which is available is only a patchwork of highly context-specific knowledge about different groups of cells that are mostly research and laboratory artefacts. The matrix approach is distinct from many traditional forms of social studies of science that ‘tended toward the dissolution of all distinctive boundaries demarcating the sciences’ (Keller, 1992, 3). In accordance with Evelyn Keller’s ‘middle-of-the-road-position’ (ibid.), regarding stem cell research as a social practice does not mean that inner-scientific dynamics and epistemic commitments do not merit close scrutiny. The models and explanatory standards accepted within a research community, as well as technological and further conditions that shape the course of science are part of matrix studies. History and philosophy of science are traditionally bound to historical biographies of scientific objects (Arabatzis, 2006) and to models and techniques (Chang, 2007) or research groups (Kohler, 1994). Rita Temmerman has demonstrated how terminological conventions bury multi-layered intersections of conceptualization, also in the life sciences (Temmerman, 2000, 103). Moreover, Ann-Sophie Barwich has argued that once philosophy and history of science look at the latter as a complex of changing material practices, instruments, discourses, etc., an extension is needed of the meaning of terminology that refers to concepts, models, objects, and discourses in the sciences (Barwich, 2013). The matrix approach addresses these shortcomings, integrating technical and conceptual details as analysed by Fagan and Laplane, with knowledge of the web of social, political, economic, and ideological factors and institutions.

3.4. Why methods and clinical goals do not distinguish a stem cell ‘field’

Notwithstanding the outlined epistemological problems, the stem cell lends a name to a diverse and sprawling multitude of research endeavours. The spread of scientific pathways taken, and the researchers involved, is evidenced by the dedicated science journals and general medical and biology journals in which relevant publications appear.

The established organization of science into distinct disciplines and specializations, each with its specific viewpoint, communities, and institutional infrastructures is modelled around objects and technologies. In this logic it seems reasonable to assume that a new kind of object and affiliated set of technologies can disrupt this order, bringing forth a new field that draws on and pulls in expertise as well as infrastructures across several fields of research. The researchers working on stem cells in evolutionary and developmental biology, in oncology, haematology, cell biology, and in reproductive medicine – providing the cells for making stem cell lines – were and still are organized in different disciplines, departments, and bound up with different institutional contexts. They did not work on a common project, but rather provided tools, material, and techniques taken up in research with stem cells or tissue engineering.

The descriptor stem cell research gained traction, and the 'field' gained reality in the sociological pragmatic sense, in the early 2000s when some biologists began to identify their professional expertise as stem cell researchers rather than staying aligned with the previous disciplinary order. Specialized training programmes in biology departments, dedicated journals, teaching books, education courses (Hauskeller, 2004), as well as academic conferences and scientific societies are other elements in the institutionalization of a stem cell research infrastructure – the International Society of Stem Cell Research (ISSCR) was founded in 2002, for instance. Common pragmatic interests favoured the organization of a unifying profile under the new umbrella term, because it opened up multiple existing governmental and charity routes to funding for research, including funds dedicated to treating specific diseases (e.g. cancer, motor neurone disease, heart disease). This also entails that an imperative to translate research from bench to bedside shapes scientists' behaviour and the accounts of their work. The directions and pathways in basic research tend to be justified with reference to new medical treatments.

Many researchers feel that a 'translational imperative' (Harrington and Hauskeller, 2014) requires them to find ways of justifying their work with its potential societal benefit. Other critics of this pressure have argued that the rebranding of basic research as working towards regenerative medicine raised unrealistic expectations that cures for a broad range of diseases would become imminently available (Kitzinger, 2008; Petersen et al., 2017). It has also been argued that the clinical goals were crucial to the rapid expansion of stem cell research and laboratories worldwide, and shaped the development of standards and methods of experimentation and explanation (Fagan, 2013, 234). Whether this is a less diffuse bond between diversely organized and oriented research teams across the world has also to be put into question. The orientation towards future clinical utility, whilst shared among stem cell researchers, is not something that necessarily fosters a sense of community among them. The translational imperative affects all basic life science research. Stem cell research competes with other approaches in genomics, nano-medicine, and so forth, for funding – and also for the attention of medical practitioners, whose enthusiasm is needed for the protracted route into the clinic via clinical trials or other experimental uses. The possible bio-economic utility and patentability of research findings (see the chapters by Beltrame, Molnár-Gábor, and Rosemann, in this volume) may increase competition rather than community. Thus it is as easy to argue that it dis-incentivizes (self-)critical assessments of the research conducted, and that it has led to a deficit in critique, honesty, and transparency. The pressures of delivering timely results have contributed to premature publication of laboratory results and some of the many instances of scientific fraud in stem cell research (e.g. Kim, 2013). In this volume, Antonakaki presents a recent case study on the technical and political aspects of the persistent problems with establishing methods to counteract fraud and to verify experimental results.

The matrix of disciplines, institutions, interest groups, and individual agents that take an interest in stem cell research can be studied as a configuration of multiple points of interaction and tension. Different standpoints and research trajectories can be taken to examine what stem cell science is in its different configurations of interacting discourses. The many empirical axes of study problematize diverse nodes of contention concerning concepts, normative tensions, economic aspects, or diverse research pathways. We propose adopting an epistemological perspective that sees responsibility for the forms of stem cell research that happen and what happens in and with them, lying not only with the natural scientific and medical contributions to stem cell research. Ethicists, lawyers and policy-makers, economic and industrial agents as well as patients and consumers carry responsibility for their contributions to what and how stem cell science happens. In the following sections we introduce the chapters in this volume in relation to the matrix approach.

4) Contributions and organization of this volume

This book presents original perspectives on the current state of stem cell science from a range of disciplines, including philosophy and various social sciences as well as laboratory research. The chapters do not themselves take the matrix perspective or question how stem cell research has been defined. They include state-of-the-art accounts that detail specific themes such as tensions over epistemology and scientific practices. Other chapters analyse cases or uses of stem cell research that illustrate the peculiar discrepancies in political aims or moral commitments that shape its societal and scientific practices. The practices studied in the stem cell matrix concern private and public enterprises, partnerships between them, patient organizations, regulatory authorities, scientific concepts, as well as political and academic interests. The disciplinary contexts in which the participants work, and their foci of attention and expertise, jointly show a matrix of points of interest and contentions in flux. Several chapters reflect on the promises of biomedicine to deliver health benefits that attract both investor and patient interest in specific situations. Complex bioeconomies have grown around stem cell research, driven by the institutions that manage private or public biobanks or industries searching for new medical products. The well-studied publicity and transparency of these conditions in and around stem cell science make it a good case study to show the relevance of the matrix approach for conceptualizing the life sciences.

Together the chapters bring out the diversity of the understandings of stem cell research in different partaking disciplines and how academic discourses frame issues. A self-recursive figure becomes apparent through this multitude of perspectives: the current stem cell 'field' notion depends on putting the cells and those who work with them at the centre, and present philosophical epistemology, sociological studies of scientific or societal practice, and legal and ethical debates, as gravitating around this object. The notion of disruptive technologies has taken hold especially in debates about social media, but many practices in biomedicine and routine parts of stem cell research challenge laws, societal conventions, and moral understandings. Patient rights and clinical research regulations stand alongside laws and norms about the use of human cells and embryos for research. The configuration of viewpoints in a flexible matrix highlights various interacting interpretations of what matters about stem cell science. The cells and the clinical orientation are only aspects of broader societal dynamics that shape and respond to what happens in the biological and medical sciences.

The first three chapters investigate societal practices directly related to and affecting the research, thereby illustrating how conditions and actions from outside the laboratory shape stem cell research. They offer insights from studies of medical markets and biobanking industries as well as patenting law. *Claire Tanner, Alan Petersen, Casimir MacGregor* and *Megan Munsie* present findings from a sociological case study of the X-Cell-Center in Germany. This case was among their research cited to explore the manifold conditions enabling stem cell tourism. They highlight the roles of regulatory loopholes, the publicly nurtured problematic belief in the healing power of stem cells, low risk perception, and the appealing treatment conditions on offer. In the next chapter *Lorenzo Beltrame* analyses how economic value is produced in new forms of biobanking through the commodification of biological materials, the assetization of knowledge and technological capacities, and the exploitation of donors. He compares these aspects across two case studies, cord blood stem cell banking, and the circulation of hESC lines. *Fruszina Molnár-Gábor* examines limitations on patentability of results from hESC research through opening clauses of international and national patent laws. Her analysis of how these opening clauses, such as ‘accepted principles of morality’, are interpreted through case law at EU- and member state levels reveals how these legal texts draw in and refer to extra-legal motivations for limits on patentability. The relationship between legal norms and extra-legal ethical standards is problematized in the end, especially concerning questions of the legitimacy of deciding upon morally contested issues by incorporating them into positive law.

The next three chapters present the social practices in laboratory stem cell research and how its internal logic works in relation to its objects, success indicators, and external conditions and pressures. Stem cell laboratory scientists present accounts of their contemporary research and its objects, a discussion that will be complemented by two philosophy of science studies on those issues. Stem cell research is thriving and has diversified its techniques and ways of achieving clinical benefits. In order to illustrate this expansion and diversification of the stem cell sciencescape, the three chapters by laboratory scientists all belong in one sense to the same specific subfield: the study of neuronal cells and neurodegenerative disorders. Yet, they present different approaches including induced pluripotent stem cells (iPSC) in clinical translation, new methods of reprogramming cells *in vivo*, that is without removing them from the body, and research on ‘diseases in a dish’. First *Stephanie Sontag* and *Martin Zenke* report on the current state and pitfalls of research with iPSC and the prospects for clinical application; they also present a brief introduction to the biology and experimental history of stem cell research from their point of view. *Maryam Ghasemi-Kasman* introduces the methods, advantages, and challenges of her current research on developing a way of reprogramming *in vivo* glial cells into neurons – changing cells without removing them from the organism with the aim of repairing the central nervous system from within. And finally *Irina Prots*, *Beate Winner* and *Jürgen Winkler* introduce their ongoing research of stem cell-based models of human neurodegenerative diseases with the aim of better understanding disease mechanisms and developing new therapeutics. They create stem cell cultures out of cells taken from patients with the respective diseases on the basic assumption that the molecular properties of the cell culture in the laboratory correspond to those in the cells of an organism with manifest disease symptoms.

The reports by laboratory researchers on their objects, objectives, and the state-of-the-art understanding of basic phenomena and clinical aspirations are complemented by the two following chapters by philosophers of science who aim to clarify the core concept in stem cell research. With her minimal stem cell model and its relation to experimental practices, *Melinda Fagan* provides an overview of the background assumptions about biological development and discusses epistemological problems, especially the evidential constraints of identifying stem cells, in light of recent debates within the philosophy of biology. Building on Fagan's insights, *Anja Pichl* then gives an explanation of how the common understanding of stem cells as clearly identifiable entities with certain intrinsic properties can still be influential on both science and society despite being epistemically untenable. The problematic societal and scientific effects of reducing complexity to retain the unifying narrative are discussed and traced back to two constituents of the field: clinical goals and methodological reductionism.

The subsequent three chapters revisit stem cell research as social practice from social science perspectives highlighting different normativities.
The chapters present perspectives from science and technology studies, philosophical ethics, and social anthropology, each illustrating the potential of reflective cooperation among the humanities, empirical social sciences and STS for examining the intersection of knowledge practices and norms of truth and ethics. *Melpomeni Antonakaki* has studied

how the scientific community intended to establish the truth and attributed personal responsibility for suspected misconduct concerning the so-called STAP (stimulus-triggered acquisition of pluripotency) technology to create pluripotency in cells. Findings from her laboratory ethnography present a detailed account of the creation of scientific facts and the establishing of credibility through record keeping and audit practices. The roles that social status and hierarchies play, as well as the observation and transparency of laboratory practices in reinforcing credibility and trust that are discussed, undercut the myths of science developing in ways driven all from within itself and the objectivity of data. Investigations of global governance discourses emphasize the fragility of the epistemic configuration and the multiple societal domains life science research is entangled with in different contexts of societal values and power orders. *Ahmet Karakaya* decentres the stagnant debate in many, predominantly Western, countries about the moral status of the human embryo in relation to its use in hESC research. He conducted, and reports from, an empirical interview-based study on the ethical positions of Muslim scholars in Turkey on research with human embryos and the normative principles to which they refer. The predominant position among these interviewees is more liberal and expresses greater regard for the well-being of social persons than the contravening powerful arguments put forth by, for example, Catholic theologians on this issue (Levada and Ladaria, 2008). This highlights the implicit biases created in uncritical hegemonial globalized ethics about the normative foci in the moral reasoning of diverse cultures, under conditions of moral pluralism. *Achim Rosemann* shows that particular forms of governance can lead to injustices such as exclusion from new forms of business and innovation opportunities for researchers and technology producers from low- and middle-income countries. Globally distributed rules and regulations, usually designed by predominantly Western industrial and scientific institutions, have produced technical and ethical standards addressing Western moral themes such as the moral status of the embryo (Beltrame, in this volume; Karakaya, in this volume; Bender et al., 2005). Hauskeller argued that these regulations tend to concur with market prerogatives of major laboratory equipment producers and the medicines industry that focus biomedical research on alleviating suffering from the diseases of the wealthy. Formal policies and regulations shape which research is conducted and how, often in unexpected ways that contradict the stated moral and legal justifications for said regulation and the stated rationales for the public investments that enable the research. Some potential avenues of research, such as therapies using autologous bone marrow stem cell grafts, are positively disadvantaged in this regulatory set-up, contrary to ethical commitments expressed by those regulators (Hauskeller, 2018). The current governance frameworks require that those who want to participate in this research must work in high-tech laboratories and evidence high standards of scientific as well as administrative expertise. Those assets and conditions are unevenly distributed across the globe. *Rosemann* examines the tensions between the management of technology risks and the demands for social justice in emerging international governance frameworks for stem cell and gene drive research. The social and ethical problems of containing genetic alterations and the risks they pose are just one example for the technological closeness of biomedical research domains and the challenges of regulating genomic technologies in and beyond stem cell laboratories.

The chapters contribute original work to their authors' respective primary disciplines, and in combination point out areas where conflicts arise between their discourses. They demarcate intersections that are part of the current stem cell matrix, without representing a comprehensive picture – acting as spotlights on diverse and contradictory societal and epistemic factors, dynamics, interests, and values that are active in the development of stem cell research. The variety of viewpoints and norms they emphasize sheds some light on ethical issues that are easily overlooked because they fall between disciplinary chairs, metaphorically speaking. Some also exemplify the case that ethics as an interdisciplinary enquiry of explicit and implicit normative assumptions of factual, sociological, philosophical, and legal studies is underway at disciplinary cross-sections – and that philosophical and STS can contribute critical normative work by concentrating on these.

Questioning what the focus of analysis is in order to define one's referent or – as we have seen above, challenge the existence of a clearly defined field of stem cell research – is important for situated, self-critical reflection in philosophy and ethics. If we assume that science develops of its own accord, philosophy and ethics are commentating outsiders. We have argued that this is a false representation of the genealogy and situation of stem cell research. The sciences, natural as well as social, have a continually reaffirmed function in a society in which knowledge informs complex socio-political negotiations and institutions and vice versa. Based on this understanding, philosophers and ethicists are part of the producers and of the production process that carves out the niches and functions of science in society. Because of the publicly conducted controversies about it in the 2000s, stem cell research provides a very effective case study to unpick depoliticized linear narratives of scientific development that cover up the complex processes that go into the creation of the sciencescape. The matrix of stem cell science contains the discourses of ethicists, lawyers, philosophers, clinical and laboratory scientists, social scientists, theologians – especially where they affect policy and the public understanding of what goes on in scientific research. It also considers the influences from non-academic participants, such as publics and the industries that contribute to the making of stem cell science and its applications.

This volume elucidates some of the constitution conditions of stem cell research to open up dialogues with scholars from all disciplines interested in furthering the understanding of the contemporary life sciences. On that basis a critical understanding of stem cell research as a social practice can emerge, that highlights the historic, societal, economic, cultural, ideological, epistemic, and material conditions and thus the changeability of the factors shaping science pathways. Drawing on and including concepts from STS the matrix approach points philosophy of science and ethics towards ways of rethinking the science and society intersection and reshaping it conceptually. Unpacking some of the black boxes concerning constituents of the field of stem cell research raises questions about what societal goals diverse social practices including the life sciences aim to achieve. In that sense, we collated this volume to present the state of the art in reflecting on stem cell research that might contribute to collectively reorienting such work towards context-sensitive ethical and political reflections.

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References

Andersen, H. (2016). Collaboration, interdisciplinarity, and the epistemology of contemporary science. *Studies in History and Philosophy of Science,* 56, pp. 1–10.

Arabatzis, T. (2006). *Representing Electrons. A Biographical Approach to Theoretical Entities.* Chicago: University of Chicago Press.

Barwich, A. S. (2013). A Pluralist Approach to Extension: The Role of Materiality in Scientific Practice for the Reference of Natural Kind Terms. *Biological Theory,* 7, pp. 100–108.

Bender, W., Hauskeller, C. and Manzei, A., eds. (2005). *Crossing Borders. Ethical, legal, economic and religious views on stem cell research. Global Perspectives*. Münster: Agenda Verlag.

Beltrame, L. and Hauskeller, C. (2018). Assets, commodities and biosocialities. Multiple bio*values* in hybrid biobanking practices, *Tecnoscienza. The Italian Journal of Science & Technology Studies*, 9(2), pp. 5–31.

Chang, H. (2004). *Inventing Temperature. Measurement and Scientific Progress*. Oxford: Oxford University Press.

Collins, H. and Pinch, T. (1998). *The Golem: What Everyone Should Know About Science*, 2nd ed. Cambridge: Cambridge University Press.

De Vries, R., Turner, L., Orfali, K. and Bosk, C. (2007). Social Science and Bioethics: The Way Forward. In: R. DeVries, L. Turner, K. Orfali and C. Bosk, eds., *The View from Here: Bioethics and the Social Sciences*. Oxford: Wiley Blackwell, pp. 1–12.

European Commission (2009). EUR 23616 EN – Global Governance of Science. Report of the Expert Group on Global Governance of Science to the Science, Economy and Society Directorate, Directorate-General for Research, European Commission. Luxembourg: Office for Official Publications of the European Communities.

Evans, M. J. and Kaufman, M. H. (1981). Establishment in culture of pluripotential cells from mouse embryos. *Nature,* 292, pp. 154–6.

Fagan, M. B. (2013). *Philosophy of Stem Cell Biology. Knowledge in Flesh and Blood*. London: Palgrave Macmillan.

Fleck, L. (1935/1979). *Genesis and Development of a Scientific Fact* (edited by T. J. Trenn and R. K. Merton). Chicago: University of Chicago Press.

Foucault, M. (1970). *The Order of Things*. London: Pantheon Books.

Foucault, M. (1998). Polemics, Politics, and Problematizations. In: P. Rabinow, ed., *Ethics: Subjectivity and the Truth. The essential work of Foucault 1954–1984*, *Vol. I*. New York: The New Press, pp. 111–119.

Geesink, I., Prainsack, B. and Franklin, S. (2009). Stem Cell Stories 1998–2008. Guest Editorial. *Science as Culture*, 17(1), pp. 1–11.

Gottweis, H., Salter, B. and Waldby C. (2009). The Global Politics of Human Embryonic Stem Cell Science. Regenerative Medicine in Transition. London: Palgrave Macmillan.

Haimes, E. (2002). What can the social sciences contribute to the study of ethics? Theoretical Empirical and Substantive Considerations, *Bioethics,* 16(2), pp. 89–113.

Haraway, D. (1988). Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective, *Feminist Studies*, 14(3), pp. 575–599.

Harrington, J. and Hauskeller, C. (2014). Translational Research: An Imperative Shaping the Spaces in Biomedicine, *TECNOSCIENZA. Italian Journal of Science & Technology Studies*, 5(1), pp. 191–201.

Hauskeller, C. (2004). How traditions of ethical reasoning and institutional processes shape stem cell research in the UK. *Journal of Medicine and Philosophy*, 29(5), pp. 509–532.

Hauskeller, C. and Weber, S. (2011). Framing Pluripotency. IPS cells and the Shaping of Stem Cell Science. *New Genetics and Society*, 30(4), pp. 415–431.

Hauskeller, C. (2017). Can Harmonized Regulation Overcome Intra-European Differences? Insights from a European Phase III Stem Cell Trial. *Regenerative Medicine*, 12(6), online first on 4 Oct., doi: 10.2217/rme-2017-0064.

Hauskeller, C. (2018). Between the local and the global: Evaluating European Regulations of Stem Cell Regenerative Medicine. *Perspectives in Biology and Medicine*, 61(1), pp. 42–58.

Hedgecoe, A. (2004). Critical Bioethics. Beyond the Social Science Critique of Applied Ethics. *Bioethics*, 18(2), pp. 120–143.

Kim, L. (2013). Denotation and connotation in public representation: Semantic network analysis of Hwang supporters' internet dialogues. *Public Understanding of Science*, 22(3), pp. 335–50.

Kitzinger, J. (2008). Questioning Hype, Rescuing Hope? The Hwang Stem Cell Scandal and the Reassertion of Hopeful Horizons. *Science as Culture*, 17(4), pp. 417–434.

Kohler, R. E. (1994). *Lords of the Fly. Drosophila Genetics and the Experimental Life*. Chicago: University of Chicago Press.

Kuhn, T. S. (1962/2012). *The Structure of Scientific Revolutions.* 50th Anniversary Edition with an Introductory Essay by Ian Hacking. Chicago: University of Chicago Press.

Laplane, L. (2016). *Cancer Stem Cells. Philosophy and Therapies*. Cambridge: Harvard University Press.

Levada W. and Ladaria L. F. (2008). Congregation for the Doctrine of the Faith. Instruction *Dignitas Personae* on certain bioethical questions, [online]. Available at: http://www.vatican.va/roman_curia/congregations/cfaith/documents/rc_con_cfaith_doc_20081208_dignitas-personae_en.html) [Accessed 25 Jan 2019].

Maehle, A.-H. (2011). Ambiguous Cells: The Emergence of the Stem Cell Concept in the Nineteenth and Twentieth Centuries. *The Royal Society Journal of the History of Science*, 65(4), pp. 359–378.

Martin, G. R. (1981). Isolation of a pluripotent cell line from early mouse embryos cultured in medium conditioned by teratocarcinoma stem cells. *Proceedings of the National Academy of Sciences USA*, 78, pp. 7634–8.

Nobel Committee 2007: Advanced information. NobelPrize.org. Nobel Media AB 2019, [online]. Available at: https://www.nobelprize.org/prizes/medicine/2007/advanced-information/ [Accessed 17 Jan 2019].

Nowotny, H., Scott, P. and Gibbons, M. (2001). *Re-Thinking Science. Knowledge and the Public in an Age of Uncertainty*. Cambridge: Polity Press.

Petersen, A., Munsie, M., Tanner, C., MacGregor, C. and Brophy, J. (2017). *Stem Cell Tourism and the Political Economy of Hope.* London: Palgrave Macmillan.

Powell, A., O'Malley, M. A., Müller-Wille, S., Calvert, J. and Dupré, J. (2007). Disciplinary Baptisms: A Comparison of the Naming Stories of Genetics, Molecular Biology, Genomics, and Systems Biology. *History and Philosophy of the Life Sciences*, 29(1), pp. 5–32.

Rabinow, P. (2003). *Anthropos Today. Reflections on Modern Equipment*. Princeton/Oxford: Princeton University Press.

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

Ramalho-Santos, M. and Willenbring, H. (2007). On the Origin of the Term “Stem Cell”. *Cell Stem Cell*, 1(1), pp. 35–38.

Rubin, B. P. (2008). Therapeutic Promise in the Discourse of Human Embryonic Stem Cell Research. *Science as Culture*, 17(1), pp. 13–27.

Satzinger, H. (2014). The Politics of Gendered Concepts in Genetics and Hormone Research in Germany, 1900–1940. *Gender History*, 24(3), pp. 735–754.

Shamblott, M. J., Axelman, J., Wang, S., Bugg, E. M., Littlefield, J. W., Donovan, P. J., Blumenthal, P. D., Huggins, G. R., and Gearhart, J. D. (1998). Derivation of Pluripotent Stem Cells from Cultured Human Primordial Germ Cells. *Proceedings of the National Academy of Sciences* USA 95: 13726–31.

Temmerman, R. (2000). *Towards new ways of terminology description: the sociocognitive approach*. Amsterdam: Benjamins.

Thomson, J. A., Itskovitz-Eldor, J., Shapiro, S. S., Waknitz, M. A., Swiergiel, J. J., Marshall, V. S. and Jones, J. M. (1998). Embryonic stem cell lines derived from human blastocysts. *Science,* 282, pp. 1145–1147.

Trounson, A. and De Witt, N. D. (2016). Pluripotent Stem Cells Progressing to the Clinic. *Nature Review Molecular Cell Biology*, 17(3), pp. 194–200.

Vogel, G. (1999). Breakthrough of the year. Capturing the promise of youth. *Science,* 286(5448), pp. 2238–9.

Zenke, M., Marx-Stölting, L. and Schickl, H., eds., (2018). *Stammzellforschung. Aktuelle wissenschaftliche und gesellschaftliche Entwicklungen*. Berlin-Brandenburgische Akademie der Wissenschaften. Baden-Baden: Nomos.

Zipori, D. (2004). Opinion: The Nature of Stem Cells: State rather than Entity. *Nature Reviews Genetics*, 5, pp. 873–878.